Climate CHANGE

Intergovernmental Panel on Climate Change
Response Strategies Working Group

Proceedings of a Workshop

on
Assessing technologies & management systems for
Agriculture & Forestry in relation to
Global Climate Change

WMO UNEP

CANBERRA, AUSTRALIA
20–23 January 1992

Department of the Arts, Sport, the Environment and Territories

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PREFACE

More than any other human activity, agriculture is dependent upon and vulnerable to climatic conditions. In a changing global climate, the role of agriculture takes on an added importance, particularly in providing for food security and the sustainable management of natural resources.

Agriculture and forestry are both significant sources and sinks of a wide range of greenhouse gases. It follows that these sectors will play a vital role in our efforts to limit greenhouse gas emissions, and in the formulation of strategies which seek to adapt to future change.

Working Group III of the Intergovernmental Panel on Climate Change (IPCC) is currently undertaking work on the development of methodologies to mitigate greenhouse gas emissions from the agriculture and forestry sectors. It seeks to identify technologies and management systems to help reduce emissions and assist in the future adaptation of global agriculture and forestry.

The Canberra Workshop was held under the auspices of the IPCC Working Group III - Agriculture, Forestry and Other Human Activities Sub-group (AFOS). It was a key technical workshop and assessed available options for the minimisation of net greenhouse gas emissions from agriculture and forestry. These options were assessed on the basis of case studies drawn from agricultural and agroforestry practices throughout the developed and developing world.

The AFOS Co-chairs invited speakers whose special knowledge enabled them to lead discussions and ensured an effective coverage of these important issues. These Workshop proceedings clearly reflect the active participation by all delegates.

Significantly, central elements of this workshop will comprise a forthcoming issue of the international scientific journal Climatic Change.

The success of the Canberra Workshop was in part attributable to the active support of the Department of Primary Industries and Energy, Department of the Arts Sport, the Environment and Territories, Commonwealth Scientific and Industrial Research Organisation and the Rural Industries Research and Development Corporation. The support of those Australian bodies is therefor gratefully acknowledged.

DR STUART BOAG
PROGRAM CO-ORDINATOR

April 1992

EXECUTIVE SUMMARY

1. Background

The theme of the Canberra workshop was the minimisation of net greenhouse gas emissions from forests and agriculture including

. the role of sustainable agriculture and related forest management practices and systems assessment and evaluation on national and regional levels in different climate zones

. the role of integrated land use planning to minimise climate-related net GHG-emissions and to aim for sustainable development of the whole ecosystem.

Throughout the workshop three main streams of discussion took place. These were termed- Intensive Systems, Extensive Systems and Integrated Systems. The nature of each of these categories is briefly outlined below together with some of the key greenhouse issues which were canvassed. ***However the concluding Plenary emphasised that many of the strategies which would limit greenhouse gas emissions and encourage sustainable development required co-ordinated action across the three strands .***

Track One - Intensive agricultural systems

These were generally defined as systems characterised by high productivity/unit, high inputs of energy, technology or labour and generally high rainfall/irrigation (eg rice, horticulture, housed animal systems)

. Some of the key greenhouse issues pertinent to intensive systems include:
- rice production and methane emission reduction strategies
- mineral nitrogen fertilisers, nitrous oxide, NO_x and other precursor emissions reduction strategies
- animal waste management and methane emission reduction strategies
- pest and disease management strategies

Track Two - Extensive agricultural systems

Systems characterised by low productivity/unit, low inputs of energy, labour or technology and generally low rainfall and nutrient status (eg grazing, broadacre cropping, fire management).

. Some of the key greenhouse issues pertinent to extensive systems included:

  - emissions from pasture and non-pasture legumes
  - sink potential for CH_4 and N_2O and rural management

- ruminant management and methane emission reduction strategies
- pest and disease management strategies
- regional climate change and potential impacts on animal production systems (covering sensitivity analyses of production systems).

Track Three - Integrated systems

Land use systems in which woody perennials (trees, shrubs etc) are grown in association with herbaceous plants (crops, pastures) and/or livestock in a spatial arrangement,, a rotation or both, and in which there are ecological and economic interactions between the tree and the non-tree components of the system(eg agroforestry for land rehabilitation, intercropping with fuel species, fodder production and shelter belts for stock, slash and burn)

Some of the key greenhouse issues pertinent to integrated systems included

- carbon sink enhancement
  .. forestry (particularly agroforestry)
  .. soil management
- biomass burning land management issues
- regional climate change and potential impacts on plant production systems (covering sensitivity analyses of production systems).

On the final day of the Canberra Workshop a special plenary session was held to identify and explore specific adaptive strategies in terms of ecological, social and economic constraints. This assisted the workshop participants to frame their recommendations on limiting greenhouse gas emissions more clearly in terms of the sustainable development of global agriculture and forestry.

2. Emergent Guidelines for Reducing GHG Emissions in Agriculture and Forestry

These general guidelines were common to all of the three streams of discussion.

(i) Holistic, systems approaches are needed. These should embrace the economic, environmental and social factors involved

- this should include the development and adoption of a common framework for the assessment/evaluation of strategies to reduce the net emission of greenhouse gases
  .. need to consider net effect and overall balance
  .. would need to consider the total system, and individual components that make up the system
  .. proposed unit was NET GHG/UNIT of product provided the total GHG production is not increased
  .. opportunity to develop mechanistic approach that will allow improved global estimates of emissions.

(ii) Measures to reduce GHG emissions

- should be sustainable
- should preserve the quality of air, soil and water.

(iii)Areas in which short and mid-term actions are possible/needed are

- agriculture practices
- research
  - .. into the measurement of emissions from various agriculture and forestry systems and investigations into the controlling processes rather than assuming the same emission in all systems and all environments
- education and information
- land use planning and management
- monitoring
- policy and program reforms.

(iv) In the development of response strategies in the areas of agriculture and forestry will require

- integrated approaches
- better knowledge
- research and development (into mechanisms and magnitudes of emissions and their climatic effects)
- education and information especially highlighting that the net emission of greenhouse gas is the difference between the total emission and the sink uptake. Net emissions can be reduced both by reducing the total emission and increasing the sink strength. This needs to be more widely recognised.

(v) Currently we pay farmers to produce food. We don't pay them to manage resources. We may have to do this in the future and should explore the means to develop and implement incentives and disincentives appropriate to different national development priorities.

(vi) Problems of waste disposal must be addressed. This closes the cycle.

(vii) As we intensify production, there is a tendency to reduce biological diversity and this is a dangerous situation. In a time of a climate change, we need diversity more than ever

- who is charged with its maintenance and what role should agricultural and forestry producers play?

(viii) Dynamic models of biophysical components of agricultural systems exist yet there is a clear need to marry these with <u>socio-economic models.</u>

(ix) Mechanisms for getting people to work together in multi-disciplinary approaches are in need of research and development

- this includes the necessity for a greater collaboration and mutual support between the major international bodies (IPCC, WCRP, IGBP) than there appears to have been so far.

(x) There is a need to convey the issues of the GHG problem to the public in order to obtain action. This is just as important as developing technical solutions.

(xi) There is a need to identify what are the barriers to adopting those mitigation strategies that exist already.

(xii) Policy makers currently face promising opportunities and significant challenges to integrate agriculture and forestry today at the international level and develop and implement the general guidelines outlined above. These include

- the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change
- the Intergovernmental Negotiating Committee for a Global Convention on Biodiversity
- the Global Forest Agreement
- UNCED including the Agenda 21 Sustainable Agriculture proposal
- GEF World Bank potential proposals
  - .. technological cooperation of agriculture and forestry technology needs
  - .. Brazil or other pilot projects tropical forests
  - .. economies in transition in Europe and the former USSR
  - .. Agro-ecological zoning projects.

(xiii) IPCC an the AFOS Co-Chairs may wish to consider additional workshops/activities to develop a common measure for comparing mitigation options

- carbon budget and net greenhouse gas emission and land use allocation methodologies for evaluating response options in conjunction with IPCC WGI
- formal methodologies for economic assessment (modelled on the process used for the WGI emissions inventory)
- integration of WGII impacts findings with mitigation options should address
  - .. competition for the same land
  - .. evaluation of climate change impacts on productive agricultural and forestry systems
  - .. CO_2 fertilisation (ie changes in soil carbon and methane with temperature and moisture).

The following general recommendations arose from the workshop discussions in each of the three strands and were endorsed by the Concluding Plenary.

3.Track 1: Intensive Agriculture

3.1 Methane Emissions From Rice

- IPCC WG I has estimated the contribution from rice paddies at about 20-100Tg/year or 10-20% of all emissions. Both Neue and Minami have made further estimations based on a larger set of direct measurements in Southeast Asia, and on functional relationships between soil properties, temperature, nutrient supply, etc. and CH_4 emissions. Both authors arrive at new minimum estimates of between 40 and 60Tg from undisturbed rice paddies. Further work is required to reduce the uncertainty of these estimates

    - development of mechanistic models of CH_4 production and emission
    - development of measurement techniques which integrate over larger areas than chambers and do not disturb the canopy microclimate, such as micrometeorological techniques
    - identification and quantification of controlling factors.

- About 80% of the CH_4 produced in rice paddies trapped in the sediments. However, some rice-growing systems involve operations which disturb the sediments and release the trapped CH_4 (5 such operations are common in the Philippines for instance: cultivation, sowing, fertilising, weeding and so on). It may be that emissions from real farm systems are substantially greater than the 40 to 60Tg/year estimated from <u>undisturbed</u> fields.

- Emissions might be reduced through implementation of a variety of alternative technologies or management practices which are developed with the fundamental objective of maintaining the productivity of the rice systems

    - selection of varieties that have high resistance to gas transport from soil to atmosphere (differences between varieties do exist)
    - use of nitrification inhibitors - chemicals that restrict oxidation of N by bacteria, thus decreasing N loss (eg. Encapsulated CaCarbide)
    - adoption of improved water management if soils are acidic through increasing rate of water percolation and frequency of draining, with attention paid to additional N_2O emissions which may result.
    - composting rice straw instead of direct incorporation into the soil.
    - encouragement of cultivation systems with lower soil disturbance such as seeding practices.

- It was noted that the US EPA has recently reviewed strategies to minimise CH_4 emissions from rice and its recommendations complement this list (see *Options for Reducing Methane Emissions from Rice Cultivation* , Technical Assessment United States EPA - January 1992)

- Two important final points are that:

    - technologies for reducing emissions can not be developed in isolation but must be worked out in conjunction with the people who will use them
    - the lead time for technology development and transfer is 10 - 15 years.

3.2 Greenhouse Gas Emissions in Intensive Arable Cropping Systems (other than rice)

The most important emission is N_2O. It is believed that most of the increase in atmospheric N_2O is due to increased use of N fertilisers and legumes. It is found during the processes of nitrification and denitrification.

- A number of minimisation strategies for N_2O are already apparent, although not fully tested. These include

    - use of the correct form, rate, and time of application of N fertilisers. (Match supply with demand; needs knowledge of soil supply of mineral N)
    - as far as possible, provision of continuous plant cover so that a large nitrogen pool does not sit unexploited in the soil
    - correct tillage, irrigation and drainage practices
    - reduction in the frequency, area, and amount of biomass burned in forests, grasslands and croplands. Biomass burning can also be reduced by increasing the efficiency of biomass used as fuels. (These also reduce emission of other GHGs)
    - additions of lime where feasible (and required)
    - use of foliar applications of N fertilisers where feasible
    - use of nitrification inhibitors (avoids formation of N_2O during both nitrification and denitrification and coated fertilisers). Research to date suggests that these can be very effective, and have the double benefits of being attractive economically because of the savings of N (no denitrification) and environmentally (no N_2O).

- There are indirect contributions to N_2O emission through volatilisation of NH_3 and emissions of NO_x into the atmosphere, and its redistribution over the landscape through wet and dry deposition. These are large problems in Europe and North America. Strategies to increase the overall efficiency of N are therefore necessary. This will involve the cooperation of

- fertiliser companies (availability, pricing of competitive N fertilisers are issues)
- agricultural advisers (correct solutions for different situations avoidance of wasteful practices even though convenient)
- farmers.

. It is probable that we can already design/recommend cropping systems to reduce GHG emissions with existing knowledge/technology, recognising that different solutions are required for different circumstances. Implementation will require changes in farmer practices which farmers may or may not choose to implement depending on expected economic returns. Therefore, strategies for promoting implementation must be developed in consultation with farmers and must include socio-economic evaluations. For example, it was suggested that assisting farmers to perform a rough nutrient (N) balance for their farm operation could be a very valuable educational tool.

3.3 Intensive Animal Production Systems

. There is a need to adopt a common frame work for greenhouse gases

  - evaluations must consider the net effect and overall balance of the total system, and individual components that make up the system
  - evaluations should be based on minimising NET GHG/UNIT of product.

. Requirement for further research into the measurement of emissions from various intensive systems and investigations into the controlling processes rather than assuming the same emission in all systems and all environments

  - opportunity to develop mechanistic approach that will allow improved global estimates of emissions.

. Requirement for a standard environmental and physical data set to be collected with the emission measurements. Emphasis would need to be on the controlling parameters.

. Requirement for the development and adoption of new agricultural production systems that simultaneously increase productivity, improve N use efficiency, and are matched to other production factors (eg. water availability). The aim is to optimise nitrogen recovery and minimise the net loss of nitrogen.

. Improved animal management strategies exist to produce needed food and fibre products and reduce methane emissions from ruminant livestock by increasing animal productivity through, for example;

- improved nutrition/diet through strategic supplementation
- use of feed additives and production-enhancing agents
- microbial balance within the rumen
- improved genetic characteristics, enabling better growth on the same food source.

. Emissions from wastes can be reduced by

- more frequent small additions
- collection and re-use of the methane
- use of aerobic storage system to prevent methane formation.

. Options are available to reduce nitrous oxide and methane emissions from intensive animal production. However, information is a

- need to get integrated measurements to overcome the problems of spatial and temporal variability
- need for investigations into ways to control processes involved in GHG production, thereby allowing the development of better management options to increase the sink capacity and reduce the net emission of GHG.

. Concerned with NET emissions - the balance between sinks and sources

- consideration should be made at an ecosystem level
- need to keep in mind the principle of conservation of mass.

4.Track Two: Extensive Agriculture

. Agriculture is necessary to supply food for the world's population. The GHG emissions arising from this inescapable activity are relatively small in comparison with those from the industrial and transport sectors.

. Within agriculture, extensive agriculture covers very large areas (~40% of earth's land surface) but accounts for relatively little GHG emissions.

- extensive agriculture has limited options for action and, even if all were adopted, would have a small impact on global GHG emissions. However, benefits could be significant for some production systems, ecosystems and nations.

. Most extensive agricultural systems are low input systems operating in highly variable environmental conditions. The interannual variability of the natural climate in these regions is as large as any expected secular climate change due to an enhanced greenhouse effect over the next few decades. Thus the development of strategies to optimise the management of these regions based on present climatic variability will be a substantial step in the development of strategies to adapt to climate change.

- Suggestions that biomass burning should be reduced must be treated with caution, since fire is an integral part of many of these ecosystems and any change in fire regime will have profound effects on the structure of the system and its value to livestock. Therefore, the best strategy is to minimise burning consistent with management requirements.

- The quantitative data on GHG sources, sinks and fluxes are inadequate to justify anything more than a 'no-regrets' policy at this time.

Of the many possible mitigation strategies, we suggest that two, one predominantly managerial and the other predominantly technological, were selected for initial emphasis. These are (1) Management for Optimum Stocking Strategy, and (2) Manipulation of Rumen Microbiota

(1) Management for Optimum Stocking Strategy

- Optimum Stocking Strategy is based on a <u>variable</u> stocking rate that doesn't run down resource base (vegetation productivity and composition, soil C, soil structure, etc over time). In practice, near constant stocking rates are often used. A safe maximum stocking rate will achieve an economic and ecological optimum in the long term.

- Based on premise that current management systems in many parts of the world are leading to degradation of resource base and declining productivity.

    - minimising GHG emissions from extensive agriculture is closely related to maintaining a healthy resource base (i.e., a stable and non-degrading ecosystem). Any minimisation strategy that exceeds safe maximum stocking rate and leads to degradation will be counterproductive.

- Adoption of lower stocking rates would lead to an increase in the net, long-term production of livestock and direct reduction of GHG emissions, simultaneously.

- Move to sustainable management practices could lead to significant increases in soil C, thus creating a sink for GHG

    - more research is needed to quantify this potential effect.

- Requires knowledge of the functioning of the entire system (soils - vegetation,- herbivores, climate, etc.) and how system responds to perturbations

- more research needed on functioning of extensive agricultural systems as whole ecosystems. Present calculations suggest that, when a system is operated at its optimum sustainable level for productivity, the production of GHG is also near its minimum per unit product.

. Diversification of herbivore type (i.e. more use of "native" fauna - bison, browsing antelopes, kangaroo - in mixed systems).

. Improved efficiency of production (through, for example, feed supplementation, forage enhancement, etc.)

  - must be evaluated carefully to ensure that overall production doesn't increase to levels which lead to secondary effects that result in additional GHG emissions through degradation processes.

(2) Manipulation of Rumen Microbiota

. Options exist to balance the rumen environment to reduce methane emissions per unit product. Strategies include

  - providing strategic supplementation of production limiting nutrients (currently available)
  - administering effective pro-biotic and/or anti-biotic agents, for example for eliminating rumen protozoa(some currently available, others are under development)
  - manipulating rumen microbiota directly(available only in the very long term)

    .. use of high technology methods (e.g., genetic engineering) to alter rumen microbiota to reduce CH_4 emissions.
    .. could be introduced to herds through single, initial inoculation. Thus, it would be a low input technique with no change in management strategy required
    .. however large scale implementation may be feasible within 10-20 years.

. Reduction strategies must be matched properly with management systems to avoid over-stocking and ecosystem degradation.

  - secondary effects need to be considered carefully. If a minimisation strategy allows increased stocking rates overall, and this occurs, it could lead to ecosystem degradation.

. Broadacre cropping was not specifically included in extensive agriculture. However, if it is, zero tillage strategies are recommended if the potential negative effects of weeds can be controlled. Zero tillage in these regions has two major advantages in reducing GHG emissions - reduced wind erosion and reduced decline in soil organic matter.

5.Track Three: Integrated Systems

- No single option in agriculture or forestry appears to have the potential to offset more than several percent of a nation's greenhouse gas emissions, but agriculture and forest options together may potentially offset 5-25% of many nation's emissions. Integrated systems may offer further potential to manage the terrestrial biosphere to conserve and sequester carbon as well as provide a sustained flow of goods and services to local people.

- On the basis of work to date, it seems likely that agroforestry can conserve and sequester of carbon on a global scale

  - in general, for a given site, and for given environmental conditions, living systems that include woody perennial vegetation can sequester and conserve more carbon than systems consisting of annual species only.

- A limitation of natural systems in terms of the global carbon balance lies in the fact that carbon sink capacity of natural systems is effectively finite. Additionally on-going effects on the global carbon balance may well be prevented by feed-backs in the system itself

  - one important option to achieve an ongoing reduction in greenhouse gas emissions lies in the use of biological systems for energy generation as partial substitution for fossil fuels. Linkages of agricultural and forest systems with energy production systems may thus provide

    - economic viability of the system
    - availability of large capital (utilities)
    - political and financial support
    - on-going reductions in total greenhouse gas emissions.

- Additional research into integrated systems should specifically focus on developing the data needed to make valid comparisons between various short-term and long-term response options to minimise the emission of greenhouse gases.

- In addition to their potential effect on reducing greenhouse gas emissions, integrated systems may also be better able to cope with changing climate. It is highly likely that changing from mono-species to multi-species and multi-layer canopies of agroforestry systems will lead to increased resilience and less inter-annual variation in net primary productivity and carbon storage in most ecosystems

- a system's resilience to perturbations is not simply correlated with its complexity, but the nature of the complexity is also critically important
- where integrating trees into a production system, consideration should therefore be given to native species as well as non-native alternatives.

. Agroforestry and other integrated systems may have further, environmental and socio-economic benefits

- a switch to agroforestry and other integrated systems may often be justified for reasons other than the reduction in net greenhouse gas emissions. A reduction in greenhouse gas emissions may then be accompanied by other net benefits to society.

. Data bases on suitable tree species for integrated systems exist and further assistance should be given to locate and improve access to these data bases. Work should continue to further refine and extend these data bases, particularly concentrating on the minimum data set required to adequately define a species' environmental requirements

- models and analysis methods need to be further developed to predict where and how well species suitable for agroforestry will grow under present and future environmental conditions.

. Despite their many benefits, farming communities in many countries are slow in adopting integrated systems

- the adoption of integrated systems requires a co-operative approach by farmers, scientists, extension officers, and the population in general at all stages of design, implementation and refinement.

. There are many potential integrated systems that can fulfil a variety of different functions and to match the most appropriate of these many potential systems to the variety of environmental, cultural and socio-economic situations where they might be used is a challenging task

- research and appropriate analytical tools are needed to identify appropriate integrated systems within developing and developed countries, and the transfer of these tools among countries should be strengthened by development assistance institutions.

. In areas with extreme population pressure there are particular problems in introducing environmentally more suitable alternatives. Strategies to overcome these problems include

- better education, including environmental education
- transfer of technology
- adoption of alternative production systems.

- A number of countries in Europe and the former USSR are undergoing rapid transition from centrally planned to market economies and this transition may have both positive and negative implications for greenhouse gas emissions

    - opportunities therefore exist to introduce international research aid and technologies with positive environmental impacts during this period of change.

- Recognising that many parts of the world have been degraded by a variety of pollutants, international co-operation is needed to

    - rehabilitate areas degraded by pollution
    - assist in technical co-operation to reduce emissions of pollutants causing further degradation, especially forest decline
    - assist in technical co-operation to integrate all nations' forest sectors into regional and global forest economies.

- Additional work is needed to further quantify the potential effect that integrated systems, including

    - further quantification of these opportunities and benefits should follow and expand upon the emissions inventory methodology being developed by IPCC Working Group I
    - future methodologies should seek to be capable of evaluating and comparing the potential of proposed integrated systems

WORKSHOP PROGRAM

PROGRAM MONDAY 19 JANUARY

OPENING PLENARY

CHAIR - Professor Doctor Klaus HEINLOTH (Germany)

09:00-09:30 Opening address by the Chair: *A plea for sustainable agriculture*

09:30-09:50 Ministerial Welcome by the Hon Ros KELLY, MP - Minister for the Arts, Sport, the Environment and Territories.

09:50-10:10 Monthip Sriritana TABUCANON (Thailand) : *Report on Bangkok AFOS workshop to explore options for global forestry management.*

10:10-10:30 Dr Graham PEARMAN (Australia): *Agriculture and climate change - a physical perspective.*

10:30-10:45 Professor Snow BARLOW (Australia): *Agriculture and the greenhouse effect-a biological perspective.*

MORNING TEA 10:45-11:00

11:00-11:20 Dr D R SAUERBECK (Germany): Report on an expert hearing by the German Parliament - Contribution by agriculture to trace gas substances of direct and indirect relevance to the greenhouse effect

11:20-1140 Dr W J McG TEGART (Australia): The relationship between impacts and response strategies in the IPCC.

11:40-12:00 Dr Ian NOBLE (Australia): What is the relevance of the IPCC, WCRP, IGBP etc to the scientist?

12:00-12:25 Plenary Discussions.

12:25-12:30 Explanation of Tracks.

LUNCH 12:30-14:00

PM PLENARY

CHAIR Dr Gary EVANS (USA)

<u>Track One - INTENSIVE AGRICULTURE</u>

14:00-14:30 Dr Suresh K SINHA (India): Methane Emission from intensive agricultural systems.

14:30-14:45 Plenary Discussion on Intensive agriculture

<u>Track Two EXTENSIVE AGRICULTURE</u>

14:45-15:15 Dr G M McKEON (& Dr S M Howden)(Australia): The management of extensive agriculture greenhouse gas emission and climate change.

15:15-15:30 Plenary Discussion on Extensive Agriculture

AFTERNOON TEA 15:30-15:45

<u>Track Three INTEGRATED SYSTEMS</u>

15:45-16:15 Dr Robert K DIXON (USA): Integrated systems: assessment of promising agroforest and land-use practices to enhance carbon conservation and sequestration.

16:15-16:30 Plenary Discussion Intensive Systems.

16:30-17:00 Open Plenary Discussion

<u>CLOSE DAY ONE</u>

PROGRAM TUESDAY 21 JANUARY

TRACK ONE - INTENSIVE AGRICULTURE

Title:Integrated Agriculture
Chair: Professor Henry NIX
Rapporteur: Dr Tom DENMEAD

09:00-09:10 Address by the Chair: Prof Henry NIX

Theme One: First intensive case study focussing on livestock and highlighting waste management and identifying minimisation strategies.

09:10-09:40 Dr S C JARVIS (& Dr B F Pain) (United Kingdom) : Case Study titled- *Gaseous emissions from an intensive dairy farming system.*

09:40-10:45 Workshop Track Discussion

MORNING TEA 10:45-11:00

Theme Two: Second Intensive case study focussing on non-rice cropping systems and identifying minimisation strategies.

11:00-11:30 (Dr I E Galbally &) Dr J R FRENEY (Australia); Case Study Titled - *Minimisation of methane and nitrous oxide emissions from intensive agriculture.*

11:30-12:30 Workshop Track Discussion.

LUNCH 12:30-14:00

TRACK TWO - EXTENSIVE AGRICULTURE

Title: Extensive Agriculture
Chair: Dr Gordon NEISH
Rapporteur: Dr Will STEFFEN

09:00-09:10 Address by the Chair: DR Gordon NEISH

Theme One: Extensive case study focussing on the use of fire and other management tools.

09:10-09:40 Dr Mark HOWDEN (& Dr Greg McKeon & Dr J C Scanlan); Case Study Titled - *Managing pastures in Northern Australia to minimise greenhouse gas emissions.*

09:40-10:45 Workshop Track Discussion

MORNING TEA 10:45-11:00

Theme Two: Extensive system case study focussing on temperate zone integrated crop / livestock systems.

11:00-11:30 Dr SIMS (USA); Case Study Titled - Integrated Crop /livestock systems for temperate regions.

11:30-12:30 Workshop Track Discussion.

LUNCH 12:30-14:00

TRACK THREE - INTEGRATED SYSTEMS

Title: Integrated Systems
Chair: Dr David WHITE
Rapporteur: Dr Miko KIRSCHBAUM

09:00-09:10 Address by the Chair: Dr David WHITE

Theme One: Integrated system case study focussing on trees for fuel and timber production.

09:10-09:40 Dr Ros PRINSLEY (Australia); Case Study Titled- *Integrated systems and agroforestry.*

09:40-10:45 Workshop Track Discussion

MORNING TEA 10:45-11:00

Theme Two: Integrated case study focussing on desertification , land rehabilitation and salinity control.

11:00-11:30 Ms Susanne LORENZ (Germany); Case Study - Agroforestry land use to combat desertification in the Sahelian Zone of Africa.

11:30-12:30 Workshop Track Discussion.

LUNCH 12:30-14:00

PM PLENARY

CHAIR - Dr Gordon NEISH

All track rapporteurs report back to the plenary and lead discussion of issues arising.

14:00-14:20	Track One (Intensive) Rapporteur - Dr Tom Denmead
14:20-14:40	Plenary Discussion on Intensive Agriculture Issues
14:40-15:00	Track Two (Extensive) Rapporteur - Dr Will Steffen
15:00-15:30	Plenary Discussion of Extensive Agriculture Issues

AFTERNOON TEA 15:30-15:45

15:45-16:05	Track Three (Integrated) Rapporteur - Dr Miko Kirschbaum
16:05- 16:30	Plenary Discussion of Integrated System Issues
16:30-17:00	Open Plenary Discussion of Overarching issues

<u>CLOSE DAY TWO</u>

PROGRAM WEDNESDAY 22 JANUARY

TRACK ONE - INTENSIVE AGRICULTURE

Title:Integrated Agriculture
Chair: Professor Henry NIX
Rapporteur: Dr Tom DENMEAD

09:00-09:10 Address by the Chair: Prof Henry NIX

09:10-09:30 Dr H U NEUE (Philippines); *Methane emissions from rice fields.*

09:30-09:40 Workshop Track Discussion

09:40-10:10 Dr K MINAMI (Japan): *Management practices for reducing methane emissions from intensive rice fields.*

10:10-10:45 Workshop Track Discussion

MORNING TEA 10:45-11:00

11:00-11:20 Dr R ACOSTA (Cuba): *Sugar cane production as an effective means to limit net carbon dioxide emissions.*

11:20-11:40 Workshop Track Discussion

11:40-12:00 Dr A ST-YVES (Canada): *Greenhouse gases from intensive agriculture - need for minimisation strategies.*

12:00-12-30 Workshop Track Discussion

LUNCH 12:30-14:00

14:00-14:30 Dr O SOEMAWOTO (Indonesia) : *Strategies for limiting emissions of greenhouse gases from intensive agriculture.*

14:30-15:45 Workshop Track Discussion

LATE AFTERNOON TEA 15:45-16:00

TRACK TWO - EXTENSIVE AGRICULTURE

Title: Extensive Agriculture
Chair: Dr Gordon NEISH
Rapporteur: Dr Will STEFFEN

09:00-09:10 Address by the Chair: Dr Gordon NEISH

09:10-09:30 . Dr J P HOGAN & Prof R LENG (Australia): *Methane emissions from ruminants in semi-arid regions.*

09:30-10:45 Workshop Track Discussion

MORNING TEA 10:45-11:00

11:00-11:20 Dr Alberto SORIANO (Argentina): *Present conditions in the Patagonian rangelands, in relation to potential impacts of global climate change.*

11:20-12:30 Workshop Track Discussion.

LUNCH 12:30-14:00

14:00-14:30 Dr B WALKER (Australia):*Extensive agricultural response strategies-an overview.*

14:30-15:45 Workshop Track Discussion

LATE AFTERNOON TEA 15:45-16:00

TRACK THREE - INTEGRATED SYSTEMS

Title: Integrated Systems
Chair: Dr David WHITE
Rapporteur: Dr Miko KIRSCHBAUM

09:00-09:10 Address by the Chair: Dr David WHITE

09:10-09:30 Dr T H BOOTH(Australia): *Determining the climatic requirement s of trees suitable for agroforestry systems.*

09:30-09:40 Workshop Track Discussion

09:40-10:00 Mr M MADE (Zimbabwe): *An overview of the agricultural systems in Zimbabwe and strategies for monitoring their effects on the environment.*

10:10-10:45 Workshop Track Discussion

MORNING TEA 10:45-11:00

11:00-11:20 Dr W GALINSKI (Poland): *Polish forest ecosystem.*

11:20-11:40 Workshop Track Discussion.

11:40-12:00 Prof Vu Boi KIEM (Vietnam): *On the agriculture response strategies to climate change in Vietnam.*

12:00-12:30 Workshop Track Discussion

LUNCH 12:30-14:00

14:00-14-30 Dr K ANDRASKO (USA): *Designing integrated/multi-sectoral land use response options.*

14:30-15:45 Workshop Track Discussion

LATE AFTERNOON TEA 15:45-16:00

PM PLENARY

CHAIR - Dr Chalapan KALUWIN

16:00-16:15 Address by the Hon Simon CREAN, MP, Minister for Primary Industries and Energy.

Track rapporteurs report to the plenary

16:15-16:25 Track One (Intensive) Rapporteur - Dr Tom Denmead

16:25-16:35 Track Two (Extensive) Rapporteur - Dr Will Steffen

16:35-16:45 Track Three (Integrated) Rapporteur - Dr Miko Kirschbaum

16:45-17:00 Plenary Discussion

<u>CLOSE DAY THREE</u>

PROGRAM THURSDAY 23 JANUARY

SPECIAL PLENARY
Agricultural Adaptation & Sustainable Development
CHAIR - Mrs RP KARIMANZIRA

Panel on Sustainable Development and Agriculture

09.00-09.25 Dr R GREEN (Australia): Sustainable Development & Forestry - an Australian perspective

09.25-09.50 Dr R MAYA (Zimbabwe): Sustainable development and agriculture/forestry in developing countries

09.50-10.10 Prof Dr H HANUS (Germany): Sustainable development and agriculture in Europe

10.10-10.45 Dr Ted HENZELL (Australia): Integrated management strategies

MORNING TEA 10.45 - 11.00

11.00-11.30 Dr John WILLIAMS (Australia): *Risk management and climate change*

11.30-12.00 Dr Timothy D MOUNT (USA): *Climate change, sustainable economic systems and welfare*

12.00-12.30 Plenary Discussions of Panel issues

LUNCH 12.30 - 14.00

14.00-17.00 **CLOSING PLENARY**

CHAIR - Mrs R P Karimanzira & Prof Dr K Heinloth

AFTERNOON TEA 15.30 - 15.45

WORKSHOP CLOSES

Mrs Ros Kelly,
Minister for The Arts, Sport, The Environment and Territories.

MINISTERIAL ADRESSES

Address by the Minister for the Arts, Sport, the Environment and Territories, MRS ROS KELLY, on behalf of the Australian Government

Ladies and gentlemen, it is with great pleasure that I welcome you to this Workshop and to Canberra, which is both my home town and my electorate. I hope that you will enjoy your stay here in the national capital and that you will have the opportunity to see both the city and the marvellous landscape that it inhabits.

I think you will rapidly appreciate the way in which Canberra has been designed to blend with the natural environment. Although it has its critics, no other large centre of population in Australia features the natural environment quite so dramatically and delightfully as Canberra does.

I am not just being parochial here. Although it may not be the definitive model for the rest of Australia, Canberra does provide proof that Europeans can live in concert with this most un-European land.

If you travel much beyond the suburban boundaries, you will see evidence that this has not always been so: the Canberra district has been occupied by Europeans since the 1830s and in that time, as in the rest of Australia, great damage has been done to the natural environment. Coming from the more robust Europeans environment, earlier generations of white Australians did not live in harmony with this fragile land, but rather abused it and left us with a legacy of environmental damage. We cannot say that they did this deliberately, as this foreign land was so different from their own. Had they understood it better, they may have taken more care for the generations that followed them.

Fortunately, our understanding of Australian ecosystems has grown and we have become much more conscious of human impacts on the environment. Australia is a resource-rich country anxious to reduce a balance of payments deficit, and we need economic development. But we are also aware, because our history has made it so tragically plain, that the environment is fragile. The ignorance and apparent disregard that previous generations brought to the business of economic development has cost us dearly.

So, while the temptation may be there to go for all out growth, the Australian Government is well aware that a balance has to be struck: we want to maintain and improve our standard of living, recognising that a clean and healthy environment is part of that standard. We want the economy to flourish, and we want the environment to flourish with it. The integrated development and management of both is the key to the future success of Australia.

The Australian Government has established mechanisms to set this course for a sustainable future. Our efforts have extended from broad-ranging inquiries into options for ecological sustainability to actual issue-specific programs. We have established a national waste minimisation and recycling strategy, major soil conservation and restoration programs, and we have set up a federal Environment Protection Agency. There are several programs under way to improve our degraded agricultural land, including the One Billion Trees Program, which will achieve its target of establishing at least one billion more trees where they are most needed throughout Australia by the middle of the decade. You might recall that our goal was to establish them by the turn of the century; we will achieve that goal by the middle of this decade.

Nations throughout the world are taking action to protect their environment and all the world should be thankful for that. But it is not enough for countries to concentrate solely on their own home environments. A frightening new development, and one which brings home to us just how small the earth is and how tenuous our existence on it, is the major environmental problems which threaten the entire globe, regardless of their origins - problems such as ozone depletion in the atmosphere, loss of biodiversity, the pollution of international waters and greenhouse-induced climate changes.

It is the last problem which brings us all together for this Workshop of the Intergovernmental Panel on Climate Change. The IPCC continues to provide the most reliable and accurate scientific data available on climate change, and deserves congratulations for the excellence of its First Assessment Report. It was that report which catalysed the commencement of negotiations on an international convention.

I understand that the IPCC is preparing a supplement to that first report and that this Workshop will be contributing to Working Group III's section of it. Working Group I met in China last week to finalise its own contribution to the supplementary report. I am reliably told that the Working Group has reaffirmed its earlier best estimate of 0.3 degrees Celsius per decade global warming due to the greenhouse effect.

The Working Group also noted that in the Northern Hemisphere the cooling effect of sulphur emissions, which cause acid rain, can be expected to offset global warming over the next few decades. No doubt this is an accurate scientific interpretation of the findings, yet it concerns me how these findings might be portrayed to the general public.

I find all too often that accurate scientific findings are inaccurately interpreted. This is not to cast aspersions on the journalists who are here this morning, I have to say! It is not uncommon to see reports that take whatever extreme end of the latest climate model predictions which best suits a particular purpose, and compare the revised "predictions" with often quite spurious predictions plucked from anywhere but the IPCC, with a view to demonstrating that the greenhouse effect is somehow disproven.

An example of what I mean can be found in recent reports in the local media. Here we were told that the forecast increase in global temperature over the next 70 years is an inconsequential 1.5 degrees Celsius. But this is inconsequential only if you are not aware that this rate of change is faster than at any time in the last 10,000 years, or since agriculture first began.

Certainly, the Australian Government will not let itself be misguided by these false prophets and will only be guided by reputable bodies such as the IPCC. Last week's reaffirmation by Working Group I of its earlier estimates only reinforces the importance of the position that this Government has taken on greenhouse. Let met just elaborate that. In October 1990, the Australian Government adopted an interim planning target to stabilise emissions of greenhouse gases - excluding chlorofluorocarbons and halons - at 1988 levels by the year 2000, and to reduce these emissions by 20 per cent by the year 2005. The Government also decided that it would not proceed to adopt response measures which have net adverse economic impacts nationally or on Australia's trade competitiveness in the absence of similar action by major greenhouse gas producing countries. This again highlights the need for us to act, and to act with other countries in the world. It shows how important it is that these issues are approached from an international perspective.

Yet it concerns me that these latest findings of Working Group I may also be interpreted to mean that we need not worry about the greenhouse effect any more or, worse still, that we need not reduce sulphur emissions because they counteract greenhouse. Are we to trade one environmental problem for another? Or should we responsibly try to lessen both? Interestingly, many of the measures to reduce carbon dioxide emissions also reduce sulphur emissions.

The science of climate change appears to have created a vast new resource for the practice of misinterpretation. I suspect it is impossible to eliminate the practice totally - if it were possible, we politicians would have done it! But scientists must take it as one of their responsibilities to do everything they can to ensure that their messages are accurately communicated and are not open to misinterpretation. If we effectively communicate the results of this Workshop we will improve our capacity to develop response strategies in agriculture and forestry through the limitation of greenhouse gas emissions and through adaptation.

I am aware that later this morning speakers with much better scientific qualifications than mine will be discussing both the science and potential impacts of climate change. But I hope you will forgive me, as a non-expert in the field, but as the person who must take primary responsibility for educating our community on this matter, if I take the opportunity to explain why I, as Minister for the Environment, am pushing hard, both nationally and internationally, for effective action to be taken.

Scientists are telling us that if the predicted climate change occurs, the impact on natural and human systems could be enormous. Altered rainfall patterns, higher temperatures, greater frequency of extreme events, altered distribution of pests and pathogens are all likely to have negative impacts on our agriculture and forestry.

It is sometimes claimed that these would be offset by positive benefits. Enhanced growth of some plant and tree species under higher levels of carbon dioxide - the so-called CO2 fertilizer effect - is often cited as a case in point. But here we enter an area of great uncertainty. This effect could only be beneficial if the altered water availability and the temperatures did not militate against it, and our understanding of these linkages is still very poor. In addition, we cannot assume that it would be the useable part of the crop that was enhanced - for instance, the effect might actually reduce the protein content of cereals. Similarly, the effect would hardly be a cause for celebration if the crop growth were offset by the growth of competitive weed species.

Obviously, we have to be aware of the secondary effects of the impact of climate change. For example, in a complex system such as a forest, changes in rainfall and temperature could affect litter breakdown, in turn affecting the cycling of nutrients and the build up of litter for bushfires.

We hear sometimes that increased rainfall would be beneficial on the whole. But a number of problems immediately present themselves. Increased rainfall is beneficial only if it occurs at the right stage of tree or plant growth, and we can hardly guarantee that. Nor can we assume that predicted averages will be the norm - the reality of "increased rainfall" is more likely to be that while some some local areas might become wetter, others might become drier. In addition, "increased rainfall" is just the sum total of the amount of rain that falls, but the predictions are actually for more intense rainfall over fewer days with longer dry spells in between. The implications for run-off and soil erosion, soil aridity and fires are obvious.

In summary, we now have a fairly good idea of what the impacts of climate change might generally be, but we do not have the degree of detail necessary to make predictions about specific consequences, or how impacts on one part of the agricultural system might interact with impacts on other parts.

Our uncertainty goes further than this: knowing what overall impacts are likely does not tell us what local impacts will be - which is, of course, precisely what every farmer and farming community needs to know. And what every Government needs to know. Obviously we can extend this observation to the global community. The truth is that, given current knowledge, any country or region which might claim to be an overall beneficiary of climate change is speaking in either hope or ignorance.

We do know that certain forestry and agricultural practices produce greenhouse gases - from burning stubble, belching ruminants, soil erosion, nitrogenous fertilizers, rice production, animal wastes, legume pastures and from fossil fuel use in machinery. But with the exception of the last of these, the scientists tell us that it is difficult to quantify emissions from these sources. So we have another uncertainty.

No doubt the word "uncertain" - and I must say I heard it a few times in Dr Heinloth's speech - will be often repeated over the next four days. It is not a word that we politicians feel terribly comfortable with because, as any reporter will tell you, it is not what people generally want to hear. I am well aware that there are very good reasons for scientists to stress uncertainties where uncertainties exist. But, if I may give some unscientific advice, in communicating your knowledge to non-specialists, it is essential that you convey unmistakably what is well-established and what is not.

The best response for governments and scientists alike remains to increase research to provide a clearer picture of what the future is likely to bring. In recognition of this, the Australian Government is funding a climate change research program. Internationally, of course, organisations such as the IPCC are playing a vital role in bringing current knowledge together for the use of policy-makers around the world.

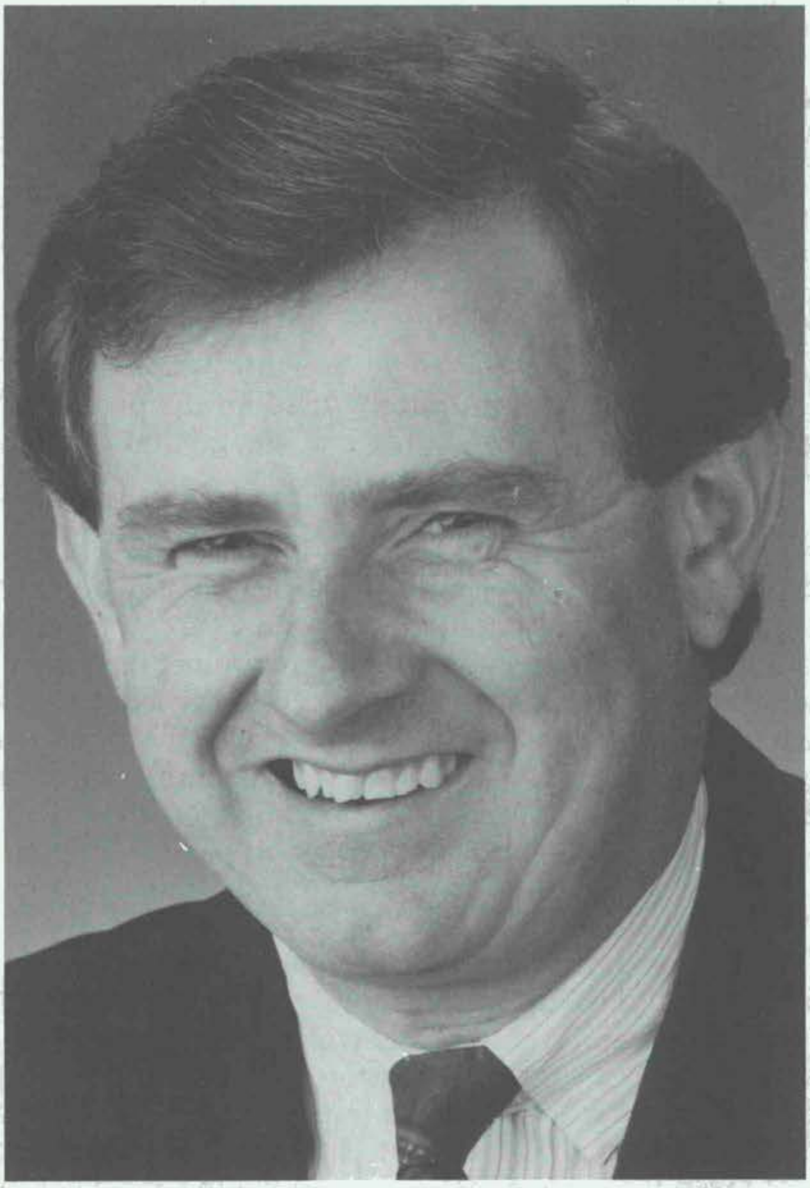
But we cannot wait for the research to provide us with a comprehensive, certain picture. The wisest choice is surely to adopt the precautionary principle and to instigate response measures in the knowledge that certain consequences are likely to flow from climate change.

Certainly, there are few excuses not to begin immediately to implement the so-called "no regrets" measures as a major part of a first-generation greenhouse response strategy. As you would know, "no regrets" emission reduction measures are those that offer economic and environmental benefits, quite apart from any lessening of the greenhouse effect. Besides reducing carbon dioxide emissions, which benefits the nation and the planet, measures that reduce energy wastage in industry and commerce, for example, offer fast and direct financial returns and the promise of being more efficient and competitive. Because measures like these make such good sense, it behoves us all - governments, individuals and industries - to pursue them with vigour.

Ladies and gentlemen, you have been nominated as experts from your respective countries to develop response measures to the greenhouse effect in the fields of agriculture and forestry. As you do so, I hope you will remember that the reason the IPCC is undertaking this work, with the support of governments worldwide, is the potential impact of climate change. That is the reason for the conference: we cannot delay in developing our response measures simply because we may not know exactly the nature of these effects, or because there is a chance that some of them may not occur.

I know I need remind no-one here that our responsibility is not so much to our own generation but to future ones. Climate change is unlikely to have a major impact in my own lifetime, but I cannot say the same for my children or the children they may have one day.

On that note I will finish. Once more, welcome to Canberra. I wish you well with your important work, and I look forward to learning the outcomes of this Workshop. I hope that the process of this Workshop will further enhance our understanding of greenhouse and how we respond to it.



The Hon. Simon Crean MP
Minister for Primary Industries and Energy

Address by the Minister for Primary Industries and Energy the Hon SIMON CREAN MP, :

Today has given an interesting insight into a Minister's work because, in addition to attending your Conference here today dealing with the agricultural and forestry perspective, I have spent my time today talking with the Coal Industry Council, which comprises the industry, the union and various governments which have State responsibilities, as well as the Federal Government. The question of the contribution of coal and energy and the greenhouse effect was very much part of our discussions in that Council. It is an interesting contrast. I know that those of you represented here have an interest - some more active than others - in the energy side as well. But I will be confining my remarks today, in the time that I have available, to the agricultural and forestry perspective.

It is an imperative internationally for all of us to ensure that we simultaneously meet the objectives of development and environment. It is what we have termed in this country the challenge of sustainable development.

Agriculture in Australia in a significant export earner for us. I am trying to make sure that we earn our export dollars from agriculture in a better way than we have in the past - on the one hand by getting better access for some of our products, but on the other hand doing much more with them. Furthermore, agriculture is a significant contributor to greenhouse gas emissions. Accordingly, this sector, quite apart from the energy sector, presents considerable challenges to the Government and the community, and particularly to the farmers.

I am firmly convinced in the time I have been in this portfolio that they are challenges that we can meet.

Recent calculations suggest that the agricultural sector in Australia is responsible for between a quarter and one third of gross greenhouse gas emissions. Only the energy sector is more important in terms of its contribution. Therefore, developing and implementing appropriate policies for agriculture and forestry will form a significant component of our national greenhouse response strategy.

When the Government took its decision in October 1990 in relation to planning targets for the reduction of greenhouse gas emissions it adopted the so-called "basket of gases" approach. It argued that increasing atmospheric concentrations of all radiatively active gases need to be addressed.

The options that you are assessing in these workshops and in plenary sessions for minimising net greenhouse gas emissions from the agriculture and forestry sectors will help us as a Government develop policy options for a comprehensive response.

Agriculture, more than any other human activity, is dependent on and vulnerable to climate conditions. Shifts in regional climate patterns are likely to have significant effects on agricultural production, and therefore on trade in agricultural commodities. Accordingly, Australia's decision on emission reduction targets acknowledged those potential economic implications as well.

In light of the uncertainties about timing, magnitude and regional patterns of climatic change, I can see great value in greenhouse policy responses that have multiple benefits, particularly economic ones.

There are policy options in the agriculture and forestry sectors that have benefits for reasons other than their relevance to climate change. As my colleague the Minister for the Environment outlined in her opening address, our Government is vigorously pursuing such no-regrets policies as a first generation response to reducing greenhouse gas emissions.

The fundamental message that I want to leave with you today is that we can have, in my view, economic development and at the same time protect and enhance our environment. In order words, we can have our cake and eat it too!

Environmental considerations need not preclude economic development, and neither should economic development preclude environmental protection. The challenge is, from whatever perspective we come in this debate, to recognise that fact.

This Workshop is developing and discussing relevant policy options to meet the objectives. For example:

- lowered stocking rates for cattle in the Queensland rangelands;
- trees planted for shelter belts, or agro- forestry; and
- improved waste management for intensive animal production.

All these can have multiple environmental and economic benefits as well as reducing net greenhouse gas emissions.

We can improve the efficiency and sustainability of production and reduce offsite effects. And climate change is the most significant and complex offsite effect that we are likely to have to confront.

However, we cannot forget that the primary role of government is to improve also the quality of life for current future generations. This means meeting essential needs for jobs, food, energy, water and hygiene. This in turn means that we must secure, sustain and develop our resource base. In other words, we must pursue policies of sustainable development.

We have an imperative, in face of a rapidly rising world population, to ensure reliable food supplies for the future. Achieving this in the context of a tightening economic and environmental set of constraints means that supply and demand signals must be simple and direct. That is, we must remove the distortionary practices, free up international trade, and ensure that national and international food, fibre, energy and other resource needs are met in the most efficient and environmentally sensitive ways.

Artificial schemes to prop up inefficient production have to be abandoned, particularly where they they place enormous drains on the sustainability of the land.

For our common future we cannot afford, economically and environmentally, to persist with policies and practices that discriminate against more efficient and ecologically sustainable production systems.

We must, nationally and internationally, develop and implement more appropriate policies and practices. Where there are unavoidable trade-offs to be made, then we need to improve our skills and institutional arrangements for resolving these conflicts at both national and international levels.

Australia has learnt some important resource management lessons, such as how to catalyse effective community action to address land degradation, and the past few years have seen significant changes in community and individual attitudes to land management. I am pleased to be associated with a launch tomorrow in a region of Australia of new initiatives to streamline and simplify the land management processes and the involvement of community groups, in particular farming communities. It is a policy approach and a direction that has the support of all the major political parties in this country.

We are now seeing a far more integrated approach to natural resource management. Issues such as dryland salinity and algal blooms in our vital waterways are no longer seen in isolation. I made the point today in another discussion that there isn't much point in Australia positioning itself to be a supplier of clean quality, fresh food to the rest of the world if what our opponents or competitors can point to is green algae floating down one of our major riverways. It is a very dramatic contrast to what we are trying to promote. Therefore, the management of waste and the technology associated with its treatment are a vital component not just from the sustainability and treatment perspective, but from the industry development perspective. They therefore cannot be seen in isolation and there needs to be a lot more integration.

Increasingly also we are developing solutions that deal with the multiple causes of environmental degradation rather than just the overt symptoms. In many respects our emissions of greenhouse gases are also a symptom of a failure to appropriately value our environment.

I do not pretend that pricing our resources more appropriately will provide all the answers, but by acknowledging, and better quantifying, the impacts of our actions, our decisions will be better informed and more consistent with sustainable development objectives.

Australia has just completed an important first step in developing a national approach and set of policies for ecologically sustainable development. Nine sectoral reports have been presented recently to the Government, and I have arranged for the national reports on sustainable agriculture and forest use to be made available to country representatives at this meeting.

Our focus is now on evaluating and implementing the many recommendations contained in those reports, but a common theme throughout them is the need to secure, sustain and develop this nation's resource base.

All the reports dealt in one way or other with the greenhouse issue. Actions to reduce net greenhouse gas emissions and to sustain and develop our resource base must work at all levels - individuals, communities, nations.

We cannot afford to address single issues, even complex issues like climate change, on its own. We must build better linkages between individuals and their communities, between communities and governments, and between nations.

Where we do not have the skills or institutional capacity to resolve conflicts - and I think that is a pressing problem in this country - or to establish the objective criteria against which we take decisions, then we must apply and develop them. In an institutional sense it is one of the priorities that I have attached to my task in the portfolio.

In conclusion, I simply want to repeat that we can't afford to be paralysed by the uncertainties that face us, and we can't afford to wait for certainty, because it may not come.

We need economic development, which is foremost particularly in the context of this nation's position at the moment, and we need to preserve and improve our environment.

We need better information, better understanding, better predictive tools and better dispute resolution mechanisms. But we also need to act.

I believe that our greenhouse response strategies for agriculture and forestry will be less dependent on developing new technologies and new techniques than in applying what we already know, in the right place and at the right time.

We face greater problems in gaining acceptance of the need to act, and in the adoption of appropriate practices - that is, changing both attitudes and behaviour.

The key to this, of course, is information, communication, education, debate and, where necesary, appropriate government policies and programs.

Having said all that, I look forward to the recommendations, intiatives and proposals that arise from your deliberations. I congratulate those associated with the organisation of this conference. I think that the gathering together of those responsible at an international level not only helps us to understand the problem better, but also to meet the task of coming up with effective solutions.

I hope that in the time you are here we will be able to demonstrate some of the areas of the activity in which we have been effective. The cross-fertilisation of those issues can only help us generally. I wish your deliberations well. I look forward to hearing of those responses and seeing where appropriately we can incorporate them.

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TECHNICAL PAPERS

BANGKOK AFOS WORKSHOP TO EXPLORE OPTIONS FOR GLOBAL FORESTRY MANAGEMENT

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Abstract

The conservation and sustainable management of forest resources is attracting increasing attention worldwide. The forest issue is high on the agenda of the United Nations Conference on Environment and Development (UNCED) which takes place in Brazil in June 1992 at the request of the AFOS group of IPCC and the UNCED secretariat, the Royal Thai Government in cooperation with UNEP, ITTO, FAO, IPCC, USA, Japan, Canada, Netherlands and United Kingdom, organised the Technical Workshop to Explore the Options for Global Forestry Management. The workshop has brought technical and policy specialists for substantive discussions related to global forest management.

The topics described in this paper include national issues related to the management of temperate, boreal and tropical forests; the need to develop a global consensus for collaborative technical assessments and action to safeguard local, national and international benefits from the services of forests; preliminary discussions of methods to estimate the costs of achieving goals at the national and international level and associated economic issues; and further action needed to promote a constructive and action oriented approach to tackling global forest problems.

I. Introduction

Global interest in forest resources has broadened recently to include all forest biomass and the need for sustainable provision of a wide range of forest services, including forest products, biofuels, carbon stock and sinks, biodiversity, and maintenance of hydrological cycles. While nations have sovereignty over their forests, the global resource aspects of forests are being increasingly recognised. A number of major international initiatives to improve management of forest resources are underway, including the Tropical Forest Action Plan, Guidelines for the Sustainable Management of Natural Tropical Forests Climate Convention, Biodiversity Convention, and Global Forest Instrument. In light of these efforts, policy-makers urgently need the best information and technical assessment of potential site-level, national and international options to protect and better manage forests.

To contribute policy-relevant technical information to assist current international discussion of initiatives, at the request of the AFOS group of IPCC and the UNCED secretariat, the Royal Thai Government organised the Technical Workshop to Explore the Options for Global Forestry Management. Over 80 experts from more than 20 developed and developing countries, and 11 international organizations and non governmental organizations gathered in Bangkok for 5 days of intensive discussions on a wide range of issues related to global forest management. The workshop focussed as follows:

1.1 Summarizing current status of linkages among various international initiatives relating to forest resources.

1.2 Evaluating land availability in different regions to meet Noordwijk Targets and other forestry options.

1.3 Evaluating technologies and practices that could be utilised at different sites and regions to manage forest area while meeting other environmental, social and economic objectives.

1.4 Assessing costs of various policy options for sustainable forest development and their implications for agriculture, forest products, trade, and economic development.

1.5 Assessing options for the coordination of national, regional and international activities pertinent to these goals.

II. National Forest Options

2.1 Tropical Moist Forests

Tropical rainforests, tropical wet forests, and tropical moist forests are terms used in reference to different life zones. Due to inadequate definition, these terms have too often been used as synonymous. Due to different interpretations of these terms, and the limitations of FAO 1980 data, it is difficult to determine the present extent of tropical moist forest cover. However, recent estimates on a country basis, indicated that of the 1,937 million hectares of tropical forests, 1,082 million hectares could be under tropical moist forest cover. Such estimates have not included forest fallows, agricultural tree-crops and traditional agro-forests. Land tenure and tree tenure problems are often central to land degradation problems. More should be done at the national level to clarify, establish and guarantee what people's rights are and to ensure that they are fully respected. Multi-purpose management of the production of tropical moist forest will have to replace single objective management. The production of timber and non-wood products, watershed protection and the conservation of biodiversity will have to be sustainably managed in one piece of forest. Traditional rotational agricultural systems or swidden fallowing systems should be reassessed. The system contributes to carbon sequestration and biodiversity and only becomes uncontrollable with insecure land tenure and rising population density. A range of land use options are considered as follows:

2.1.1 Tropical moist forest for protection

The case studies revealed that the countries represented all have a commitment to put land aside for protection purposes. The need to manage forest for many purposes is as essential for tropical forests as it is for temperate forests and a balance has to be struck between conflicting objectives.

2.1.2 Tropical moist forest for production

There is a wide range of experience in managing tropical moist forest. Although about 20 management plans have been prepared and different silvicultural systems tried, results have not been altogether successful. Concessionaires have not shown an interest in silvicultural treatment whilst harvesting causes unnecessary damage to the remaining forest. Control of harvesting has been inadequate.

2.1.3 Swidden/fallowing systems

There was some consensus that the place of traditional agricultural systems should be re-evaluated. In situations where the population is low, this farming system is appropriate, sustainable and contributing to biodiversity and carbon fixing. The appropriateness of this form of agriculture is very closely related to the issue of land tenure and the rights that people acquire by clearing land for agriculture.

2.1.4 Tree crop plantation

Discussion focussed on tree crops that produced timber as an end product and particularly rubber, although the timber of coconut and oil palm can be utilised. Such tree crop plantations can make a substantial contribution to the fixing of atmospheric carbon. However, large scale plantations do not contribute to the conservation of biodiversity.

2.1.5 Forestry Plantations

Vigorous plantation programmes are included in many of the case studies presented. The *taungya* system in which farmers are allowed to cultivate their crops in the first few years of plantation establishment, offers one method of establishing plantations cheaply. It has fallen into disrepute in areas where there is land shortage because the farmers tend to settle on the land and destroy the young trees.

2.1.6 Agroforestry

Two kinds of agroforestry can be distinguished. Traditional agroforestry systems such as home gardens and the new technology agroforestry systems in which multi-purpose trees are introduced into the farming system where the fallow period has shortened to such an extent that the landscape is virtually treeless and farmers are convinced of the need to plant trees. Agroforestry offers a relatively cheap way of introducing trees that can fix carbon.

2.1.7 Wasteland Rehabilitation

The land should only be used for food production when the basic human needs of the people have not been met.

2.2 Dry Tropical and Subtropical Forests

Dry tropical forests cover approximately 1.7-1.9 billion hectares of land. The potential for carbon fixation is significant and plays a vital role in the conservation of soil fertility. Dry tropical forests provide a steady and affordable flow of timber and non-timber products for billions of people: indeed, their surprisingly rich biodiversity is only now beginning to be realised. However, they are at risk because of agricultural clearance, urban fuel needs, desertification, population growth and land accumulation in adjacent more favoured areas. Only limited land use intensification is possible in these areas without significant resource inputs. There is a need to reduce uncertainty of land tenure so as to improve incentives for good community forest management. Experience in some countries shows that when tenure rights are vested in individual farmers, this results in limiting the access of landless people to common property resources. There is also need for action for farm forestry and agroforestry to be conserved by local people rather than the creation of new plantations and provision of fuelwood for large and rapidly growing urban populations. The urgent need is to identify workable ways to promote switching to alternative fuels for urban communities.

2.3 Temperate and Boreal Forests

According to FAO data approximately 767 million ha. of forest belong to the temperate zones. This equals 13% of the total land area of temperate zones. Forest area in boreal zones amounts to about 920 million hectares which is 47% of the total land area of boreal zone. It is estimated that in the last 10 years the total wooded area in the temperate and boreal zones increased by about 12 million hectares or 0.6% of forest area, respectively. At the moment, information about the net change of biomass and stored carbon in temperate and boreal forests is incomplete. Forestry options in temperate and boreal zones can be summarised as follows:

2.3.1 Slowing deforestation and forest degradation
Preserving existing forests

Management and maintenance of existing forest is the most effective approach in terms of carbon fixation, costs, and ecological aspects. Strategies to manage and maintain forests have the advantage of immediate beneficial impacts compared to other options in order to keep carbon stored in biomass. These can be achieved by implementing sustainable forest management systems, halting conversion of forest areas to non-forestry purposes and conservation or ecologically appropriate management of boreal and temperate primary forests.

2.3.2 Afforestation

The feasibility for afforestation of potential areas differs from region to region and from country to country. For the boreal zones, the potential to increase the forest area is marginal. Most of the remaining land area is environmentally incapable of supporting forest ecosystems. In the temperate zones, substantial areas might theoretically be available for afforestation during the next several decades. In some countries considerable opportunity exists for tree planting outside the forest estate on lands where forestry is not the prime land use. Examples include urban plantings for improved amenity, agroforestry, and plantings on rural lands for shelter belts or to address land degradation.

2.3.3 Increasing biomass and yields in existing forests

There is significant potential for increasing biomass in existing forests, especially in young, understocked, over logged and/or misused forests. It is important to note, however, that increases in biomass resulting from a better balance of age classes will be temporally limited. It is pointed out that the approach to increase yields of actual forests is not a feasible option for large areas within the next decades. This is due to the actual tree species, age classes, silvicultural regimes, site conditions etc. to be found in forest ecosystems.

2.3.4 Improved use of wood
Wood from sustainably managed sources is an environmentally friendly raw material and fuel. The forecast increase in world demand may best be met through increased wood production where that is feasible, in combination with a more effective use of wood, rather than substitution by non-renewable materials such as concrete, plastics, steel and aluminium. The most promising approaches are to use wood more efficiently (eg. reducing waste and using wood in more long lived products), use of wood as an energy source to replace fossil fuels and recycling of wood products including paper and paper board.

III. Economic and Cost Issues

Since many of the benefits from forests are difficult to quantify in financial terms, they tend to be underestimated by markets and policy makers.

There is an urgent need to generate better information on the costs, benefits and opportunity costs of forest actions in temperate, boreal and tropical areas. Most existing economic analysis only take account of one or two out of the range of benefits, typically timber production, and do not take into account maintenance, management or opportunity costs. Further work must be done on a collaborative international basis on the cost effectiveness of different options, the valuation of benefits, and the institutional feasibility of options in different circumstances.

IV. International and Global Issues

International cooperation complementing national action can contribute substantially towards the wise use of forests and forest lands. Areas where particular contributions can be made are in the relationship between international trade and sustainable forest management, forest management guidelines, technologies for the use and protection of forests and forest products, and in providing assistance as necessary to enable less developed countries to prepare and implement appropriate forest and development policies and action oriented programmes. It was recommended that research, monitoring, evaluation and improved information and technology transfer should be strengthened. Greater attention should be paid to education, the role of women, non-government organisations, and community participation, and to extension activities which focus on the sustainable management of forests and on the establishment of forest and tree cover.

There were a number of proposals for restricting the trade in forest products and joint recommendations from consumers and producers to ensure that traded forest products come from sustainably managed sources. Periodic monitoring of international trade, addressing the current and future demand and supply of timber and non timber forest products should also be conducted.

The conclusion for the feasibility of achieving the target established at the Noordwijk Conference on Atmospheric Pollution in December 1989 for a net global increase in forest area of 12 million hectares in the 9 years until the year 2,000 were made as follows.

4.1 given estimated current rates of loss of forests globally, and rapidly growing populations in many areas of the world which would add to the pressures on forest land, the prospects for halting the net rate of loss of forest areas within the next decade and longer were very limited;

4.2 on the basis of work already carried out to assess the scope for national action in 50 countries, it seems possible that over the longer term to 2050, the net rate of forest loss could be slowed and reversed. The main constraints were likely to be financial, economic, social and institutional rather than the availability of land;

4.3 an analysis for Africa and Asia indicated that some 200 million hectares of land currently without significant tree cover could be forested through regeneration, farm forestry and, to a lesser extent, plantations, by the year 2050. In addition, one scenario suggests that almost 100 million hectares of forest that would otherwise be lost in Africa and Asia by 2050 could be maintained under forest cover through broad-ranging policy initiatives. However, the overall analysis concluded that even with successful implementation for both these measures, Africa and Asia are likely to see a significant net reduction in forest cover between 1990 and 2050. For the reasons given above, participants urged great caution in the use of these figures;

4.4 it was important to assess the feasibility of increasing forest areas in temperate and boreal areas. Industrial plantations may be the best approach in such regions, whilst in the tropics a more appropriate way to increase forest and tree cover may be through social and community efforts.

V. Conclusions

The main conclusions from the workshop are as follows:

5.1 the wide variety of valuable papers presented and discussed should be transmitted urgently to the Secretariat to the UN Conference on Environment and Development (UNCED) to contribute towards deliberations on a global consensus on forests for the 1992 Rio Conference; to the Intergovernmental Negotiating Committee (INC) to support its work to prepare a framework convention on climate change and to the Intergovernmental Panel on Climate Change (IPCC) which is providing objective scientific and technical advice for these negotiations; to the UNEP *Ad Hoc* Working Group of Legal and Technical Experts on Biological Diversity to support their work towards a global biological diversity convention; and to other international fora including, *inter alia*, the ITTO, FAO and IUCN;

5.2 the prospect of further such technical workshops should be welcomed as a useful way of assembling information and technical data to facilitate the work of the UNCED and other fora, especially where such workshops were hosted by important forest countries;

5.3 there was a need for better information on the extent of forests, including further effort to ensure that appropriate definitions were used for each forest type and objective. Nomenclature for tropical rain forest is extremely variable; this leads to considerable confusion over their extent, biomass and diversity. In considering carbon fixation objectives, for example, it was noted that agroforestry and agricultural tree crops may need to be taken into account. It was also noted that on-farm trees, which are generally not included in figures on forest cover are in many countries at least as important in carbon terms as formal forest areas;

5.4 a collaborative global and regional effort was urgently required, building on existing remote sensing and ground truthing capacity, to reinforce work on monitoring the status of and changes in forest in boreal, temperate and tropical regions. Current data on open forests and scattered farmland trees, which are very important to the total figure, are weak because these formations are poorly identified by remote sensing;

5.5 it was essential in all discussions to acknowledge that trees and forests provided a wide variety of social, economic and environmental functions, both for present generations and for those to come. A comprehensive approach was therefore essential in addressing forest issues.

5.6 better information on the cost effectiveness of, and the social and economic basis for, different options for global forest management, and on quantifying the multiple roles of forests, was an urgent research priority;

5.7 policies and programmes need to be tailored closely to local conditions and circumstances, in particular the socio-economic and institutional setting and constraints;

5.8 there is a continuing need for substantial and high quality technical and financial cooperation in the management of the world's trees and forest.

VI. References

Proceedings of Technical Workshop to Explore Options for Global Forestry Management, April 1991

AGRICULTURE AND CLIMATE CHANGE - A PHYSICAL PERSPECTIVE

(Abstract)

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The radiative properties of certain gases (greenhouse gases) in the Earth's atmosphere influence the mean temperature of the Earth's surface. In turn, this influences the dynamical motions of the atmosphere and oceans, the winds and rainfall.

Human activities are now changing the composition of the atmosphere, particularly with respect to greenhouse gases. Understanding of the complex climate system is sufficiently advanced to predict a high probability of significant global warming in the next few decades, as a result of the anticipated continuous increase of these gases.

There are uncertainties in the magnitude and timing of these changes, while their impact on the regional distribution of climate patterns is not yet predictable. It is these regional changes that need to be understood before reliable assessments of impacts can be made. In the meanwhile, it is important to establish the sensitivity of human and natural systems, including agriculture, to climate change by using plausible changes to sets of climate parameters, - so-called scenarios.

The agricultural community has an important role to play in assessing sensitivities to climate change. At the same time, agriculture is strongly implicated in the emission of greenhouse gases, and may be called upon to contribute to efforts to slow down the rates of emissions.

AGRICULTURE AND THE GREENHOUSE EFFECT - A BIOLOGICAL PERSPECTIVE
(Abstract)

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The biosphere occupies a unique and central position within climate change, because it simultaneously contributes to it through the emission of greenhouse gases, ameliorates it through the absorption of CO_2 and responds to changes in climate. Therefore considerable scope exists within the biosphere to exacerbate and/or ameliorate climate change.

Agriculture, including forestry, is the most potent manipulator of the terrestrial biosphere and with the exception of the potential global impact of greenhouse gases, the most important manipulator of the total biosphere.

There are strong indications that the extensive and intensive manipulation of the biosphere is resulting in the emission of greenhouse gases. However, the importance of these emissions has been questioned on the grounds of the variability of the data in relation to comparable industrial emissions of other greenhouse gases, such as CO_2. Such comparisons should not be interpreted as uncertainties, but rather as manifestations of the well established variability of biological systems.

The agricultural/biological research community must use the accepted methodologies for dealing with variability to evaluate the potential of the agricultural managers to manipulate emissions of greenhouse gases. Elsewhere policy makers should recognise that such methodologies are distinctly different from those applicable to the manipulation of energy sector emissions.

THE CONTRIBUTION BY AGRICULTURE TO TRACE GAS SUBSTANCES OF DIRECT AND INDIRECT RELEVANCE TO THE GREENHOUSE EFFECT

- Report from a hearing by the German Parliament in Nov. 1991 -

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ABSTRACT

The German Parliament maintains a study Commission "Protecting the Earth's Atmosphere". After having published three earlier reports on protecting the atmosphere and the tropical forests, and, even more ambitiously, on "Protecting the Earth", this Commission now concentrates on the mutual interactions between agriculture and climate change.

A first expert hearing was held in November 1991, dealing with agriculture as a source of greenhouse gases. It discussed a number of questions, of which (1) the 'trace gas emissions by agricultural activities', (2) the 'sinks for trace substances in the agricultural sector', and (3) the 'potentials for reducing the impacts of agriculture on climate and atmosphere', were the most important ones.

This presentation will summarise the results, with particular reference to new findings and considerations which update the earlier statements in 1990 by the IPCC. Part of the materials which were presented there have now been incorporated into the recently drafted supplementary IPCC-WG III-AFOS report.

In 1987 the German parliament established a special Study Commission on "Preventive Measures to Protect the Earth's Atmosphere". A first report on 'Protecting the Earth's Atmosphere - An International Challenge' was published in 1989. This also was one of the incentives to the establishment of the IPCC. A second report on the 'Protection of Tropical Forests - A High-Priority International Task' appeared in 1990. In the same year, the Commission released a third, even more ambitious report on 'Protecting the Earth - A Status Report with Recommendations for a New Energy Policy' (German Bundestag, 1989, 1991a, 1991b).

Now, in its second working period, this "Enquete Commission" is going to concentrate on the interactions between agriculture and climate change. A first expert hearing was held in November 1991, dealing with "The Contribution made by Agriculture to Trace Substances of Direct and Indirect Relevance to the Greenhouse Effect'. Another hearing in February 1992 is scheduled on 'The Impacts of Foreseeable Climate Changes on Agriculture'. Since the emphasis of this present Canberra meeting is on technologies and management systems for agriculture and forestry which can contribute to minimizing greenhouse gas emissions, the following report will be restricted to those kinds of considerations which are of particular relevance here.

As far as the background information on 'Agriculturally Used Land Areas' is concerned, it suffices to say that Dr. Bouwman from Wageningen produced a series of comprehensive and well explained tables, which summarise all pertinent data from World Bank, UNDP and FAO. Including such items as food demand, fertilizer use and numbers of animals, these data allow some new and most interesting predictions about future worldwide agriculture-related greenhouse gas emissions (Bouwman *et al.*, 1991).

The hearing then went on to the 'Influence of Different Management Practices', pointing out that food transfers from the high commercial-energy agriculture of developed countries into low commercial-energy developing ones is not very useful even in view of the greenhouse effect. Food security should be sought mainly within the individual countries or at least geo-political country groups themselves. The panel then discussed the strong limitations for the reclamation of additional land and the - at least regionally - much better chances of increasing food security by appropriate soil cultivation and management of the existing land.

Concerning the 'Indirect Impacts of Agricultural Activities', much emphasis was given to the problems of intensive agriculture with all its consequences as far as specialization, high input-requirements, one-sided input/output orientation and undesirable influences on other ecosystem compartments are concerned. The subsequent discussion on the 'Distribution/Impact of Trace Gases' dealt with mutual trace gas interactions, such as between NO, or CO and CH_4 with OH-radicals and tropospheric ozone, with particular reference to the importance of biomass burning. In general, the magnitude of these burning-related trace gas releases as formerly stated by IPCC was confirmed.

Regarding the 'Emissions by Agricultural Activities', there were some statements about the cultivation-induced drops in soil organic matter, and some rather impressive Gton figures for the corresponding carbon dioxide release were quoted in this connection. However, most experts agreed that virgin soil carbon contents just cannot be maintained after cultivation. However, if cropping and tillage practices remain constant, the carbon in agricultural soils sooner or later attains a new, site and management-dependent steady-state equilibrium. Although this level can be influenced by different farming practice to some extent, it can almost never compete with that of undisturbed rangeland or forest soils. Also quite important was the forecast that global warming would accelerate soil humus decomposition, thus adding further to the CO_2 released into the atmosphere (Jenkinson *et al.*, 1991).

As far as the greenhouse gas methane is concerned, there was an interesting controversy between Dr. Sinha from India and his German colleagues Dr. Neue and Dr. Rennenberg, concerning the precision of CH_4-measurements from rice paddy fields. As Dr. Sinha will certainly point out during this present meeting as well, he questions the very high IPCC data of 110 Tg/year methane and feels that these should be corrected downward to only some 20 Tg. This could however, not, or not yet, be confirmed by the other two specialists. Whatever the correct figure might be, the immense research requirements in order to reduce rice-induced methane releases, at least in the long term, have been strongly stressed.

Regarding the methane produced by ruminant farm animals, there was an agreement about the benefits of improved feed composition and utilization, at least in the more developed and accessible animal husbandry systems of the world. However, this and the other potentials to reduce methane from enteric fermentation were not dealt with in greater detail, except for the very strong questioning of the present large-scale animal husbandry systems in many developed countries with all their undesirable environmental consequences.

Both, methane- and nitrogen-related environmental problems were also discussed in connection with livestock waste. The corresponding calculations presented by Bouwman (1991) quote about 17 Tg CH_4 from this particular source. However, with the most recent assumptions about waste composition and treatment according to Casada and Safley (1991) in mind, one may easily arrive at a worldwide methane release figure of about 27 Tg/year.

In relation to dinitrogen oxide, the panel agreed that much of its increasing concentrations in the atmosphere must be attributed to the about 80 Tg of fixed N presently added to the world ecosystem as mineral fertilizers each year. However, an equally important amount of 90 Tg N or so enter our arable soils worldwide year after year by the cultivation of leguminous plants. In this context the very large, partly animal husbandry-derived, nitrogen surpluses in the agriculture of many developed countries, especially in the EC, have been strongly criticised.

However, to be realistic, one just has to realise that not only the nitrogen excesses, but virtually all the man-made or -induced fixed nitrogen, irrespective of whether it is used by the plants or lost directly to the environment, will eventually return to the atmosphere by denitrification. This means that not only a more careful balance-, but also a much more cycling-oriented nitrogen management must be achieved in order to minimise N_2O formation. This principle applies to mineral fertilizers as well as to animal manure- or legume-derived nitrogen.

The discussion about 'Sinks for Trace Substances in the Agricultural Sector' raised some controversy as to the possibilities of a lasting carbon sequestration in agricultural soils. There is no question that reduced tillage and a judicious use of both plant and animal residues as soil amendments can retard the cultivation-induced breakdown of organic matter from virgin, or even result in a small, but significant increase in the humus level of long-standing arable soils. This certainly is of considerable benefit to soil fertility, but in terms of an overall CO_2 reduction this effect is most limited both in time and extent.

Finally, coming to the 'Potentials for Reducing the Impact of Agriculture on Climate and Chemical Composition of the Atmosphere', one option for both CO_2 and N_2O reductions would be to improve the productivity of existing farmland instead of creating new areas from present forest or rangeland soils. The theoretically discussed substitution of fossil energy by plant biomass, either through reforestation or energy farming on arable land, is in practice most limited due to the fact that about 370 million hectares would be required to sequester just 1 Gton of carbon per year in useable wood. This stands against the 6 Gtons of fossil carbon presently consumed by mankind every year. Nevertheless, re- or afforestation in thinly populated areas should not be disregarded as a real chance.

Contrary to its extensive land use-concerned considerations, the panel did not deal very much with the problems of methane reductions from enteric fermentation by ruminants. It just accepted what has already been stated about this in the literature, although with some reservations in mind as far as some apparently most optimistic expectations on the reduction potentials by improved feeding, rumen modifiers or even by animal breeding processes are concerned. Livestock waste management, on the other hand, should certainly be looked at more critically, both as a source of CH_4 during storage, and, if this waste is not properly used as a fertilizer, also of N_2O.

Regarding the overall nitrogen economy in agriculture, it was pointed out that this is particularly poor during the conversion of plant into animal protein. It is even more unsatisfactory if animal farming is not closely linked with crop production, due to the before mentioned fact that any such disintegration of farm operations neglects the essential importance of closing the nitrogen cycles as far as possible. Thus, a reduction or at least limitation of N_2O releases from agriculture stands and falls with the ability to manage and maintain our overall nitrogen economy, not only of soils, but within the whole agricultural system, so as to require a minimum of external nitrogen inputs.

This latter and most of the other suggestions essentially correspond with the concepts of "Sustainable Agriculture", the main topic of this Canberra meeting. Accordingly, it is hoped that these introductory considerations contribute a little bit to setting the scene. An authorised printed report on the ongoing deliberations of the German Bundestag can be expected in due course.

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THE RELATIONSHIP BETWEEN IMPACTS OF CLIMATE CHANGE AND RESPONSE STRATEGIES (WITH REFERENCE TO FORESTRY AND AGRICULTURE)

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ABSTRACT

It is clear that human activity in forestry and agriculture contributes to nett greenhouse gas emissions on the one hand and is affected by climate change on the other. Thus considerations of impacts of climate change must be linked to response strategies, since adaptation to minimise adverse impacts will inevitably feed back into potential impacts.

So far the somewhat arbitrary division of the IPCC into three Working Groups has led to a lack of interaction between the workers studying impacts of climate change and those developing policy responses. This is particularly evident in the case of agriculture and forestry. Thus agriculture will adjust at two broad levels - the farm level as a result of decisions by farmers, and the regional, national and international levels as a result of government policies e.g. on trade and tariffs. Forestry will also adjust at two levels - the regional level in managed forests as a result of decisions by forest managers, and the national and international levels as a result of government policies e.g. limitation of exploitation of tropical rainforests.

This paper will discuss these interactions and their policy implications.

Introduction

In preparing its First Assessment Report for the Second World Climate conference in October 1990, the Intergovernmental Panel on climate Change made use of three Working Groups on Science, Impacts, and Policy responses. These three Groups essentially worked independently in preparing their contributions to the First Assessment report and little was done to ensure that there was interaction between them.

The preparation of the Supplementary Report has provided an opportunity to improve the interaction by bringing together workers studying impacts and those studying policy responses. This is vital to ensure that policy makers are presented with a clearer picture of the options open to them. While it is possible to take a "snapshot" of potential impacts of climate change at a given time, an almost continuos response is occurring at the "grass roots" level as humans adapt to changing situation s due to natural variability of climate and to changes in trade patterns. This is particularly true in the case of agriculture and forestry.

Climate change due to the enhanced greenhouse effect places a further additional constraint on the situation and the predictions of overall global temperature increase have to be translated into regional changes in temperature and precipitation, both of which strongly influence agriculture and forestry. The initial report of Working Group II documented the available evidence on regional impacts of climate change in agriculture and forestry and concluded that there will be significant regional variations. Thus, for example, horticultural production in mid latitude regions may be reduced while cereal production could increase in northern Europe. There may be severe effects in some regions, particularly decline in production in regions of present day vulnerability that are least able to adjust, eg, Brazil, Peru, the Sahel region of Africa, Southeast Asia, the Asian region of the former USSR and China.

The initial report of Working Group III focussed its attention on the emissions of greenhouse gases from agriculture and forestry; these accounted for approximately a quarter of total carbon equivalent greenhouse gas emissions from anthropogenic sources in the 1980s. These sources include deforestation, rice production, ruminant animals, fertilisers, loss of soil organic matter, land conversion and biomass burning. This proportion of total emissions can confidently be expected to increase in future as food production rises to meet the needs of an increasing world population particularly in the developing countries and as deforestation, particularly of tropical forests, continues at an increasing rate.

Implications for Agriculture
Climate change may alter the length of growing seasons, modify the range between maximum and minimum temperatures, and lead to rainfall variability. The most sensitive agricultural regions are those where water supply problems exist at present and these will get worse as a result of global warming. This is especially true in regions where warmer, drier conditions may reduce soil moisture in drought-sensitive soils, where agriculture is rain-fed or is reliant on limited irrigation, or where there is strong competition for water supplies. With global warming, farmers will compete for fresh water with foresters, conservationists, recreational users, industries, river transport, hydropower and urban areas. Agricultural regions in semi-arid climates may be especially sensitive to even slight drying, and coastal agriculture may be adversely affected by saline intrusion due to sea level rise resulting from global warming.

Policy responses for agriculture must take account of both the need for increased production together with the need to reduce greenhouse gas emissions. These two objectives may, or may not, be compatible depending on the regional situation.

Implications for Forestry
Global climate models suggest that climate change will lead to the greatest changes in temperature at mid-to-high- latitudes. Forests in these regions are likely to be severely and adversely affected. Historically, natural ecosystems have responded to long-term climate change by migration of individual species at differential rates. This implies dispersal and establishment of the leading edge of the forest and decline on the retreating edge that is induced by competitive displacement or by drought. However, human-induced climate changes appear likely to occur over a time period too short for trees and other plants to migrate.

Increased temperatures, sustained over a period of years, could produce a widespread, catastrophic, drought-induced decline in the world's temperate and boreal forests. Tree species in the warmer and drier parts of these ranges, particularly in soils that are thin, coarse and in upland areas, will be at risk. Highly specialised species - those with very specific habitat and food requirements - will be especially vulnerable. If global warming occurs, species are likely to become extinct at an accelerating rate.

Tropical forests are equally at risk from drought or lengthy dry seasons but this is compounded by deforestation of tropical rain forests. This can directly alter regional climates because the loss of vegetation can significantly reduce regional rainfall. For example, 50 per cent of the rainfall in the Amazon region comes from evapotranspiration of the forest itself. The rate of deforestation of tropical forests appears to be increasing.

Conclusion

The policy objectives developed in the Working Group III Report to reduce greenhouse gas emissions from agriculture and forestry were:

Agriculture:
- To reduce methane emissions from ruminants and rice cultivation.
- To reduce nitrogen loss from cultivation, especially in the form of nitrous oxide.

Forestry:
- To reduce the scale of destructive deforestation.
- To promote reforestation and afforestation.
- To promote sustainable forest management.
- To promote more complete utilisation of forest products, including recycling.

While they are laudable objectives, they need to be seen in the context of the impacts of climate change. Thus, in the case of agriculture in Asian countries, the thrust will have to be for increased rice production to sustain the rapidly growing population. For example, in India where anticipated temperature rises are likely to reduce wheat production in northern and central regions and also sorghum production in southern regions, rice yields could increase substantially given sufficient increases in rainfall. Thus despite changes in agricultural practice to reduce emissions from rice paddies, total emissions of methane will probably continue to increase.

In the case of forestry, reforestation and sustainable forest management entails the use of sophisticated techniques and levels of investment that are often not available to developing countries most in need of them. The impact of climate change on boreal and temperate forests must be considered when promoting such objectives. thus, with anticipated temperature rises, conditions usually supporting boreal forests could move north into the current tundra zones. This would lead to a reduction in area potentially supporting boreal forests of approximately 37 per cent. Further, the area of subtropical forest zones would decrease by 22 per cent under the same scenarios. While the appropriate techniques and sufficient investment are available in most of the countries with boreal and temperate forests to promote reforestation and afforestation using managed forests, there must be some doubt as to whether the anticipated reductions can ever be compensated for by possible increases in other areas. It appears that during the next 30-50 years, in response to climate changes, forests everywhere in the world will be sensitive to some decline and thus their contribution as sinks of carbon dioxide will be less than initially anticipated.

WHAT IS THE RELEVANCE OF THE IPCC, WCRP, IGBP ETC TO THE SCIENTIST?

(Abstract)

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The success of all our attempts to tackle the challenges of global change depend on clearly recognising problems, identifying responses and conveying this information to decision makers. However, our success also depends on an effective research base, which in turn depends on the support of individual scientists. In the frenzied activity of the past few years in the area of global change there has been an allocation of roles agreed upon by the various organizations that have come into being. For example, IPCC recognises IGBP (International Geosphere Biosphere Programme) and WCRP (World Climate Research Programme) "as the two major research programmes devoted to decreasing our uncertainty in relation to global climatic change". However, at times the individual researcher feels swamped by the apparently independent goals, methods and priorities of the multifold acronymic organisations both national and international. If we are to mobilise the scientific community effectively there has to be a greater collaboration and mutual support between the major international bodies than there appears to have been so far.

METHANE EMISSION FROM AGRICULTURAL SYSTEMS

(Abstract)

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The realisation that methane is an important 'greenhouse' gas which is increasing in the atmosphere, has lead to investigate the 'sources' and 'sinks' of this gas. Agricultural systems, especially rice paddies and livestock with enteric fermentation have been attributed as major sources of methane. However, there is a large amount of uncertainty of emission of methane from both rice paddies as well as animals. A detailed analysis shows that the uncertainty arises because of methodological and extrapolation problems. Evidence shows that the rice plant does not produce methane by itself but only serves as a transport mechanism from the waterlogged soils to the atmosphere. The source of carbon for producing methane, the occurrence and growth of methanogeneric bacteria and soil conditions favourable for reducing environment are essential for emission of methane. Diurnal variation in emission of methane is suggestive of the involvement of photosynthesis and hence of stomatal mechanisms. Reducing environment created by redox potential is not generated in well drained soils. Even in less drained soils, 3-4 weeks waterlogging is essential for generation of methane. In addition, there is an apparent relationship between biomass and methane emission when soil conditions are favourable. The estimates of methane emission have been made considering (i) methodology (ii) soil characteristics and (iii) biomass relationship. Results show that rice paddies possibly contribute methane to the extent of 10 Tg annually to the atmosphere as against 60 Tg now proposed in the revised IPCC report. Better techniques such as remote sensing at field level may help improving the estimates of methane.

THE MANAGEMENT OF EXTENSIVE AGRICULTURE: GREENHOUSE GAS EMISSIONS AND CLIMATE CHANGE.

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ABSTRACT

Extensive agricultural systems include grazing lands (cleared pastures and woodlands) and semi-permanent cultivation. Globally, permanent pastures are an important form of land use (25%) and along with grazing from forests and woodlands and associated cropping, extensive systems contribute substantially to national economies in food and fibre production, revenue from exports and capital accumulation in herds and land development. The management of extensive systems to provide these benefits for human existence, necessarily results in greenhouse gas emissions. For example, ruminants produce CH_4, burning of pastures and woodlands emits a range of greenhouse gases (CO_2, CH_4, CO, N_2O, NO) whilst tree clearing, overgrazing and cultivation reduce biomass pools of carbon thus emitting CO_2 into the atmosphere. Furthermore, legume-based pastures fix nitrogen thus increasing emissions of N_2O.

The relationship between the production of food/fibre and greenhouse gas emissions is likely to be non-linear. For example, with increasing stocking rate (animals per ha), production (liveweight gain per ha) will increase to an optimum and then decline whilst greenhouse gas emissions will continue to increase. There is a need to determine the management practices which reduce emissions without reducing production.

Climate change may increase emissions. For example, a warmer wetter climate will provide more opportunities for pasture burning, tree clearing in marginal areas, and the development of legume-based pastures. The effect of increasing CO_2 on plant growth could result in both increased emissions through a change to more intensive land use or reduced emissions through greater carbon storage.

The use of agricultural systems models will allow the evaluation of the impact of management options and climate change on greenhouse gas emissions. In this way the need to reduce emissions can be balanced against the need to produce food and fibre. Recent research has shown that management options exist that both reduce emissions and are also beneficial for sustaining the use of extensive systems. Our challenge as advisers is to overcome the understandable reluctance of land managers to change management practices before the problems (global warming and land degradation) actually occur.

Introduction

Our paper examines the issues of: (1) defining extensive systems and their current condition; (2) their role in greenhouse gas (GHG) emissions; (3) response strategies to reduce GHG emissions; (4) the potential impact of climatic change on extensive agriculture; and (5) the opportunities for action.

Extensive Systems: definition and condition

Extensive systems are grazed agricultural systems which are characterised by (1) low productivity per unit area; (2) low inputs in management, technology and capital; and (3) high year-to-year climatic variability, especially in rainfall. A key reason for low inputs is the high chance of restricted growing seasons (eg. drought). In the tropics and subtropics extensive systems are mainly in areas where climatic variability is linked to the El Nino/Southern Oscillation (ENSO) phenomenon. Drought and flood conditions occur during El Nino and La-Nina phases respectively depending on location. Global circulation models are currently limited in forecasting regional climatic change since the effect of global warming on ENSO is yet to be evaluated.

Extensive systems include most of the world's arid and semi arid lands, and cover 35% of the world's surface including half the world's nation. Extensive systems support 20% of the global human population, 50% of cattle, 33% of sheep, 67% of goats and 100% of camels. The purpose of animal production varies greatly e.g. meat, milk, fibre, draught power and manure. despite the variation in desired animal product, the issues of determining the 'best' stocking rate (animals per unit area) and stocking strategies are common to all extensive systems (Behnke 1985, Foran and Stafford Smith 1991).

A large proportion (75%) of the world's drylands (Mabbutt 1984) is threatened by 'desertification'. Regional surveys in Australia have reported similar proportions (40-70%) of extensive lands showing degradation with reduced productivity (e.g. Woods 1983, Tothill and Gillies 1992, Mott and Tothill 1992). The latter studies identified stocking policy as the major management problem. Such surveys are necessarily subjective, reflecting not only the impact of management, but also short and medium term climatic fluctuations and short-term management modifications. despite this lack of quantifiable objectivity, there is no doubt that significant areas of extensive systems have suffered degradation throughout the world.

The reasons for reduced productivity are important in relation to managing extensive systems for GHG emissions. Where reduced productivity results from the invasion of unwanted plant species (unpalatable shrubs and grasses), greater storage of carbon, acting as a sink for CO_2, may occur despite reduced useful production. Management efforts to change to a more desirable state by biomass burning, chemical control of unwanted species or rotational heavy grazing, are likely to increase GHG emissions. Conversely, where degradation is expressed as increased bare ground, loss of soil organic matter, increased salinity and loss of desirable perennial species, then corrective management will <u>both</u> increase productivity and reduce emissions. Future surveys should seek to discriminate between the reasons for reduced productivity so that more accurate calculations of management effects on GHG emissions can be made.

Extensive systems and greenhouse gas emissions
All agricultural management options in extensive systems contribute GHG emissions. Grazing produces CH_4 through enteric fermentation and animal wastes. clearing of woodland contributes CO_2 and N_2O through decomposition of tree/shrubs and soil organic matter. biomass burning contributes a range of gases (CH_4, N_2O, CO, NO_x) depending on fuel load and fire temperature. Broadacre cropping contributes CO_2, N_2O and NO_x with soil organic matter breakdown and fertiliser application. Improving pastures with legumes contributes N_2O but sequesters carbon through increased nitrogen fixation.

Carbon Dioxide
Land clearing of forest and woodlands, especially in the developing world, is a major agricultural contributor to global CO_2 emissions (20% Houghton *et al.*

1991). From 1976 to 1986, forest and woodland in developing countries declined by 8.6 M ha/year with crop and 'other land' increasing by 3.6 M ha/year and 4.6 M ha/year respectively (Humphreys 1989). The net change in 'pasture' land was relatively small (0.9 M ha/year). The need to feed an increasing population, including meeting their dietary protein requirements from animal products, will result in continued pressure for such land use changes, and hence will result in changes in carbon storage and CO_2 emissions. When accounting for changes in carbon storage, other land management processes must be considered including carbon stored by shrub encroachment and wildfire suppression. The potential role of extensive systems in storing carbon as a result of increased CO_2 concentration has yet to be evaluated.

Methane
Globally, enteric fermentation and animal wastes are currently estimated to be 20% of all (natural and anthropogenic) CH_4 emissions (Houghton et al. 1991). Management of extensive systems can also affect CH_4 emissions through its effect on biomass burning and the activity of termites, each contributing about 7% of global CH_4 emissions. Termites can be either increased or reduced by grazing depending on termite species and location.

Nitrous Oxide
N_2O emissions from extensive agriculture are difficult to quantify. burning and pasture legumes are the major contributors. The possible role of woodland clearing and overgrazing in releasing N as N_2O requires further research.

The overall contribution to global emissions from extensive systems is difficult to evaluate and depends on the accuracy of estimates of (1) land use change, (2) GHG emissions, and (3) global warming potential (GWP) of the respective gases (Shine *et al.* 1990). We have made a preliminary calculation (based on data in Houghton *et al.* 1991) for a 'worst case' time horizon of twenty years, which increases the weighted contribution of CH_4. Considering only the GHG's of CO_2, CH_4 and N_2O, this calculation suggests that extensive systems contribute less than 20% of total anthropogenic GWP.

Response strategies to reduce GHG emissions in extensive systems
The strong relationship between GHG emissions and agricultural production is a major problem in devising response strategies. Land use for human benefit in extensive systems is likely to be in conflict with practices that reduce GHG emissions. The evaluation of land use alternatives in terms of production, social and economic value, sustainability and GHG emissions is a necessary first step. Traditional practices, such as biomass burning to prevent woody weed invasion of grasslands and to develop new grazing and cropping land, are likely to increase GHG emissions.

The clearing and subsequent development of woodlands is a common method of increasing production in extensive systems. For example, in north eastern Australia, clearing woodland for cattle production can result in an eight fold increase in liveweight gain (LWG) per unit area: woodland produces 10 kg LWG/ha; cleared grassland, 30 kg LWG/ha; forage oats, 80 kg LWG/ha. Each stage of development usually results in a decrease in biomass carbon storage and hence increased CO_2 emissions. The method of tree clearing (pulling, stem injection or aerial application) can have large effects on both natural decomposition rates and the proportion of biomass burnt, and hence on the type of GHG emission (Howden *et al.* this volume). Both stem injection and aerial application leave wood standing with reduced rates of decomposition. In contrast to the above changes, the use of pasture legumes can increase cleared grassland production to 40 kg LWG/ha while storing more carbon in the biomass and soil than occurs with annual forages. Grass/legume pastures may represent a compromise between maximising production and minimising CO_2 emissions, but the impact on N_2O emissions is uncertain.

The high proportion of extensive systems with 'reduced productivity' suggests that there are opportunities where lower stocking rates would increase carbon storage and reduce emissions. A preliminary simulation study for grazed pastures in northern Australia (Howden *et al*, this volume) showed that where heavy pasture utilisation was occurring (greater than 40% of pasture growth consumed) then a reduction in stocking rate would increase beef production while reducing GHG emissions. Such studies allow the evaluation of the cost of response strategies to reduce GHG emissions and indicate where opportunities are likely to exist.

The calculation of <u>potential</u> carbon storage in degraded lands is worth pursuing. Mabbutt (1984) indicated that 3100 M ha of rangelands was threatened by desertification. J. Williams (personal communications) has suggested that a change of 0.5% organic carbon in the top 10cm is possible with restoration. This represents 7 t C/ha assuming a bulk density of 1.4 g/cc. Therefore restoration of 3100 M ha of degraded lands could absorb 22 Gt of carbon or 80 Gt CO_2 from the atmosphere. This compares with deforestation and land use change which currently produces emissions at the rate of 1.6 Gt CO_2 per year (Houghton et al. 1991). Hence the <u>potential</u> increase in carbon storage on degraded lands could be equivalent to carbon emissions from deforestation over fifty years at the current rate.

For restoration of degraded lands to play a useful role as a sink for carbon, we need (1) a more reliable and quantitative estimate of the area of degraded lands (e.g. Pickup 1989); (2) monitoring of changes in these lands so that their net impact on GHG can be assessed over time; (3) demonstration of the potential increases in soil organic matter with better managed pastures; and (4) evaluation of the practicality of reducing animal numbers to facilitate pasture restoration. In addition, where there are demonstrable methods for pasture restoration, these must fit with local social systems, and the cost-benefit of the operation in relation to control of GHGs must be shown to be worthwhile.

The impact of climatic change and CO_2 increase on extensive systems

All management options in extensive systems are likely to be influenced by climatic change. For example, a change to a warmer wetter climate for northern Australian savannas will reduce the current climatic and economic constraints on savanna development. tree clearing, pasture burning, legume establishment and cropping would become more reliable options thus further contributing to GHG emissions. However, such a climatic change would not be completely beneficial. Increased temperatures would have direct effects on animal production (e.g. reducing fertility of sheep in northern Australia) and indirect effects by reducing digestibility. Extensive systems are often associated with low soil fertility. The increased plant growth likely to result from increased CO_2 concentration will dilute plant nitrogen concentration (protein) resulting in lower animal growth. The possibility of reduced winter rainfall in northern Australia would shorten the length of the growing season, a major determinant of production per animal. Greater rainfall variability and increased evaporation rates would increase the risk of surface water droughts. Increased CO_2 may promote C_3 woody weed competition in C_4 grasslands. A range of biological and physical factors, pests, diseases, salinity, and soil erosion will require management changes in extensive agricultural systems.

Opportunities for action in management of extensive systems

The capacity to reduce emissions and respond to climatic change depends on the individual farmer's desire to act. farmers will require clear demonstration of the management alternatives either as physical 'models' (e.g. pilot studies on the use of fodder trees) or through agricultural decision support systems (e.g. economic assessment of lower stocking rates, Foran and Stafford Smith 1991). Action even within a 'no regrets' policy is unlikely to occur unless the benefits (social or monetary) are clear.

Given the apparent uncertainty of the magnitude of global warming compared with immediate problems (such as drought or floods associated with the 1991 El Nino event, low world commodity prices, global recession), action is not likely to proceed until the effects of global warming occur. We suggest therefore that the required response of agricultural scientists should be:

1. to prepare for climatic change by developing more flexible approaches to management, for example, stocking rate strategies should include the current status of the pasture resource and the likelihood of drought or flood as forecast from the current understanding of ENSO, McKeon *et al.* 1990;

2. to monitor closely the climatic changes that will affect agriculture, for example, the currently increasing night time temperatures in May in northern Australia are extending the potential growing season for C_4 grasses, reducing frost damage to pasture quality but increasing the risk of disease development on winter forages.

Conclusion

Extensive systems will be under increasing and conflicting pressure to contribute to food production but reduce GHG emissions. The opportunities for management to meet these conflicting goals are uncertain but the preliminary analysis presented here has suggested some possible compromises. Agricultural scientists should play a leading role in (1) analysing agricultural systems to find the best balance between production and emissions, (2) demonstrating the value of management alternatives, and (3) speeding the process of adaptation to a changing climate.

Where farmers and livestock managers have been pressured to maximise short term production, they have increased the risk of irreversible land degradation as indicated by the surveys referred to above. The challenge for sustainable land use is to reduce this risk in a variable and possible changing climate. The adoption of practices (e.g. lower stocking rates) that reduce degradation risk are also likely to reduce GHG emissions.

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INTEGRATED SYSTEMS: ASSESSMENT OF PROMISING ALTERNATIVE LAND-USE PRACTICES TO ENHANCE CARBON CONSERVATION AND SEQUESTRATION

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ABSTRACT

Degraded or sub-standard soils and marginal lands occupy a significant proportion of boreal, temperate and tropical biomes. For example, salt-affected soils occupy 7% of the earth's land area. Management of these lands with integrated agroforest systems represents a significant global opportunity to reduce the accumulation of greenhouse gases in the atmosphere. Establishment of extensive agricultural, agroforest and forest systems on marginal or degraded lands could sequester 1-2 Gt C per year, globally, over a 30 year time frame. Moreover, slowing soil degradation by impeding desertification could conserve up to 0.5-1.5 Gt C annually.

A global analysis of biologic and economic data from 94 nations representing diverse climatic and edaphic conditions reveals a range of integrated agroforest systems to establish and manage vegetation on marginal or degraded lands. Revegetation practices can be employed to sequester atmospheric CO_2 and temporarily store carbon on formerly degraded lands. Establishment of low-intensity agroforestry systems can store up to 50 tons C/ha in boreal, temperate and tropical ecoregions. The mean initial cost of soil rehabilitation and revegetation, range from $500-3,000/ha, for the 94 nations surveyed. Natural regeneration of woody vegetation or agroafforestation establishment costs were less than $1000/ha in temperate and tropical regions. Alternative land-use practices such as fuelwood and fiber plantations, intercropping systems, and shelterbelts/windbreaks are also viable options to improve productivity of sub-standard soils and marginal lands.

Implementation of technical options to sequester and conserve carbon on marginal lands is influenced by social, economic and political factors. Technical suitability of the soil system (eg, salt-affected or arid soils), as well as, the socio-economic availability of land merit careful consideration. Regional or national programs which address land suitability issues have been launched in Australia, Brazil, India, USA, USSR and other nations in recent years. Successful programs have a common feature: consideration of local needs for goods and service in concert with national or global goals to reduce the accumulation of greenhouse gases in the atmosphere.

Introduction

Preliminary assessments suggest that significant potential exists for managing the terrestrial biosphere, particularly agricultural and forest systems - and land use systems that combine agriculture and forestry practices at both the site and landscape scales - to reduce the accumulation of greenhouse gases in the atmosphere (Dixon and Turner, 1991; Andrasko, 1990). Degraded or sub-standard soils and marginally productive lands currently occupy about half a billion hectares (ha) of boreal, temperate and tropical biomes. Establishment of extensive agricultural, agroforest and forest systems on marginal or degraded lands could conserve and sequester up to 1-2 Gt C per year, globally, over a 30 year time frame (Dixon *et al*, 1991). Additionally, slowing soil degradation by impeding desertification could conserve up to 0.5-1.5 Gt C annually (Johnson and Kerns, 1991). However, significant barriers hinder widespread adoption of these systems.

Soil Management

Globally, 1.5-3 times more carbon occurs in soil systems than has been measured in terrestrial vegetation. Soil management can alter belowground carbon pools and flux (Dixon and Turner, 1991), if appropriate land use practices and soil inputs and conditions are present. Conversion of forests or grasslands to intensive agriculture generally results in a decrease in soil carbon because of increased rates of decomposition and respiration (Schlesinger, 1990). Conversely, conservation tillage or establishment of forest or agroforest systems can increase carbon accretion in most soils, over years to decades until a new soil carbon equilibrium is reached (Howlett and Sargent, 1991; Lal, 1989). Carbon sequestration rates for land management practices range from 21 t/ha/yr for stubble-mulching of crops in semi-arid environments to 240 t/ha/yr from manuring of farm plots within tropical latitudes (Lee, 1991). Promising strategies for maintaining, restoring and enlarging soil carbon pools include: enhancement of soil fertility and maintenance of neutral pH; concentration and intensification (rather than extensiveness) of agriculture; preservation of wetlands (rather than conversion to cropland); agroafforestation and forestation; and conservation tillage to reduce soil aeration, heating and drying (Johnson and Kern, 1991).

Agroforestry Systems
Alternative land-use practices such as establishment and management of fuelwood and fiber plantations, intercropping systems (mixture of tree, agronomic and horticultural crops), and shelterbelts/windbreaks are also viable options to sequester and conserve carbon in terrestrial systems (Garrett, 1991). Establishment of one hectare of agroforestry or extractive reserves within tropical latitudes can provide food, fuel and fiber to local people and offset up to 5-10 ha of deforestation (Browder, 1992). fuelwood plantations and intercropping systems have been employed in temperate (eg. China, USA) and tropical (eg. India, Thailand) ecoregions to temporarily sequester carbon and offset reliance on fossil fuels. Agroafforestation of the Russian steppe demonstrates a large scale capability to integrate agronomic and forest systems to preserve ecosystem function (Krankina and Dixon, 1992).

Integrated Agroforestry Projects
Integrated forest development projects in particular may offer a higher probability of success, by including a variety of land-use components to meet socioeconomic needs of local communities in ways that tailor the mix and size of project components to match biophysical conditions and organisational capabilities, and provide carbon management (Trexler *et al*, 1989). Such integrated projects may include areas in forest reserves, fuelwood plantations, agroforestry, and intensive agriculture, managed as a single unit. For example, the Thailand Forest Village program was initiated in 1967 to slow deforestation and land degradation due to shifting cultivation. Agroforestry and plantation systems established in this program have conserved and sequestered approximately 0.01 Gt of carbon over the past 20 years.

Innovative integrated systems are being practiced on a small scale that offer models for more sustainable management of soils, vegetation, crops, and livestock. Many of these systems offer a sustained flow of food, fuel, and fiber, in addition to substantial economic returns to local communities, according to limited studies available. Examples of promising systems in use in the tropics, for example, include biosphere reserves, extractive reserve forests, silvopastoralism, and community forestry (Howlett and Sargent, 1991; AFOS, 1990). Comparisons of the relative ability of different components to offset conversion of forest to other land uses (primarily agriculture and pastures) have recently shown that component efficiency varies across ecological and social organisational systems. from a carbon conservation standpoint, protection of standing forest and increasing agricultural intensification offer especially high potential to reduce forest loss (Andrasko *et al.*, 1991; Dixon *et al.*, 1991; Trexler, 1991; Trexler *et al*, 1989; Andrasko, this volume).

Potential for Implementation
Implementation of technical options to sequester and conserve carbon on marginal lands varies greatly, and is influenced by social, economic and political factors (Howlett and Sargent, 1991). Soil system capability and limitations (eg, salt-affected or arid soils), as well as the socio-economic availability of land, merit careful consideration. Nations with 100 million ha of land biophysically suitable for establishment of agroafforestation and forestation include: Russia, US, China, Brazil, India, Mexico and Zaire (Dixon *et al.*, 1991; Houghton *et al.*, 1991). Regional or national programs have been launched in recent years in Australia, Brazil, Canada, India, USA and other nations that successfully combine production of goods and services for local needs, with national goals to restore degraded lands, and in some cases to reduce greenhouse gas accumulation through carbon sequestration.

Table 1

Potential Carbon Storage Through Forest Management, by Major Biomes, Over 50 Years

Biome	Forestation	Silviculture
	Tons of Carbon per Hectare	
Boreal	15-40	3-10
Temperate	30-180	10-45
Tropical	30-130	14-70

Source: Dixon *et al.*, 1991

Carbon Benefit and Cost Estimates
A Global analysis of biologic and economic data from 94 nations representing diverse climatic and edaphic conditions reveals a range of integrated agroforest systems in practice to establish and manage vegetation on degraded and non-degraded lands (Dixon *et al.*, 1991). Establishment of low-intensity agroforestry systems can store up to 50 tC/ha in boreal, temperate and tropical ecoregions. The mean initial cost of soil rehabilitation and revegetation ranges from US$500-3,000/ha for the nations surveyed. Natural regeneration of woody vegetation in temperate and tropical regions.

While these establishment costs appear prohibitively expensive, when viewed in terms of the cost per ton of carbon sequestered (or avoided emission), and compared with alternative opportunities to reduce CO_2 emissions in the energy sector, the costs are comparatively low. These are establishment costs only (without including maintenance costs). However, they are not <u>net</u> costs - i.e., they do not include the economic <u>benefits</u> derived from the sale of, or the avoidance of cash outlays for, forest products. Net costs are likely to be negative (i.e., positive rates of return to investment), in many cases. Tables 1 and 2 summarise the survey of data for 94 countries from Dixon et al., 1991. The median cost efficiency of management practices, based on establishment costs considered over 50 years, is about $5/tC, with an interquartile range (i.e,. indicating the middle 50% of observations) of $1-19/tC.

Table 2

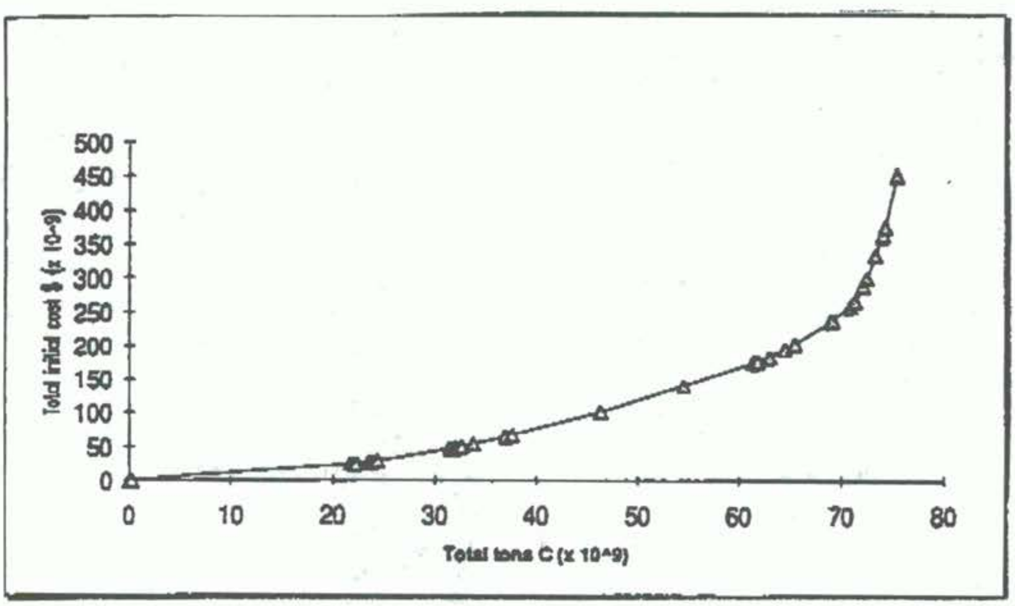
Establishment Cost per Ton of Carbon of Major Forestation and Agroforestry Practices

Zone of Latitude	**Practice**	**Establishment Cost/Ton of Carbon (US$/tC)**	
		Median	**Interquartile Range**
Boreal:	Natural regeneration	5	4-11
	Reforestation	8	3-27
Temperate:	Natural regeneration	1	1
	Afforestation	2	1-5
	Reforestation	6	3-29
Tropical:	Natural Regeneration	1	1-2
	Agroforestry	5	2-11
	Reforestation	7	3-26

Source: Dixon *et al.*, 1991

Figure 1

Total Global Establishment Cost of Sequestering Carbon in Forest Systems Employing Forestation and Forest Management Practices



Source: Dixon *et al*, 1991

A cost curve of forest/agriculture land use opportunities can be assembled by ordering the lowest-cost practices (and estimates of the land requirements) at the beginning of the curve, and adding progressively more expensive practices, until a curve summarizing the cumulative (or marginal) costs and associated land areas is developed. Using the data from 94 countries assembled by Dixon *et al.* (1991), the total global establishment cost of sequestering carbon in forest systems is shown in Fig. 1. The total cost rises gradually until storage reaches about 55 Gt (billion tons) of carbon, at an approximate total cost of $150 billion. Costs escalate more rapidly beyond this point. To reach 55 Gt of storage, on 570 million hectares of land, about 24 Gt would be sequestered in humid tropics, 20 Gt in dryland ecoregions, and 11 Gt in humid temperate zones; only at higher levels would any land be drawn from the boreal zone. The marginal cost (not shown) of storing 45-65 Gt is roughly $3/tC. At carbon storage goals above 70 Gt, the marginal cost climbs sharply to over $100/tC. (These are establishment costs only, without land rental or purchase, maintenance costs, or the value of forest products produced. Net cost estimates are not currently available).

Table 3

Estimated Global Land Management Targets Required to Achieve the Noordwijk Declaration Reforestation Goal, by forest management options of Andrasko (1990: 1991)

	Latitudinal Zones			
Forest management options	Boreal	Temperate ha × 10^6/yr	Tropical	Total
1. Maintaining forest area				
Protection of forest reserves (including reforestation of harvested and forests lost by wildfire and pests)		all nations at their current levels		
Extractive reserves				
2. Reduce loss of forests	0.5	0.5	1.5	10.0
Natural forest management Increased use of pastures				
Sustainable agriculture			7.5	
Agroforestry			5.0	5.0
3. Expand forest area				
Reforestation (& afforestation)	2.0	3.0	3.0	
Restoration of degraded lands	1.0	1.0	10.0	20.0
Total	3.5	4.5	27.0	35.0

Source: Dixon *et al*, 1991

Land availability remains highly uncertain (Houghton *et al.*, 1991). An expert systems analysis in over 50 tropical countries estimated land available for regeneration, agroforestry, and plantations (Trexler, 1991; Trexler and Haugen, 1992). The study concluded that the feasibility coefficient of "plausible implementation rates" for these practices was 71% of land available for regeneration, 40% of agroforestry lands, and 93% for plantation lands. Of 530 million ha considered available globally, 65% was estimated to be plausible to implement in identified practices.

Nordwijk Declaration Analysis
An assessment of the feasibility of the world forest management goal articulated by the 1989 Noordwijk declaration of a *net* increase of 12 million hectares per year by 2000 has been performed in Dixon *et al.*, 1991. The admittedly optimistic analysis assumes that the easiest areas to delay deforestation and reforest would be targeted first, while research on field techniques and implementation obstacles began on difficult areas targeted for later stages.

Table 3 presents estimates to achieve expansion of the world's forest area by 20 million ha annually by 2000, for 40 years, to offset current deforestation of 17 million ha/yr and projections of up to 30 million ha deforested per annum by 2045. This expansion could be achieved by: 1) maintaining (protecting) all current forest area, 2) reducing forest loss, via natural forest management and increased use of pastures (2.5 million ha/yr) and sustainable agriculture and agroforestry(12.5 million ha/yr), and 3) expanding forest area via reforestation and afforestation (8 million ha/yr and restoration of degraded lands (12 million ha/yr).

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GASEOUS EMISSIONS FROM AN INTENSIVE DAIRY FARMING SYSTEM

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ABSTRACT

A case study is presented which discusses the likely role of various components of an average, typical dairy farm in SW England in emitting greenhouse gases (eg CH_4 and N_2O) to the atmosphere. The various sources of N_2O within the complete production system include fertilizer, NO_3-derived from excreta returned at grazing and from farm wastes returned to the swards. The extent of denitrification loss and the emission of N_2O from each of these sources is estimated and means of control discussed.

As far as CH_4 is concerned, the major potential sources are directly from the rumen, from anaerobic soils and from anaerobic conditions associated with the handling and utilization of farm wastes. Although estimates of losses can be made from measurements of methane released from housed animals, there is no data for the net losses when animals are in the field. There is also little available information on the extent to which grassland soils may act as a sink for methane: preliminary data for well-drained soils indicate that this process may be an important consideration in determining the net flux from a production system.

Each major component of the dairy farm management system is discussed in relation to the factors controlling net leakage of gases and to any remedial measures that may be taken to reduce losses.

Introduction

Intensive grassland production systems are currently the subject of considerable scrutiny because of their potential for leaking potentially damaging ions, gases ad other materials into the wider environment. Much attention has, for example, been focused on their role in the transfer of nitrate ions, to drinking waters which is the subject of legislation within EC countries. There is also concern that such production systems may be major sources of gaseous compounds which are environmentally active. In the present case study, we estimate the net flux of two greenhouse gases, methane (CH_4) and nitrous oxide (N_2O), from a typical, representative intensive dairy farming enterprise.

The Dairy Farm

The representative system is described in Table 1 and is based on that of Thomas *et al* (1991) with the inputs as shown. The holding is situated in SW England (rainfall > 1000 mm) with production based on fertilized grass swards growing on a loam/silty loam soil. The fertilizer input represents an average input for lowland grass systems in the UK. We consider losses from the various components of the soil/plant/animal interactions involved in the grazing cycle and of relevant aspects of the housed component, including farm waste storage and disposal on land. Our estimates of N_2O and CH_4 from some of these components of the system are often based on limited information.

A further unknown component is the impact of soil. Firstly, wet, poorly drained soils may act as sources, and this will be enhanced when farm wastes are applied. Secondly, under many circumstances, soils may act as an important sink, absorbing CH_4 from the atmosphere. The balance between these two activities is not known.

Controls over CH_4 losses.

The largest impact is likely to arise through greater efficiency of dietary utilization by the animal: CH_4 production per unit of food consumed decreases markedly with feed intake (Blaxter, 196?) so that measures taken to increase production per animal will reduce emissions. These will include correcting any dietary deficiencies, choice of appropriate diet, and the use of novel additions (EPA, 1990). Other opportunities may arise through manipulation of the gut microbial population through feed formulation and treatment, bioengineering and changing the balance of the species present and, for example, encouraging a system that generates propionate.

As far as the other components of the farm are concerned, every opportunity should be taken to enhance the sink capacity of the soil/sward system by sustaining the aeration status and reducing any possible interactive effect with N. Where wastes are being stored, the obvious solution is to collect and utilize any biogas production and to reduce opportunities for losses from land by appropriate timing, choice of sites and frequency of application.

Table 1.

Characteristics of a representative dairy farm in SW England, UK

Land use	:	80 ha long-term grass
Soil type	:	loam/clay loam
N use	:	200 kg ha^{-1}
Stock	:	90 cows
		80 others
Feed	:	1085 t silage
		144 t concentrates
Milk yield	:	5250 l per cow
Wastes	:	1466 m^3 slurry
		360 m^3 dirty water

Nitrous Oxide Sources

Nitrous oxide is the product, in the main, of microbiological denitrification processes which reduce nitrate ions to N_2 in varying proportions which are as yet not well quantified. It occurs in anoxic conditions, i.e. primarily in wet soils, when O_2 is limiting and when nitrate ions and energy sources are present. There may also be a release from nitrification but the extent of this is not yet quantified and is ignored in our calculations. The sources of nitrate ions in our dairy farm system are from the mineralization of soil organic matter, mineral N derived from excreta and from fertilizer additions made to the sward. Denitrification is a very variable process, both spatially and temporally, so is difficult to quantify.

A number of assumptions have been made to derive the data shown in Table 2: these are (i) that the equivalent of 10% of the fertilizer addition is lost by denitrification under grazing conditions on this type of soil (Jarvis *et al*, 1991), (ii) that of the N in stored farm wastes and dirty water (total 7690 kg), 20% is lost as NH_3 before application to land, 45% of the remainder is present as ammonium ions of which 20% is denitrified (Pain *et al*, 1990) and (iii) in both cases the ratio of the (N_2:N_2O) products is 3:1. Using all these assumptions, the overall annual loss of N_2O is 538 kg N: this represents a relatively small but significant proportion (2.4 %) of the total N input to the farm of 22230 kg yr^{-1}.

It is likely that this is an under estimation since there is considerable scope to improve methodology to produce integrated measurements which reduce the impact of variation. Measurements also often do not take account of the possibilities that denitrification occurs from deeper parts of the profile or that dissolved N_2O is being removed from the soil in drainage and other waters.

Controls over N_2O Loss

Whilst the local accumulation of nitrate ions from excreta promotes areas of high denitrification activity, the major losses are usually coincident with large inputs of substrate derived directly from fertilizer or from wastes. Forms of fertilizer (i.e. ammonium ions as opposed to nitrate ions) are important as is the timing of application in relation to the potential for utilization by the sward and/or the ambient climate/weather/soil conditions. Fine tuning of fertilizer application decisions and the prevention of an accumulation of mineral N in the soil in autumn after grazing would do much to reduce losses from this source. Timing and appropriate conditions are also crucially important with respect to farm waste returned to land. Application to land at times (eg. spring) when nitrate ions will be preferentially taken up by the sward rather than denitrified, will reduce losses. Delaying nitrification of NH_4^+-N applied in slurry till spring through the inclusion of a nitrification inhibitor, is effective for autumn/winter applications in some circumstances (Pain *et al*, 1990). It is also important to consider the impact of measures taken to avoid leakage of other forms of N from applied slurry. The major form of loss is as NH_3 and increasing pressure to reduce emissions of this gas may result in new application procedures (eg. direct injection into soil) which enhance losses via other routes, especially denitrification. As the drive towards greater efficiency of N utilization continues, perhaps through dietary manipulation, mineral N contents of wastes will be reduced, as will opportunities for N_2O escape.

Sources of CH_4

Methane is produced under anaerobic conditions from the microbiological degradation of organic material. The main sources for this gas on our farm are the ruminant digestive system, stored wastes and, under appropriate conditions, possibly from the soils upon which the production is based: where wastes are returned to soil this possibility increases. Of these sources the ruminant itself is the largest: the release from the rumen of cows is thought to range from 19-117 kg CH_4-C per year (Moss, 1992) and is dependent upon species, age and, particularly, diet. If an overall loss of 49 kg C per animal is assumed (EPA, 1990), the annual loss from the 178 animals is 8722 kg. These data are derived from animals housed under controlled environment conditions: there is little or no information for grazing animals.

There are also few data for losses from stored farm wastes. Losses can be calculated from information on biogas production from storage in anaerobic lagoons (Safley and Westerman, 1988) and assuming (i) an emission of 0.03 m^3 biogas m^{-3} waste per day (the lowest of the values quoted) and (ii) that 70% of that gas is CH_4, the wastes on the dairy farm (1466 m^3 stored for 200 days) would result in 3294 kg CH_4-C. Dirty water from the farm (360 000 l) of BOD 3000 mg l^{-1}; would produce a further 174 kg CH_4-C per year assuming 0.165 kg CH_4-C per 10^6mg BOD (EPA, 1990).

Table 2.

Estimated annual losses (kg) of N_2O and CH_4 from a representative dairy farm in SW England, UK.

Gas/source		Annual loss (kg)
N_2O - N		
Fertilized /grazed swards		400
Applied wastes		138
	TOTAL	538
CH_4 - C		
Ruminants		8 722
Dirty water		178
Stored wastes		3 294
Soils ± wastes		?
	TOTAL	12 194

Conclusions

Intensive animal production systems such as dairy farms are likely to be important net sources for N_2O and CH_4 emissions under current conditions and managements. Whilst economic pressures may instigate changes over the longer term, there are options currently available which could be taken up to minimise effects. However, there is still much unknown about the emission of these gases. Firstly, there is a need to quantify fluxes and to obtain integrated measurements to overcome at least some of the problems of spatial/temporal variability. Secondly, detailed investigations of the controls on the processes involved are required so that better management options can be devised. This is particularly important if there are feed back mechanisms between greenhouse gas emissions, global environmental changes (moisture, temperature, etc.) and, in turn, enhanced gaseous fluxes.

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MINIMIZATION OF METHANE AND NITROUS OXIDE EMISSION FROM INTENSIVE AGRICULTURE.

(Abstract)

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The long lived, radiatively active trace gases methane and nitrous oxide play a significant role in the chemistry and physics of the atmosphere and account for about 20% of the anticipated global warming. Agriculture and conversion of land to agricultural use account for about one quarter of the total effect. The main agricultural sources of methane are rice cultivation and domesticated animals, and the main sources of nitrous oxide appear to be biological nitrogen fixation and fertilizer use.

In order to stabilise the global atmospheric methane and nitrous oxide concentrations at present day levels, reductions in the global man-made emissions of about 17% and 75%, respectively, are required.

Various measures have been proposed for the reduction of methane emissions from flooded rice fields including: selection of rice varieties, increasing competition between sulfate reducing bacteria and methangers, addition of dams to rice fields and management of organic residues and water regimes. For nitrous oxide the suggested minimization techniques are: improve nitrogen use efficiency by correct selection of form, rate and time of fertilizer application, inhibit the conversion of ammonia based fertilizers to nitrate, improve irrigation and tillage practices, reduce biomass burning, modify urea excretion from animals and lime soil to reduce the proportion of N_2O to N_2 produced.

Most of these suggestions need to be researched before management practices can be put into place. In this presentation we will outline a technique for limiting methane and nitrous oxide emission which will result in reduced emissions if instituted now.

MANAGING PASTURES IN NORTHERN AUSTRALIA TO MINIMISE GREENHOUSE GAS EMISSIONS

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Introduction

Global climatic changes have been widely forecast to result from increases in the atmospheric concentration of radiatively-active (or `greenhouse') gases such as carbon dioxide, methane and nitrous oxide (e.g. Houghton *et al.* 1990). Methods for evaluating and reducing greenhouse gas emissions are being sought actively for a range of Australian industries, including the northern beef cattle systems. In these tropical grazing systems, greenhouse gases including carbon dioxide, methane, carbon monoxide, nitrous oxide and other oxides of nitrogen can be emitted by ruminants and other herbivores, termites and other detritus feeders, and by burning. However, these systems can act as sinks for greenhouse gases, since carbon can be stored if the biomass of trees, shrubs or grass is increased, and because some soil bacteria consume methane. Simulation models are necessary to analyse emissions from these grazing systems, because of the interactions that exist between the system components. For example, cattle stocking rates affect burning regimes by controlling fuel loads, and burning influences the growth of shrubs and trees, which in turn affects grass growth and thus stocking rate. All of these affect net greenhouse gas emissions.

To calculate emissions from grazing lands, Howden *et al.* (1991) modified an existing simulation model, GRASSMAN (Scanlan and McKeon 1990) which evaluates the impact on beef production and cash flow of different management options (e.g. changing stocking rate, clearing trees, changing burning regime), each of which interact with other options. This agricultural decision-support model was adapted to include sources, sinks and storages of greenhouse gases, so that it could be used to identify management options that reduce greenhouse gas emissions whilst maintaining farm productivity and profitability. The model does not yet include the effects of management on soil organic matter.

Changing stocking rate or fire frequency are the two main tools for managing pastures in grazing systems in tropical northern Australia. The model of Howden *et al.* (1991) is used here to investigate the effects of changes in these management tools on greenhouse gas emissions and productivity.

Methods
A case study is made here of a pasture of native grass species growing on duplex soils with a medium density, mature woodland of Silverleaf Ironbark (*Eucalyptus melanophloia*) trees and a shrub understorey. The basal area of trees was 6.0 m^2/ha. Termite biomass was high (96 kg/ha) as is often found in these ecosystems (Holt 1988; Holt and Easy 1991). Pasture burning was carried out every third year if there was adequate litter to support a burn. This situation was chosen as being representative of parts of northern Queensland.

Different greenhouse gases vary in their radiative activity and in their atmospheric residence time. To allow for these differences, the relative Global Warming Potentials (GWP) of Shine *et al.* (1990) for a 100-year integration period were used to convert all emissions to carbon dioxide equivalents. It should be noted that the GWP's used are currently under review.

Emissions are calculated in two different ways in this study: 1) *net* emissions where these are the differences between the sources and sinks for the various gases when they are all expressed in terms of CO_2 equivalents, and; 2) *anthropogenic* (man-made) emissions where this is the difference between the net emissions under any management option and the net emissions in the natural, ungrazed state. All emissions are calculated on a per hectare per year basis.

The index of productivity calculated here is animal production per unit area (kg liveweight gain/ha/year) for growing castrated male cattle. A `production efficiency' coefficient is calculated as the liveweight gain per hectare divided by either the net or anthropogenic emissions.

Two simulation studies were completed. The first investigated the effect of changes in stocking rate on emissions. The second investigated the effect of fire frequency on greenhouse gas emissions. In the second study, stocking rates were held constant at 0.22 AE/ha as this rate gave both a safe summer pasture utilization of 30% (approximately 40% utilization of annual growth) and near maximum production. This `best' stocking rate is used as a baseline for comparing management options for the stocking rate simulation. Stocking rates are expressed throughout as adult equivalents (AE). Simulation studies were conducted for 15 average years.

Results
The woodland grazing systems of northern Queensland investigated here are significant net emitters of greenhouse gases (261 kg CO_2 equivalents/ha/year; Fig 1a) in their natural state (i.e. with no grazing by cattle). These net emissions are the difference between emissions from the burning of grass, trees and shrubs, and emissions from termite activity and kangaroos (which are very minor sources of methane (Kempton *et al.* 1976) in these systems) and the consumption of methane by soil organisms.

The effect of stocking rate on greenhouse gas emissions was slightly non-linear and non-proportional (Fig 1a). For example, a 20% reduction in net emissions would require a 52% reduction in stocking rate from the `best' stocking rate. In contrast, a 20% reduction in anthropogenic emissions would require a 22% reduction in stocking rate. This reduction in stocking rate would result in about a 5% (1.2 kg LWG/ha/year) reduction in liveweight gain (Fig 1b). These relationships are due to the interactions in the system between stocking rate, plant growth, fire frequency and fuel load, quality and quantity of intake of cattle, consumption of herbage by termites and tree regrowth. Increases in stocking rates above the the estimated 'best' stocking rate of 0.22 AE/ha resulted in increases in greenhouse gas emissions but decreases in liveweight gain (Fig 1a,b) in the grazing system investigated here.

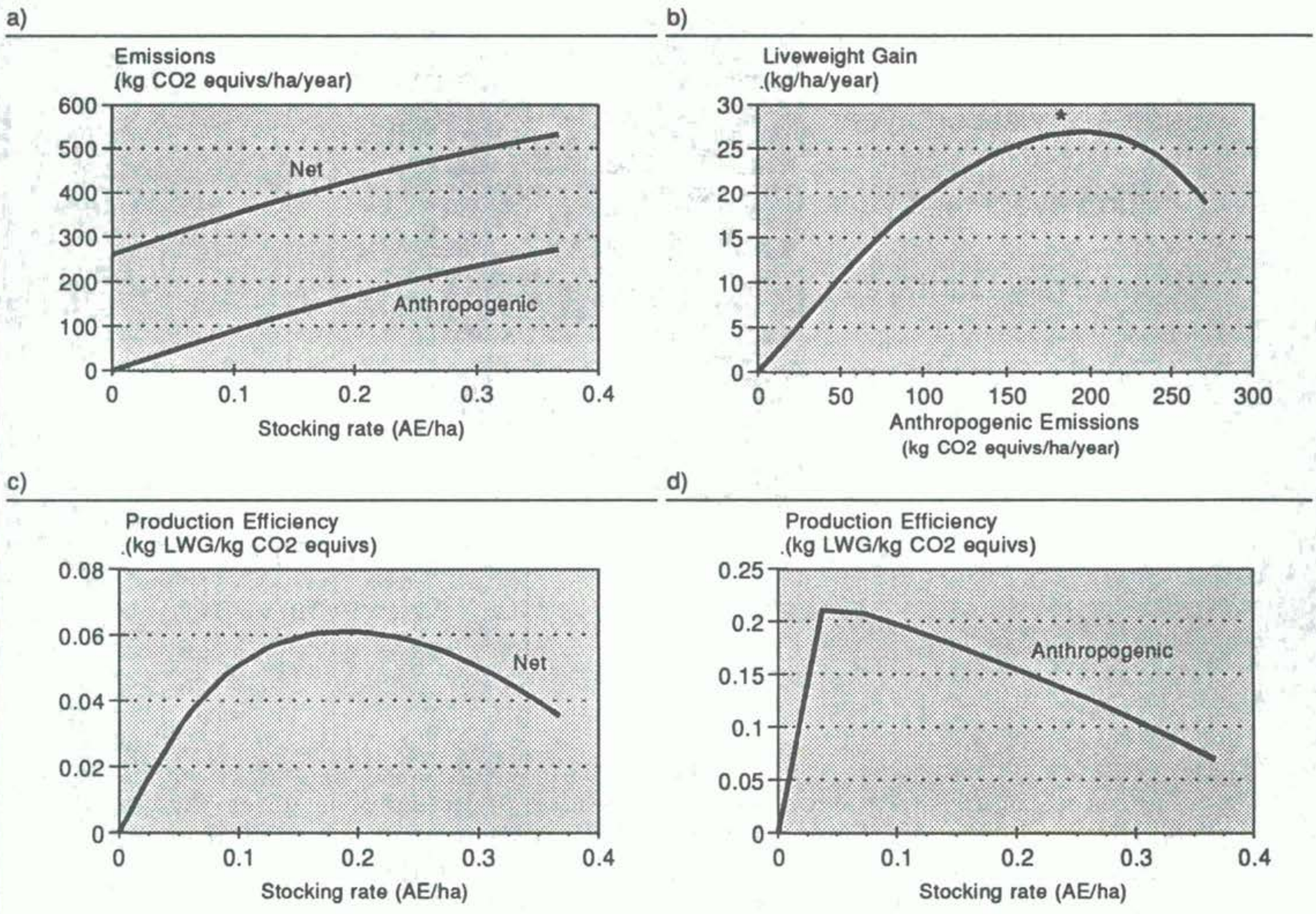

FIGURE 1.

Relationships between; a) net and anthropogenic greenhouse gas emissions (kg CO_2 equivalents/ha/year) and stocking rate (AE/ha), b) liveweight gain (kg/ha/year) and anthropogenic emissions (net emissions can be calculated by adding 261 to x-axis values), c) net production efficiency (kg LWG/kg net emission CO_2 equivalents) and stocking rate and, d) anthropogenic production efficiency (kg LWG/kg anthropogenic emission CO_2 equivalents) and stocking rate for a native pasture woodland grazing system in northern Queensland. The mark (*) on figure b) indicates a stocking rate of 0.22 AE/ha.

The liveweight gain per unit of *anthropogenic* greenhouse gases produced (production efficiency) was greatest at stocking rates of 0.03-0.10 AE/ha (Fig 1d). At higher stocking rates, the production efficiency decreased such that at 0.35 AE/ha, about fourteen kilograms of anthropogenic CO_2 equivalents were being produced for every kilogram of liveweight gain. The liveweight gain per unit *net* emissions was greatest at a stocking rate of about 0.15-0.22 AE/ha and decreased rapidly with either higher or lower stocking rates. Figures 1c and 1d clearly show that the opportunity exists to optimise greenhouse gas production efficiency by changing the management of grazing systems.

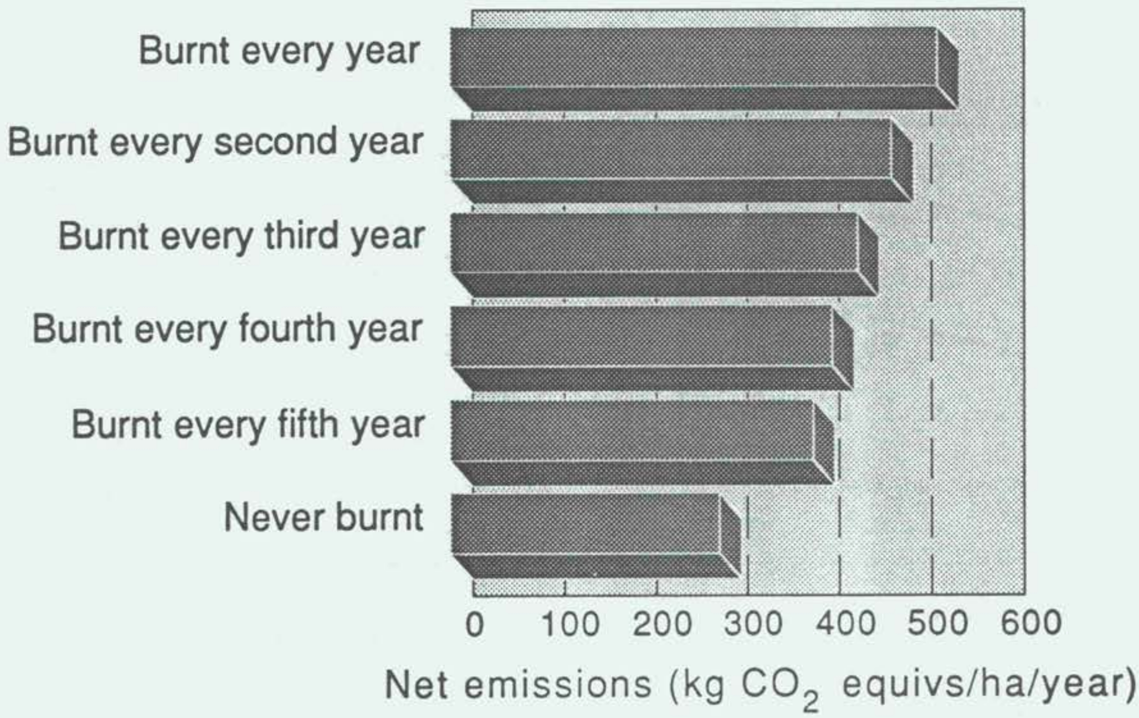

FIGURE 2.
The effect of fire frequency on net emissions of greenhouse gases (kg net emission CO_2 equivalents/ha/year). Fire frequency was varied from nil burning to burning every year. When fire was excluded from the grazing system, net greenhouse gas emissions averaged 290 kg CO_2 equivalents/ha/year (Fig 2). Increasing the frequency of burning increased emissions such that when the pastures were burnt every year, average emissions were almost doubled (520 kg CO_2 equivalents/ha/year).

The version of GRASSMAN used in the case study represents a general view of these woodland grazing systems. However, animal production and pasture biology vary between properties and regions. Whilst the values presented here represent a particular case study, in other situations, the basic pattern of response is likely to be similar to that described above.

Discussion

Studies using a model of some northern Australian agricultural systems showed that these systems are substantial net emitters of greenhouse gases in the natural, ungrazed state, and that increasing stock numbers increased emissions above this level in a non-linear manner. Relatively minor changes in pasture and stock management, at some commonly used stocking rates, can result in large reductions in anthropogenic greenhouse gas emissions without large reductions in productivity. Hence, if anthropogenic emissions are considered, reducing greenhouse gas emissions from these pasture systems by about 20% over the next 15 years may be possible with little economic cost. Reduction of net emissions by the same amount will require larger management changes and would result in substantially lower productivity. The large differences between net and anthropogenic emissions are due to the substantial emissions occuring from these landscapes in the natural state. The results presented here show that emission definitions are of critical importance in determining feasible emission reduction strategies.

Increases in stocking rate over the 'best' stocking rate calculated here by GRASSMAN, resulted in both increased emissions and reduced productivity. Studies by Burrows *et al.* (1991) and Tothill and Gillies (1992) suggest that many producers may be using such stocking rates. In these heavily grazed systems, the relatively small reductions in stocking rate that are needed to reduce anthropogenic emissions significantly may also have the effect of reducing soil and vegetation degradation, thereby improving the sustainability of these enterprises. Implementation of these stocking rate recommendations to reduce greenhouse gas emissions could be achieved as part of overall sustainable farming.

Heavy stocking of the grazing systems under study resulted in anthropogenic emission of the equivalent of fourteen kilograms of carbon dioxide for every kilogram of liveweight produced. Reduction of stocking rates resulted in increased liveweight gain per unit emission from the whole grazing system. At very low stocking rates this trend was reversed. These results clearly demonstrate that the opportunity exists to optimise the efficiency of production in terms of greenhouse gases by changing the management of these grazing systems.

Emission reductions could also be achieved through minimisation of burning. However, burning is an integral part of the management of grazing lands in the north of Australia. For example, burning is used to control the growth of shrubs and trees (`woody weeds') which would otherwise reduce grass production (Scanlan and Burrows 1990) and increase the difficulty of mustering. Fires are also used to control the occurrence of undesirable grasses (Orr *et al.* 1992), provide livestock with high quality feed (post-burning `green pick'), to prevent patch grazing (Andrew 1986) and for many other purposes. Hence, recommendations to minimise burning to reduce greenhouse gas emissions have to be consistent with these high priority management objectives.

GRASSMAN is continuing to be tested with current agronomic trials and, where appropriate, modified to account for regional differences in processes. Thus, by using this type of model for calculating greenhouse gas emissions, the benefits of the results from current agronomic and atmospheric research can be quickly used to improve the model and more correctly calculate emissions and determine management strategies which could reduce greenhouse gas emissions, whilst maintaining the stability and productivity of Australia's grazing and other agricultural systems.

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INTEGRATED CROP/LIVESTOCK SYSTEMS FOR TEMPERATE REGIONS.

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Landscapes around the world are under extreme pressure to produce forage for large numbers of domestic and wild ruminants, as well as food, fiber, and fuel for human populations. Excessive vegetation degradation and soil erosion are evidence of the intensity of grazing pressure on these resources. Most grazing lands are used in excess of their ability to produce forage and still conserve the least renewable components of these resources. Over fifty years of research at the Southern Plains Range Research Station has been designed to determine the carrying capacity of mixed prairie resources and to show that the carrying capacity of these rangelands can be significantly improved by integrating the use of rangelands with complementary perennial and annual forage. Rangeland improvement practices alone, such as control of undesirable species and proper grazing intensity, improved beef production efficiency by 20-30%. Such improvements resulted in 2-3 kg/ha increase in beef production and a 25-35 kg greater gain per yearling animal. Complementing native rangeland with improved perennial grasses reduced the land required to support a yearling animal by 40%. Complementing native rangeland with an improved perennial grass, however, resulted in a 67% increase in gain per unit area over the native rangeland system. Complementary systems that optimally combine resource quantity, quality, stability, and flexibility can result in highly significant increases in efficiency of forage-beef production systems. If managers are willing to input the time and skills required, significant benefits in terms of production per hectare and per animal can be attained. Such complementary systems will allow producers to use cows with increased milk production potential, animals with greater growth ability, crossbreeding, and multiple births to a greater advantage than with simpler production systems.

AGROFORESTRY AND ITS RELATION TO CLIMATE CHANGE - RESEARCH AND ITS ADOPTION

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ABSTRACT

Agroforestry, the management of trees or shrubs on farms, is becoming a more widespread form of land use across the world. Trees integrated with agriculture have the potential to improve the sustainability and profitability of agriculture as well as being a strategy for the minimisation of greenhouse gas emissions from agriculture. In many countries agriculture and forestry departments see agroforestry as a solution to both the problems of land degradation and shortage of forest products. Two brief case studies of agroforestry in Australia and in Zimbabwe will be used to demonstrate the potential benefits of agroforestry and to outline the key problems in implementing these. A major problem is that recommendations from research and extension agencies are often not adapted by farmers. The ways in which the two countries are dealing with the problem of how to successfully extend agroforestry will be described.

The Greenhouse Effect is but another symptom of man's exploitation of the earth's non-renewable resources. It has the potential to make management of those resources more difficult and uncertain. With increasing populations, there are greater demands on limited resources which are being rapidly degraded by non-sustainable land use systems.

When combined with population changes, the area per capita under cereal crops has dropped by about 40% since 1950. Although there has been an increase of 26% in the area cropped (Robinson 1986), the yield of many cereal crops is decreasing. It has been estimated that the annual rate of desertification of cropland in tropical areas alone is 2.5 million hectares (Burley 1984). Similarly, it has been suggested that all 3600 million hectares of rangelands are deteriorating (UN 1977), resulting in lower productivity of livestock in the face of greater demand. While 16 million hectares of forests are being cleared every year, only about 1 million hectares are being reforested (CAS 1980).

It seems clear that crop, animal and wood products are likely to be in short supply in the future, and in some cases are already limited on a regional and local basis. Further there are strong indications that the sectoral approach to predicting supply and demand of natural resource products (livestock, agricultural crops and forestry) fails to appreciate the interrelated nature of these resource production systems (Robinson 1986). For instance the expansion of cropland is at the expense of either forests or grazing land. With conventional single industry systems it is hard to see how expansion can occur in the use of land for any one of these production systems without consequent reduction in at least one other.

Thus in many countries the Departments that deal with cropping, livestock and forestry are different so that any attempt at rationalising these three land uses are complex. Unfortunately, policies on climate change tend to come from yet a fourth sector which is usually a Department of the Environment. A role of this department is often to look for the benefits to carbon dioxide emissions as a justification for costs of implementation of new policies.

It is within the context of the degradation of many land use systems and of the competition between land for crops, livestock and forestry, that interest has grown in the capacity of agroforestry systems to reverse this trend. Agroforestry has the potential to obtain more sustainable and efficient production from available resources. Agroforestry also has the capacity to act as a carbon dioxide sink, so that its various benefits often outweigh the costs of its implementation where the one of the benefits alone may not justify these costs.

This paper outlines the benefits of agroforestry, discusses the limitations to adoption of research and describes a method for design of appropriate research that will be adopted by farmers.

What is agroforestry?
Agroforestry is a collective name for land use systems in which woody perennials (trees, shrubs etc) are grown in association with herbaceous plants (crops, pastures) and/or livestock in a spatial arrangement, a rotation or both, and in which there are ecological and economic interactions between the tree and the non-tree components of the system (Young 1989).

Some people identify agroforestry with a particular practice, usually grazing of livestock on pastures grown under widely spaced timber trees. However if agroforestry is to serve people's needs in a wide variety of agricultural land use systems, **it is important to see it as an approach to land use**, rather than as a fixed arrangement of trees and agricultural commodities. The appropriate practice of agroforestry for a given farm depends upon a combination of climate, soil, topography, land use, socio-economic factors and policy factors and thus usually varies a little between different farms within a region, more between farms in different regions and even more between farms in different countries.

Benefits of agroforestry
Agroforestry can have four main categories of benefits:

1 Environmental benefits
2 Increases in agricultural productivity
3 Increases in timber production
4 Increased and diversified farm income

Agroforestry can provide all of these benefits simultaneously. While the last two benefits of income from timber production and other products from trees such as fodder are self-explanatory, the first two benefits require further details which follow.

Environmental benefits
The reduction in carbon dioxide emissions is an environmental benefit of agroforestry which is particularly relevant to policy makers who are trying to minimise greenhouse gas emissions. This is because it acts as a CO_2 sink.

However, agroforestry has been demonstrated to have many more environmental benefits, including the reduction of salinity of soil and water, reductions in wind and water erosion, amelioration of soil acidification and increases in soil fertility of agricultural land. Many of these benefits to the soil which promote soil conservation and tight nutrient cycling mean that carbon is conserved in an agroforestry system where it would be lost from most other agricultural systems. This is one of the reasons that agroforestry is promoted as a land use which can reduce carbon emissions to the atmosphere. There can be little doubt that an agricultural system which contains trees will conserve and sequester more carbon than one which does not.

Increases in agricultural productivity
Agroforestry can increase productivity directly by maintaining soil fertility (Young 1989). Agroforestry can also increase crop, pasture and livestock yields more directly through the use of trees in windbreaks. For instance in Rutherglen in Victoria, Australia, oat yields in the sheltered zone of a tree windbreak increased by 45% (Burke 1991).

Why don't all farmers practise agroforestry?
There are countless examples of research leading to technically sound recommendations which are not adopted by farmers (Douglas 1986; Abel and Prinsley 1991). A significant reason why this happens is because the objectives and methods of scientists do not always match those of the land users. So while there is a need for much research to be carried out concerning land use options for reducing greenhouse emissions, it is important that those engaged in such research retain an awareness of the context in which their findings will be implemented. Ultimately the benefits of such research will be measured by whether or not and to what extent they are taken up and used.

Farmers are rarely consulted or involved in the formulation of research strategies for their area. Yet the most direct, and often the most accurate and comprehensive source of knowledge about land use systems is the farmers themselves. They are the primary source of information regarding their own production strategy and its constraints and possibilities (Chambers 1983). Their knowledge is complementary to the more mechanistic and generalised knowledge of scientists. Participation of landholders with scientists in design and implementation of agroforestry research also gives more 'ownership' of the research to the farmers as well as providing more appropriate solutions. These factors all contribute to effective implementation.

It is also very important to remember that if our aim is to implement agroforestry in order to reduce carbon dioxide emissions (as well as providing other environmental and economic benefits), then widespread adoption of alternative 'medium carbon dioxide sequestering' systems may be far more effective than isolated adoption of systems which have maximal carbon dioxide sequestering characteristics. Thus although it is important to understand what sort of system will provide maximum carbon sequestering capability. Technical purism and a lack of understanding of existing production systems may result in wasted research, extension and demonstration efforts. Farmers are much more likely to adopt a practice which fits into their current production system than a new technology which means that they need to change other aspects of their farming system drastically. Most farmers, particularly in developing countries, will certainly **not** plant trees to mitigate the Greenhouse effect! Neither will most governments in developing countries have the resources to subsidise farmers to do so.

The achievement of significant carbon dioxide sequestration and the development of sustainable integrated land use systems that will be resilient in the face of climate change will only be achieved if millions of land users implement them across the world. Research designed and implemented together with the users - **appropriate research** - is more likely to be adopted, and will certainly be adopted more quickly.

How to achieve appropriate research

Agricultural scientists often do not know how to elicit farmers' knowledge or use it to guide and inform their research programs. In many cases, scientists tend to view land managers as a constraint to the implementation of research rather than as an integral part of that research. These problems are being partly overcome in Australia with the formation of land care groups which have the communication channels to request that certain research is carried out to meet their needs (Campbell 1991). Researchers have traditionally determined the research that is done and extension officers have tried to convince farmers to use these results. Some research is now being carried out with farmers in a very small number of cases in Australia (Scott 1991). However compared to many developing countries in the world Australia has a relatively small number of comparatively well educated farmers. Therefore they are more likely to be in a position to interact with the research community and demand that certain research is done. It is much more difficult to determine what is appropriate research in less developed countries where there are literally millions of farmers with diverse and complex farming systems and whose educational opportunities are less than those available in Australia.

Scientists can work successfully with landholders to develop a research strategy and there are well-documented examples to demonstrate this. However developing such an interaction can be extremely costly and this provides a concern for many scientists and funding agencies. This has resulted in the development of several methods which reduce the time and money needed to develop successful interactions between scientists and farmers. One such method is rapid appraisal for agroforestry research and extension. This approach was developed by the Commonwealth Science Council, the Zimbabwe Forestry Commission and funded by the Ford Foundation (Abel and Prinsley 1992, Abel *et al* . (1989).

The objectives of the rapid appraisal method are (Abel and Prinsley 1992):

- to learn about the production strategies of local farming households and how they are constrained;

- to describe and analyse the contribution of woody plants to these strategies;
- to assess the ecological and economic interrelationships among woody plants, arable production, livestock and other enterprises;
- to understand the present roles of woody plants in soil and water conservation;
- to work with households to develop improved ways of using and managing woody plants;
- to identify gaps in knowledge about agroforestry and propose appropriate research and extension activities;
- to facilitate the work of institutions responsible for developing and implementing agroforestry;
- to identify and appraise potential agroforestry interventions.

The principles of the rapid appraisal method are described below and the complete procedure is outlined in Abel and Prinsley (1992) and can be found in full in Abel *et al* . (1989).

(i) rural societies are stratified by wealth and power, so that access to the factors of production is unequal. Households in each stratum have a characteristic production strategy reflecting their level of access;

(ii) production strategies and constraints can only be understood if viewed from the households' perspective. That viewpoint is best acquired through 'interactive research', learning from and with farmers;

(iii) an important step toward understanding resource constraints from the standpoint of farmers is to use local classifications of land resources, rather than imposing imported categories used in other societies;

(iv) different kinds of household require different types of agroforestry intervention suited to particular household circumstances. These may or may not include trees;

(v) time, personnel and transport constraints face most research and extension staff. This is why the programme was based on 'Rapid Appraisal' methods, which economise on these scarce inputs. A crucial aspect of rapid appraisal is making full use of a readily available resource: local knowledge.

Conclusions

Agroforestry has multiple benefits to the environment and to productivity and farm income. Planting trees on cleared agricultural land may reduce carbon dioxide emissions and, as such, is another benefit of agroforestry. Research performed out of context of the needs of the land users is inefficient and usually extends the adoption period or results in non-adoption. However appropriate research will be adopted more quickly and can best be achieved by 'working together' from the outset. Cost effective methods are available which facilitate interaction between scientists and farmers.

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AGROFORESTRY LAND USE TO COMBAT DESERTIFICATION IN THE SAHELIAN ZONE OF AFRICA

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ABSTRACT

Tropical drylands cover more than 2000 million hectares. They are expected to expand due to climatic changes and man-made desertification. It is therefore necessary to assess their role in the world's greenhouse gas balance and to discuss appropriate land use strategies.

Total biomass resources of dry lands are marginal if compared with tropical rainforests. Thus their contribution to emissions as well as to storage of greenhouse gases is small. Emissions originate mainly from extensive annual burning. The released CO_2, however, is entirely absorbed by immediate regrowth keeping net emissions at practically zero. Other gases such as methane and oxides of nitrogen are being emitted as well as large quantities of smoke and dust. Desertification, however, results in substantial net transfers of greenhouse gas from the biosphere to the atmosphere.

To combat desertification, integrated land use, such as agroforestry, holds some promise, at least as far as the loss of organic matter is concerned. Silvopastoral systems should be monitored with regard to methane releases, carrying capacities and environmental compatibility. Increasing pressure on the natural resources in the Sahel, foremost in the transition zone between migratory pastoralism and sedentary agriculture may add to net greenhouse gas emissions and to salinity problems. Due to limited biomass growing stock in the Sahel, the role of this region within the world's carbon dioxide balance will, however, remain marginal.

Introduction

Arid and semiarid areas cover over a quarter of the globe's total land surface. In the tropics, more than 2,000 million hectares may be classified as savannas and semi-desert grass or shrublands. About 50% thereof may be called humid savannas with more than 600 mm annual rainfall and a more or less closed vegetation cover, dominated by grass.

The extent of these lands is expected to increase subject to changes of the regional and global climate, to tropical deforestation, and to man-made desertification. Therefore, it is important to assess their role in the world's future greenhouse gas balance and to discuss strategies of appropriate land use.

Total biomass resources of the tropical dry lands average around 6t of dry matter per hectare. This is marginal if compared with tropical rain forests with above 120t per hectare. Thus the contribution of tropical drylands to emission as well as storage of carbon is relatively small.

Emissions originate mainly from burning which occurs foremost in the humid savannas. The CO_2 released, however, is almost entirely absorbed by the subsequent vegetation regrowth. Net emissions are thus practically zero. Other gases such as methane, CO2, and oxides of nitrogen, in contrast, are set free as well as large quantities of smoke and dust. During the Harmattan period (November to February/March) major parts of the African savanna zones and adjacent rainforests may be covered by what resembles extremely heavy smog in industrialised countries as a result of savanna vegetation burning.

Even more important, although less distinctly visible, is the creeping vegetation loss caused by overall degradation and finally desertification. These developments result in net emissions of the greenhouse gases to the atmosphere and a medium to long term - if not irreversible - loss of a carbon sink. To combat desertification by means of integrated land use is therefore an effort not only to preserve productive lands and genetic resources, human societies and economically needed ecosystems, but also to reduce net emissions of greenhouse gases.

The Case of the Sahelian Zone

The Sahelian Zone of Africa stretches from the Atlantic coast of Senegal to the Indian Ocean coasts of East Africa, and from the southern fringe of the Sahara desert to the Sudan savanna and Miombo lands. The total area may amount to over 100 million hectares, subject to slightly varying definitions. Average annual rainfall remains under 600 mm and occurs (at least in the Western parts) predominantly between July and October. Evaporation rates are high, and the vegetation cover remains discontinuous and is subject to marked seasonal changes. Total growing stock of biomass under undisturbed natural conditions ranges between 0.5 and about 2.5t dry matter per hectare.

Desertification is a permanent threat to the region, and life may be characterised as almost permanently under stress. Typical features of the prevailing ecosystems are low persistence but high resilience, resulting in a high degree of "mobility" of plant, animal, and human life.

Poor water availability is the main constraint to land use. This refers both to seasonal distribution within a year and unpredictable sequences of several years' drought periods. Water availability is also affected by unfavourable horizontal and vertical distribution and occasionally by salinity.

Land use in the Sahel has, therefore, to be sensitively adapted to the relevant site conditions which may vary even over short distances, subject to soil types and groundwater. Three main groups of land use may be distinguished:

- rainfed farming
- irrigated farming, and
- nomadic or transhumant pastoralism.

All three have strong traditional roots but are undergoing changes in recent years, due to technical development, population growth, and political conditions. All three may involve agroforestry practices.

Agroforestry Systems in the Sahelian Zone

Agroforestry, being rather a strategy than a specific structure or technique, can broadly be classified into silvo-pastoral agro-silvo-pastoral and agri-silvicultural systems. all three aim at maintaining and as far as possible increasing site productivity, harmonizing ecological carrying capacities with human demands, reducing risks, and finally, preventing further desertification. by site-specific combination of plant and/or livestock components efforts are made to improve the land equivalency ratio (LER) beyond what may be gained by monospecies and single-storey management practices. This can be achieved by controlled competition, improved compatibility over time and space, and observing mutual dependencies within the relevant systems.

Silvo-pastoral systems prevail over the largest parts of the Sahel, especially in the drier northern regions. Traditionally, nomadism takes place in the poorest arid parts with low productivity and high risk, requiring a very high degree of resilience and mobility and low population and livestock densities. Further south the system shifts to seasonal transhumance, merging into agro-silvo-pastoral systems.

From the point of view of integrated land use and greenhouse gas balances the silvo-pastoral systems offer at least two interesting aspects:

- The first is a general observation (supported by findings of scientific works especially by the French organizations ORSTOM and IMVT) that by specific combinations of grass with woody vegetation the total biomass production can be raised substantially, sometimes more than three times, over that of pure grasslands. Moreover, the quality of the animal feed is improved both by adding vitamins and minerals to the animal feed in the course of browsing, and by extending the period of green grass.

- The second is that a higher carrying capacity for livestock can be reached, especially if cattle, sheep, and goats are combined in adequate numbers within the herds, thus utilizing the plant resources in a more balanced way and even providing for sustainable tree and shrub regrowth by seed dispersal, breaking seed dormancies and reducing grass competition for the woody plants. This, however, helps to increase the total number of livestock within the region which, in turn, has an effect on methane emission.

Agro-silvo-pastoral systems are typical for the transition zone from the pastoral region in the north to the region with predominant rainfed agriculture further south. Land use may be rather intensive in that during the wet season sedentary or shifting agriculture with millet, sorghum, etc. is practised whereas during the long dry season transhumant or sedentary pastoralism, based on agricultural residues and browsing takes place. Trees are included into the system because of their protective and/or soil improving benefits and of their important contribution to livestock feeding. Two different forms deserve special mentioning: the Acacia albida (syn.Faidherbia albida) systems in the western and central parts, and the Acacia senegal systems, predominantly in the southwestern Sudan.

The total amount of biomass per hectare is higher than in the northern pastoral zone, reaching an average of about 2 tons of dry matter and even above on favourable sites, with marked fluctuations between the seasons. However, the threat of desertification may be pronounced due to heavy pressure on the still limited resources by both, agriculture and pastoralism and by the fact that agriculture increasingly encroaches sites which are no more suitable for farming. In drought periods such fields are left without a protecting vegetative cover and thus easily eroded and windblown. carbon, normally stored in the upper soil layers (roots, seeds, litter) is lost. Part of it is released to the atmosphere, and revegetation may be seriously retarded or even prevented.

Agri-silvicultural systems concentrate in the southern part of the Sahel and on sites with favourable groundwater regime and soils. trees and shrubs are considered of marginal use, and monocultures with cereals, groundnuts, cotton, etc. preferred. Livestock (with an increasing number of small ruminants as compared with the cattle or camel dominated herds in the north) is raised by village communities but given secondary importance. Total biomass per hectare (average over the whole year) may reach beyond 10 tons of dry matter. Part of that is exported to other regions. Mineral fertilizers, although still too expensive for general use, are starting to play a role and mechanization takes place where people can afford it. Efforts are made to secure sustainability of the land use which would lead to a net balance of at least carbon dioxide. Fire, however starts playing an increasing role for land clearing similar to what happens in the more humid savannas, releasing various greenhouse gases, ashes and dust to the atmosphere.

In trying to summarise the effects of all three agroforestry land use systems, including special forms like the management of oases, ripparian (gallery, marigot) sites, irrigated lands, etc.:

- Total biomass in the Sahelian Zone of Africa is rather low, about 1.5 tons of dry matter per hectare as an average over all sites and the whole year. There is a vigorous growth, mainly of grass, during the short wet season and a general drying out during the rest of the year and during drought periods. In the long term, however, there has been an almost complete recycling of all emissions.

- Growing populations, resulting in heavy pressure on the natural resources (increasing number of livestock, agriculture encroaching marginal sites, export of agricultural products) have accelerated the pace of desertification which releases greenhouse gases into the atmosphere and impedes revegetation. Increased livestock numbers, moreover contribute to more methane emission. The trend is continuing and accelerated.

- Sustainable land use, such as agroforestry, has a tradition, especially in the central parts of the Sahel (the transition zone between pure pastoralism and prevailing sedentary farming). It retards or even prevents desertification and accumulates biomass per area unit. Improving the human-ecological carrying capacity and absorbing, at least to some extent, carbon dioxide from the atmosphere. Agroforestry has until now nowhere been applied to prevent or combat salinity. Problems have so far only occurred in irrigation schemes of the Sudan and on a few other small places although the potential threat is evident, including groundwater resources.

Reliable data on the extent of present and foreseeable future greenhouse gas emissions form the Sahel, and on the role, agroforestry may play in this context, are lacking or at least are limited to very specific conditions and sites. They will have to be based on inventories of the total area of the various vegetation and land use types, the amount of biomass growing stock and its fluctuations over the seasons and longer periods, the percentage of biomass burned and its carbon content, the emissions caused by livestock management and by agricultural waste disposal. In general, however, the Sahelian Zone of Africa, although covering a vast area of about 100 million hectares, does have a rather limited effect on the world's greenhouse gas balance. With an average of 2 tons of dry matter per hectare as against more than 100 tons in the tropical rain forests, the role of the Sahel with regard to the greenhouse gas balance of the atmosphere may be placed in the range of an equivalent of 1-2 million hectares of rainforest.

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RICE FIELDS AND MITIGATION STRATEGIES

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Rice is the Staple Food for More than Half of Mankind

Rice is the only major grain crop that is grown almost exclusively as human food. More than 90% of the world's rice is produced in Asia, 3.2% in Latin America (Brazil and Colombia account for 62% of the production), 2.1% in Africa (Egypt and Madagascar account for 48% of the production), and 2.5% in the rest of the world. Less than 5% of the world rice production is traded on the international market. Rice provides between 35 and 50% of the calories consumed by 2.7 billion people in Asia. In Africa and Latin America, rice provides 8% of the food energy for not quite 1 billion people (IRRI, 1989).

The world harvested rice area increased during the past 40 years by 41% and rough rice production by 30.4%. Today, rice production in Asia is twice that of 25 years ago, the land area planted to rice has increased 17%, while average yields have increased 72% and population has grown by 67% (IRRI, 1991). The harvested rice area mainly increased because double and triple rice cropping became possible due to the development of short duration, photoperiod insensitive rice cultivars and expanded irrigation. The great production gains have been in the irrigated rice and favorable rainfed rice areas, where modern high yielding rice cultivars coupled with improved cultivation technologies are able to express their yield potential.

Global Emission Rates are Highly Uncertain

Irrigated rice fields are the major source of methane from rice fields. Comprising only 50% of the harvested rice area irrigated rice produces 70% of the rice harvested. The assured water supply and control, intensive soil preparation and fertilization, and the resultant improved growth of rice, mediating the methane flux to the atmosphere, favor methane production and emission in irrigated rice. Methane emissions are much lower and highly variable in space and time in rainfed rice because of drought periods during the growing season and poorer growth of rice. In deepwater rice methane production may be high but related emission rates may be low because of reduced emission pathways. Upland rice is not a source for methane emission because upland rice is never flooded for a significant period of time.

Global extrapolations of emission rates are highly uncertain and tentative. Recent global methane budgets from rice fields range from 20 to 100 Tg year^{-1} which corresponds to between 5 and 30% of the total anthropogenic methane emission (Khalil and Rasmussen, 1990). Accounting for variations of emission rates due to climate, soil properties, duration and pattern of flooding, organic amendments, fertilization and rice growth reveals that most published extrapolations are too high. Adjusting a basic emission rate of 0.5 g m^{-2} day^{-1}

according to rice ecologies or soil types results in global emission rates of about 40 Tg year^{-1} (Neue 1990, Bachelet and Neue 1992). But reported measurements of CH_4 fluxes in rice fields do not account for ebullition induced by soil disturbance due to wet tillage, transplanting, fertilization, weeding, pest control and harvest. A large proportion of soil entrapped methane, that may account for up to 80% of the methane generated and is oxidised in undisturbed rice fields, likely escapes to the atmosphere during these cultural practices. Therefore the global emission rate is likely higher than 40 Tg year^{-1}.

Diffusion Through Rice Plants and Ebullition the Main Emission Pathways
In flooded rice fields methanogenesis is favored by anoxic conditions, the availability of organic matter from roots, stubbles, the photosynthetic aquatic biomass and organic amendments, a soil pH near neutral, and soil temperatures between 20-30°C during the rice growing seasons. Methane production is enhanced in the rooted soil zones (Sass et al 1991). Up to 80% of the methane produced in the anaerobic rice soil is apparently oxidized in the rice rhizosphere and the oxidized soil-floodwater-interface (Holzapfel-Pschorn et al 1985).

In undisturbed rice fields up to 90% of the CH_4 released to the atmosphere is emitted through the rice plant via a special tissue (aerenchyma) that allows the diffusion of atmospheric oxygen to the roots. The aerenchyma has its own openings at the stem and is not connected to the stomatal gas exchange. However, under actual field conditions large portions of the soil entrapped methane is likely be released to the atmosphere through ebullition caused by cultural practices.

Mitigation Candidates
<u>Water management</u>.
Aeration of soils by increasing water percolation or temporarily stopping irrigation will enhance methane oxidation and decrease methane formation. However, water management as a mitigation practice is only feasible in irrigated rice where there is complete control of water supply and drainage. But there are limitations. In the rainy season most rice fields are naturally flooded and defined drying periods can't be implemented. In drought prone rainfed areas water is to valuable to be drained. Drying of most rice terraces at hillsides can cause severe cracking and collapse of the terrace construction. Higher water percolation and intermittent drainage requires more water and may cause detrimental leaching of nutrients and increased gaseous losses of nitrogen as N_20 (nitrification - dinitrification). Significant quantities of methane may also be leached and subsequently released to the atmosphere from drainage water.

Water stress at any growth stage reduces yield. Moisture contents of 50 kPa (slightly above field capacity) may reduce rice grain yield by 20-25% compared to continually flooded treatments (De Datta 1981). Intermittent drying or keeping soils only saturated considerably lowers rice yields (Borell et al 1991). But in subtropical China, Japan and Korea intermittent drying periods as well as percolation rates of up to 35 mm/day are associated with maximum rice yields, likely, because of accumulated organic and inorganic toxins. Short aeration periods at the end of the tillering stage and just before heading improve wetland rice yields only if followed by flooding (Wang Zhaoqian 1986).

The rice plant is most sensitive to water stress during the reproductive stage causing a high percentage of sterility (Yoshida 1981). Water deficits during the vegetative stage reduces plant height, tiller number, and leaf area that will highly reduce yields if plants do not recover before flowering. Generally, the duration of a moisture stress is more important than the growth stage at which the stress occurred.

Rice cultivars.

The aerenchyma and intracellular space of rice plants mediate the transport of air (oxygen) to the root and methane from the anaerobic soil to the atmosphere. The flux of gases in the aerenchyma depends on concentration gradients and diffusion coefficients of roots and internal structure including openings of the aerenchyma. The number of tillers m^{-2}, the root mass, rooting pattern and metabolic activity should also influence the gas fluxes. Oxygen diffusion and exudation of oxygen radicals combined with the abundant methane-oxidizing bacteria result in oxidation of methane in the rhizosphere while organic root exudates and root litter are a source of methane formation.

There is a wide variation of these traits and related emission rates among cultivars that opens up the possibility to breed rice cultivars with a low methane emission potential. The inheritance of underlying traits and relationships to yield potentials have still to be elucidated.

Fertilization and other cultivation practices.

Organic amendments (rice straw, green manures, aquatic biomass) increase methane production and emission. Application of composted material which has a higher degree of humification did not increase methane formation and fluxes (Yagi and Minami 1990). Quality and quantity of added organic materials are decisive. Sound technologies have to consider both maintaining/increasing soil fertility and reducing methane emission. To reduce methane emission from wetland rice fields it may be necessary to minimise rather than to maximise organic amendments. But green manures and recycling of crop residues is sometime the only soil conditioner and nutrient source for many resource-poor farmers. In general, organic amendments decline as chemical fertilizer, especially nitrogen fertilizer, become available and responsive modern rice cultivars are grown.

Urea accounts for approximately 80% of the nitrogen applied to rice in Asia and ammonium sulfate approximately 6%. Most farmers apply nitrogen fertilizer in two or three splits. The first split is applied during final land preparation or shortly after planting and the remainder is topdressed at later growth stages, especially at panicle initiation. To minimise volatilization losses it is recommended to incorporate or deep place basal applied nitrogen fertilizer. In general, K and P fertilizer are basically applied during final land preparation. Potassium chloride is the principal fertilizer source of K and superphosphate is the primary source of P fertilizer. On acid rice soils phosphate rock may be applied.

The direct impact of chemical fertilizer applications on methane emission is not clear. Because most methane is emitted through the rice plant, improved rice growth (more tiller and roots) due to fertilizer application increase emission. But source and mode of application may have also direct effects as reported by Schütz et al (1989). Sulfate containing fertilizer reduce methane emission. Sulfate reducing bacteria with methanogens for the limited hydrogen but the amount of sulfate normally added as fertilizer seems to be insufficient to have significant effects.

Nitrification inhibitors, like nitrapyrin and acetylene, slow down nitrification and related N_2O emission. Nitrification inhibitors also limit methane production without reducing much methane oxidation when incorporated into the soil. Slow release of acetylene from in urea encapsulated calcium carbide highly reduced methane and N_2O emissions from rice in greenhouse experiments, while increasing rice production (Bronson and Moiser 1991).

Impacts of various other cultural practices (land preparation, seeding and transplanting, pest control, harvest) on methane emission have not been studied in detail yet. Few observation at IRRI reveal that soil disturbances caused by current cultural practices release large amounts of soil entrapped methane. The increased adaptation of direct seeding (wet and dry seeding) instead of transplanting likely reduces methane emission. In direct seeded rice flooding periods are shorter and cultural disturbance of reduced soils is less intense and less frequent.

Conclusion

The complex interaction between methane formation, methane oxidation, rice growth and cultivation, and methane emission require an immediate, integrated and interdisciplinary approach, including socioeconomics and farmer participation, to achieve feasible and effective mitigation technologies. With current cultivation technologies methane emission from rice fields are expected to increase as rice production has to be raised by 50 to 100% in the next three decades. There is great potential to stabilise or even reduce methane emission from rice fields while increasing rice production with a combination of feasible mitigation technologies without dramatically changing cultural practices nor sacrificing rice yield.

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MANAGEMENT PRACTICES FOR REDUCING METHANE EMISSION FROM INTENSIVE RICE FIELDS.

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ABSTRACT

Methane (CH_4) is an important greenhouse gas. Each additional kilogram of CH_4 added to the atmosphere is 20 to 60 times more effective in trapping heat in the Earth's atmosphere than each additional kilogram of CO_2. Anthropogenic emissions of CH_4 are responsible for almost 70% of all emission sources. Flooded rice field is the primary anthropogenic source of CH_4. It has been estimated between 25-170 Tg CH4/yr, approximately 30% of the annual anthropogenic CH_4 sources.

Therefore, management practices for reducing CH_4 emission from intensive rice fields are important for controlling greenhouse gas emissions and reducing the threat of global warming. As emission of CH_4 from rice fields is related to net CH_4 production, oxidation, and transport to the atmosphere, it is important to control CH_4 movement in rice fields.

To elucidate the differences in CH_4 emission caused by different agricultural management practices, I report here the effects of organic matter applications and water management practices on CH_4 emission from rice fields.

About ten years have passed since the first evidence for an increase in the concentration of atmospheric methane (CH4) was reported. Up to the present time, several time-series measurements of the trend of atmospheric CH4 had been carried out in various locations of the world. The results obtained showed that the average temporal increase of atmospheric CH4 during the last decade was about 1% per year. Analysis of ancient air trapped in polar ice cores revealed that the concentration of atmospheric had remained almost constant at less than about half of the present concentration until 300 years ago, and that the accelerated increase in the concentration started in the 19th century for CH4.

Methane plays an important role in the photochemical reactions of the troposphere and the stratosphere. In addition, it is so-called greenhouse gases as well as CO2, CFCs and N2O, which have strong absorption bands and trap part of the thermal radiation from the earth's surface, accounting for almost 15% of the radiative forcing added to the atmosphere (IPCC, 1990).

Atmospheric CH4 is produced by a wide variety of natural and anthropogenic processes. Many researchers listed major sources: wetlands, termites, ocean, freshwater, CH4 hydrate, rice paddies, enteric fermentation, animal wastes, domestic sewage treatment, landfills, biomass burning, coal mining, natural gas and petrol industry, asphalt pavement, and estimated emission values of CH4. However, there are large uncertainties in the estimated value of individual sources and in the leading causes of the increasing concentration of atmospheric CH4.

Of the wide variety of sources for the atmospheric CH4, rice paddy fields and enteric fermentation of animals are considered as an important source because of the recent increase in their harvest area and livestock population in the world. IPCC estimated the global emission rate from paddy fields and enteric fermentation of animals to be ranging from 25 to 170 and from 65 to 100 Tg/yr, which account for about 10-30 and 10-20% of the total emission from all sources, respectively. In case of paddy fields, this figure is mainly based on the field measurement of CH_4 flux from paddy fields in California, Spain, Italy and Japan.

The measurements in various locations of the world show that there are large temporal variations of CH_4 flux and that the flux differed markedly with soil types or application of organic matter and mineral fertilizer. The wide variations in CH_4 flux indicate that the flux is critically dependent upon several factors including climate, characteristics of soil and paddy, and agricultural practices. On the other hand, about 90% of the world's harvested area of rice fields is located in Asia. Of the total harvested area in Asia, about 60% is located in India and China. We need more detail information about CH_4 flux values in Asia.

Table 1. Emission rates of CH_4 from rice paddies

CH_4 Tg/yr	
Holzapfel & Seiler (1986)	67-166
Cicerone & Oremland (1988)	60-170
Aselman & Crutzen (1989)	60-170
Schutz et al. (1989)	47-145
Neue et al. (1990)	25-60
Bouwman (1990)	51-111
Minami & Yagi (1990)	22-73
IPCC (1990)	25-170
Matthews et al. (1991)	100
Yagi and Minami *	12-113

* Not included in the draft of the 1992 IPCC Supplement

(IPCC Supplement, draft 1992)

Table 2. Estimated sources and sinks of CH_4

CH_4 Tg/yr		
Atmospheric increase	44	40-48
Sinks		
Reaction with OH	420	340-500
Removal by soils	30	15-45
Removal in Stratosphere	10	
Sources		
Wetlands	115	100-200
Termites	20	10-50
Ocean	10	5-20
Freshwater	5	1-25
CH_4 Hydrate		0-5
Coal Mining, Nat. Gas & Pet. Ind.	100	70-120
Rice Paddies	<60	20-100
Enteric Fermentation	80	65-100
Animal Wastes	25	20-30
Domestic Sewage	25	?
Landfills	40	20-70
Biomass Burning	30	20-80

(Houghton, J T, Jenkins, G J and Ephraums, J J eds. 'Climate Change, the IPCC Scientific Assessment', 1990)

First, I report here the composition of soil atmospheres and methanogenesis in soils, factors affecting CH_4 production in soils, factors affecting CH_4 flux from rice paddy fields, effects of agricultural management on CH_4 emission from rice paddies, and distribution of paddy soil in the world; then the estimation of fluxes of CH_4 from global rice paddies will be presented. Finally, I discuss the effects of organic matter applications and water management practices to reduce CH_4 emission from rice paddies.

Table 1 shows global emissions of CH_4 from rice paddies reported by several researchers. From this and other data, we are now preparing the draft of 1992 IPCC WG-1 Supplement to the Scientific Assessment-Section A as shown Table 2. The title of Section A is sources and sinks of greenhouse gases.

Seasonal variations of the CH4 flux from the paddy field in Ryugasaki in Japan are shown in Fig. 1. along with the daily mean temperature of soil and air, the soil Eh, and the agricultural practices. Fig. 2. shows effects of water percolation rates on CH4 from lysimeter paddy fields. Fig. 3. shows changes of Eh and daily mean temperature in the soil at a depth of 5 cm during cultivation period.

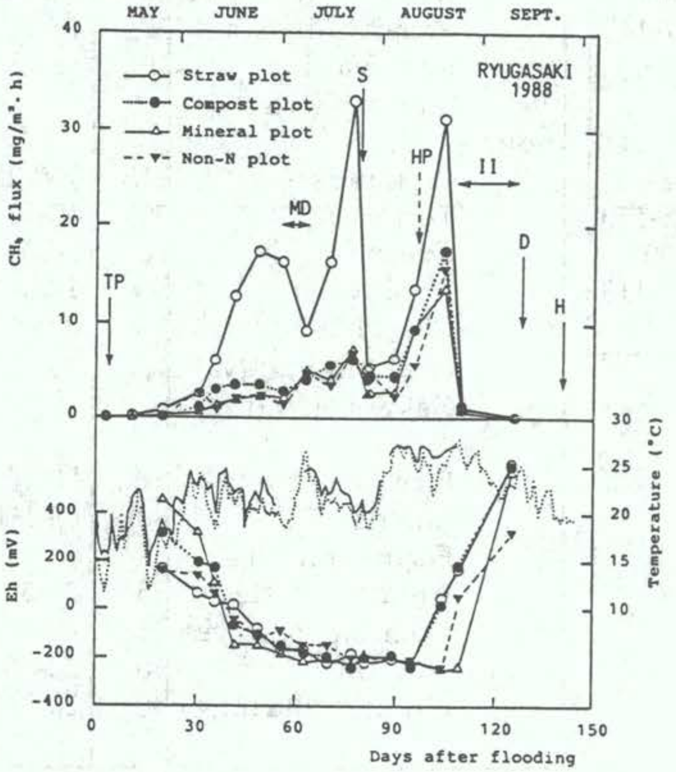

Fig.1. Seasonal variation of CH4 fluxes, daily mean temperature of soil at 5 cm (solid line) and air (dotted line), and soil Eh in Ryugasaki paddy field.

Yagi,K. and Minami,K., Soil Sci. Plant Nutr., 36, 599-610, 1990

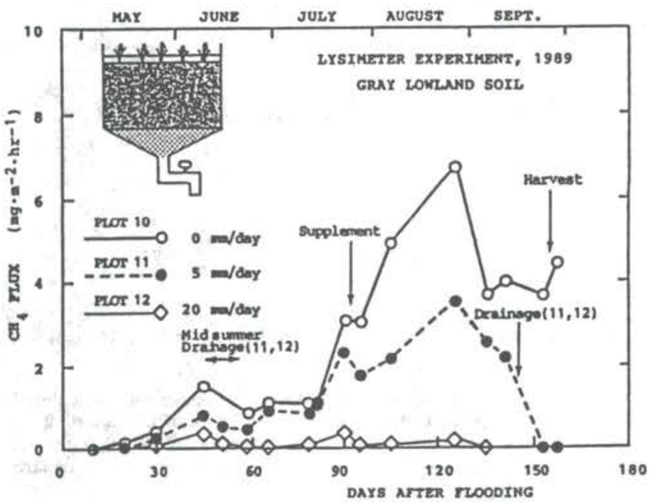

Fig.2. Seasonal variations of CH4 emission from the lysimeter paddy fields during 1989 cultivation period, along with cultivation practices

Yagi,K., Minami,K. and Ogawa,Y., Res. Rep. Div. Environ. Planning, NIAES, 6, 105-112, 1990

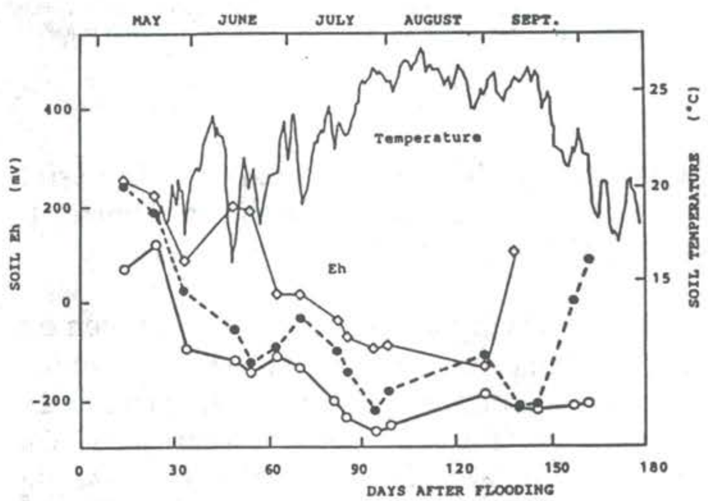

Fig.3. Changes of Eh and daily mean temperature in the soil at a depth of 5 cm during 1989 cultivation period. The symbols of the Eh data are the same as Figure 2.

Yagi,K., Minami,K. and Ogawa,Y., Res. Rep. Div. Environ. Planning, NIAES, 6, 105-112, 1990

SUGAR CANE AS EFFECTIVE BIOMASS TO DECREASE NET CO_2 EMISSIONS. AN ISSUE TO BE INCLUDED IN THE RESPONSE OPTIONS TO CLIMATE CHANGE.

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ABSTRACT

Carbon dioxide is the major man-made greenhouse gas and efforts to enhance carbon sink capacity and limit its emission through fossil fuel substitution, are central to the development of future response strategies.

The present paper shows that intensive sugar cane production has a potentially large carbon sink effect where sustainable agricultural practices are applied. A range of sustainable agricultural practices can be used in sugar cane production and these are shown to contribute to a decrease in net CO_2 emissions directly, or indirectly. Such practices include: phase-out burning fields, blanket of trash cane, minimum soil ploughing, good drainage and irrigation practices, use of biofertilizers. Case studies are described which show that implementation of such practices can result in an estimated sink capacity of around 1.3-2.1 tC/ha/annum.

Integrated management of sugar cane production can capitalise on the high energy potential of sugar cane, through more efficient use of bagasse (for energy production) and the production and use of fuel alcohol.

The above considerations suggest that while sugar cane management cannot make a major contribution to limiting global GHG emissions, adoption of such practices is beneficial and constitutes a potentially significant adaptive response to greenhouse-induced climate change.

Introduction

Carbon dioxide is a major greenhouse gas and efforts to enhance carbon sink capacity and limit its emission through fossil fuel substitution, are central to development of response strategies to limit climate change.

Forests are an effective CO_2 sink, one reason why adequate forest management and reforestation plans have a huge importance. They also have other benefits. It has been estimated that, through reforestation, it is possible to fix around 2-3 tC/ha/year in temperate zones, and as much as 10 tC/ha/y in the tropics. The majority of agricultural crops, however, are not efficient sinks, because the amount of CO_2 fixed is almost the same as further emissions.

Intensive sugar cane production can be an exception, because it has a potential sink effect when sustainable agricultural practices are applied. This sink capacity is calculated in the paper for different sugar cane plantation yields. The value is between 1.3-2.1 tC/ha/y, as shown in the table.

Sugar Cane Production

Sugar cane is the largest primary biomass producer among commercial crops, even more than different kinds of forest, for example, *Eucalyptus* and *Pinus*. Its higher photosynthetic efficiency allows it to subtract high amounts of CO_2 to produce biomass. The fixed CO_2 does not totally return to the atmosphere because an important part of the biomass (35%) can stay in the field. Consequently, this organic matter with its intrinsic carbon content, is an important input for soil formation through humus production. Despite the fact that sugar cane is not a perennial crop, it has the advantage of not needing intensive annual soil ploughing, because sugar cane plantations have a life-time of 5 or more years. This fact contributes to the process of carbon soil fixation which is different from other crops such as cereals, vegetables and tubers.

A range of sustainable agricultural practices can be used in sugar cane production and these are shown to decrease net CO_2 emissions directly, or indirectly. Such practices include: phase-out burning fields, blanket of trash cane, minimum soil ploughing, good drainage and irrigation practices, use of biofertilizers and compost. These practices must be extended and used worldwide.

In other respects, it is a fact that sugar cane is the crop with the highest energy fixation per cultivated area and therefore it has a high energetic potential. Another advantage of this crop with respect to its energetic potential, is that the energy used for cultural crop activities only represents 5% of its dry matter energetic value - this is less than other crops such as *Eucalyptus*, corn and sugar beet.

Due to the high energetic potential of this biomass, its use as a substitute for large amounts of fossil fuel is a real possibility at the current level of technology. Nevertheless this possibility has not been used enough. Bagasse, an important energy source, has been used inefficiently in most parts of the world. Sugar cane trash has rarely been used for energetic purposes. The production of sugar cane alcohol for motor fuel is at present low in comparison with its possibilities, in spite of that it is the most profitable biomass for this purpose. Otherwise, biomass alcohols have the advantage in comparison with methanol obtained from natural gas, that they do not contribute to increasing the greenhouse effect. It is necessary to take into account this fact in order to evaluate the most adequate responses for transport fuel switching.

Integrated management of sugar cane production can capitalise on the high energy potential of sugar cane, through more efficient use of bagasse and cane trash (for energy production) and the production and use of cane ethanol as motor fuel, limiting net CO_2 emissions in many countries of the world. Switching fossil fuel by such approaches increases the capacity of sugar cane to reduce net CO_2 emissions between 6-10 tC/ha/annum, depending on the alternative adopted and sugar cane plantations yields, as is presented in the table. The majority of these alternatives are at present profitable, other ones could be profitable when environmental costs associated with climate change have been taken into account.

The results of these analyses show that it is a fact that the capacity of sugar cane to reduce net CO_2 emissions would be comparable with forest capacity on the basis of specific area. Nevertheless, taking into account the surface area used worldwide for sugar cane plantations (167 M ha), it is evident that its global effect on minimizing net CO_2 emissions is relatively small. However, it can be very important for many countries and this fact must be taken into account to formulate adequate responses to climate change under the precept: `Think globally, act locally'.

As a consequence of the results reached, several conclusions were elaborated. They are important to enhance the role of this crop in limiting net CO_2 emissions.

Conclusions

1. When it is cultivated using sustainable agricultural practices, sugar cane can be a moderate CO_2 sink, especially in high yield conditions,.

2. Measures to improve the energetic efficiency of the sugar cane industry, to achieve full use of residues for energetic purposes, and to produce alcohol as a motor fuel will substantially increase its capacity to reduce net CO_2 emissions.

   When considering substitution of gasoline with alcohols in automotive transport, a process which will increase in the developed world during the next few years, the use of ethanol should be promoted over methanol obtained from natural gas, as ethanol does not contribute to an increase in the greenhouse effect.

3. The joint effect of sugar canes sink action and potential for substitution of fossil fuels is much greater than that of other commercial crops.

4. Projects for developing the cane industry and full use of the crops energetic potential should receive a priority similar to that being given to reforestation on the international level.

5. Considering that the total world area planted with sugar cane is only 16.7 M ha, it is clear that its global effect in reducing net CO_2 emissions to the atmosphere is much less than that of forests. However, it can be a local response of considerable important in many countries.

6. Important documents concerning the study of climatic change and solutions for it have recommended elimination or reduction of subsidies for activities which tend to increase concentration of greenhouse effect gases in the atmosphere. The situation of the world sugar and alcohol industries should be analyzed in this respect.

7. In light of the fact that sugar canes ability to reduce net CO_2 emissions is much greater than that of either corn or beets, subsidies for the beet sugar industry and for alcohol production from corn are of questionable value. Trade barriers blocking expansion of the sugar cane industry worldwide should be examined, with particular reference to expansion where forest clearance is not required.

8. Sugar cane should be included as an option for dealing with climate change given its great capacity for reducing net CO_2 emissions. The Intergovernmental Panel for Climate Change and its subgroup AFOS (Agriculture, Forestry and Other Human Activities Subgroup) must contribute to the fulfilment of this objective.

SUGAR CANE POSSIBILITIES FOR MINIMIZATION OF NET CO_2 EMISSIONS
(Carbon tons/ha/year)

CALCULATED ON THE BASIS OF SUGAR CANE PLANTATION YIELDS:		
	WORLD AVERAGE (60 t/ha/y)	HIGH (100 t/ha/y)
	SINK	
I. Carbon Fixing by Soil	1.3	2.1
Fossil Fuel Substitution		
II. Bagasse combustion at current efficiency level	1.9	3.2
III. Improving bagasse combustion efficiency and using surplus bagasse to generate power or other energetic purposes	0.6	1.0
IV. Using sugar cane trash for energetic purposes.	0.9*	1.5*
V. Producing alcohol for motor fuel (from molasses jointly with sugar production)	0.3	0.5
VI. Producing alcohol for motor fuel (directly from sugar cane)	1.8	3.0
NET EFFECT		
Current Situation (I + II)	3.2	5.3
Carrying out action III (Plus I + II)	3.8	6.3
Carrying out action V (Plus I + II + III)	4.1	6.8
Carrying out action VI (Plus I + II + III)	5.9	9.8

NOTE:
* It does not produce net CO_2 reduction because affect carbon fixation by soil.

GREENHOUSE GASES FROM INTENSIVE AGRICULTURE: NEED FOR MINIMISATION STRATEGIES AND ADAPTATION

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ABSTRACT

Regarding emission of greenhouse gases (GHG) from intensive agriculture, minimisation strategies should be set after the investigation of the whole agri-food system in a holistic approach in order to find suitable solutions to the problem. Globally, studies show that intensive agriculture in developed countries contributes mainly in emission of CO_2, CH_4 and N_2O from diffuse sources and from large territories. The carbon and nitrogen cycles should be closely scrutinised and their balance properly drawn up.

Many possibilities exist for intensive agriculture to contribute to reduced net GHG emission, to mitigate its effect and to, simultaneously, achieve environmental goals. For example, the adoption of low input and sustainable agricultural technology should give positive results. Intensive agriculture could be the first victim of its abuse, less now than tomorrow for future generations.

So, there is a need for a long-term vision and a short- and medium-term action plan. Working out minimisation strategies, directions can be considered in three major areas of emphasis: economic, environmental and social, on a grand scale but also from practical and local realities. Agricultural practices, research, education and awareness, land use planning and management, monitoring, policy and program reform are some priority actions.

The inadequacy of the present knowledge on potential impacts of GHG impedes the identification and adoption of useful and most valuable responses. It is clear that research and development are needed to better understand the mechanism, magnitude and control of the emission of GHG and the effects of changes in climate on crops, livestock and other physical processes and to propose well-adapted, flexible, reliable and efficient technologies as solutions.

Education and information are of prime importance in order to change the way of doing things (standpoint, habit and behaviour on the one hand, policies, program, agreements, etc. on the other) for the farmers involved in intensive agriculture as well as for people from the whole agri-food system and society at large.

Summary

Agricultural and environmental issues interact in many ways, inextricably linking their future. But agriculturists and environmentalists often oppose their goals: intensive farming, in developed countries, in particular has gradually lost its status as being in harmony with nature and, with the onset of massive chemical inputs, has become an increasing source of environmentalists concern, for global catastrophe.

Climatic change is one of these important global issues. As more greenhouse gases (GHG) are discharged into the atmosphere, the warmer the earth becomes. From this, agriculture is an exposed discipline because of the new positive or negative uncertainties raised by these foreseen conditions (nature and speed of changes) and the food security issue. As contributor to GHG and one of the legatees of the effects of climatic changes, intensive agriculture should join other industries in having a closer look at its practices and processes, both locally and abroad.

Regarding emission of GHG from intensive agriculture, minimisation and adaptation strategies should be set after the investigation of the whole agri-food system in a holistic approach and with a vision in order to find suitable solutions, some more general and others, industry specific.

Globally, studies show that intensive agriculture in temperate developed countries contributes mainly in anthropogenic emissions of carbon dioxide, methane and nitrous oxide.

Most of these fluxes originate from diffuse sources which are usually small but numerous and cover large areas. Generally, this involves a lot of people, different practices and processes. It also implies that the carbon and nitrogen cycles should be closely scrutinised, their balance properly drawn up and the interactions between GHG better understood for each production unit.

It is necessary to keep in mind that human and natural resources are the foundation of the agri-food system. The production from these resources must be adapted and of a suitable quality to meet the demand of efficient processing of products and highly diversified market.

In setting strategies, all the actions should be fitted one by one into the sequence: **Resources - Production - Processing - Market**. Each link should be studied for its inputs and outputs (internal and external) and the same should be done overall the whole chain. The impacts on air, soil, water and energy should be determined for products, technologies, wastes, losses, transportation etc. This basic procedure clarifies potential directions. The most overall, appropriate and efficient actions should be retained.

This is a holistic system view, which implies that an isolated study of its parts will not permit a good understanding of the complete system because the separate parts are linked in an interacting manner. A perturbation in one part will affect not only that one part, but the system as a whole and furthermore, its environment.

There is a need for a long-term vision. Intensive agriculture and agri-food industries could be the first victim of their abuse, less now than tomorrow for future generations. Although it is felt that intensive agriculture has been effective but could have also been harmful for the environment, there are concerns about many of the proposed changes towards a more extensive agriculture and about how food security and nutritional needs can be approached in the future.

The vision will encompass such key variables as:

- A safe resource base of agricultural land and soil to support the long-term productivity and food security;

- An agri-food system that is able to respond to atmospheric and climatic changes;

- An agri-food system that is more energy efficient, less polluting and less dependent on fossil energy sources;

- An agri-food system that can cut its contribution to air, soil and water degradation and pollution;

- An accessible and sufficiently diversified genetic resource base that can be efficiently utilized to assure adaptation to new conditions and for future generations.

Working out minimisation and adaptation strategies, besides technical aspects, directions can be considered simultaneously in three major areas of emphasis: economic, environmental and social.

The major objective of a strategy for the future should be to keep the agri-food sector healthy, profitable and stable to ensure food security now and for the future generations. In that respect, the speed and the nature of change to cut on GHG emission should be support by a most cost effective approach, an improved international cooperation and coordination and concerns about a more market-driven food production and technologies (yield vs quality).

In fixing environmentally sustainable strategy, quality standards and baseline data should be established to allow monitoring of impact of our current agri-food industry technology on emission of GHG and the environment (air, soil, water) and the improvement over time. Environment is a complex issue where synergism of an induced practice must be examined in a broader context, to make sure that the problem has not been pushed away in time, space or mean it has been resolved.

Farmers, agri-food sector and society in general are not well aware of potential GHG emission and climatic changes. To succeed, strategies should respond to society's cultures, needs and concerns. There is a need for better knowledge of local potential GHG emission and climatic changes, nutrition and agri-food practices and processes, food security and health inter-relations, and of impact analysis of the new technologies and products on people (farmer and other). A public communication strategy on these issues and better and different work of technology transfer for suitable solutions should be part of the deal.

Many possibilities exist for intensive agriculture and food industry to contribute to reduced net GHG emission, to mitigate its effects and to, simultaneously, achieve environmental goals. For example, the adoption of low external input and sustainable agriculture and food industry technology should give some positive results. On that point, quality of air, soil and water can be deeply related, regarding the technology to be adopted. With the farmer, for instance, it may be easier to work on water quality than air quality: water pollution being more visible and calling more for actions. But the results could be beneficial to air quality as well depending on the technology chosen.

Some short and mid-term actions required to move intensive agriculture and food industry towards the reduction of GHG emission and adaptation, include improvement of agricultural practices, more strategic research, education, training, and information (well personalised, made-to-measure), focussed on best management practices, appropriate land use planning and management, proper monitoring and development of adequate indicators, and policy and program reform supportive of the strategy.

The principal change faced by intensive agriculture and agri-food industry in seeking solutions to reduction of GHG emission and adaptation to climatic change deal not so much with the types of activities in which they engage, since these remain essentially the same, but more with the approach to them.

There is a need for an integrated approach in seeking solutions to agricultural emission of GHG given the multitude of factors involved (site characteristics, natural or environmental inputs, management inputs, environmental processes, product outputs, economic, social, etc.) their interrelation and their dynamics. Particular care must be taken to consider both in research and implementation, all these factors and the total agri-food-ecosystem over time.

The inadequacy of the present knowledge on potential impacts of GHG and of climatic changes impedes the identification and the adoption of useful and most valuable responses. It is clear that research and development are highly needed to better understand the mechanism, magnitude and control of the emission of GHG and the effects of changes in climate locally and abroad on crops, livestock and other physical biochemical processes and to propose, as solutions, flexible, reliable and efficient technologies responding to economic, environmental and social issues as well.

Education, training and information are of prime importance in order to change the way of doing things (standpoint, habit and behaviour on the one hand, policies, programs, agreements, etc. on the other) for the farmers involved in intensive agriculture as well as for people from the whole agri-food system and society at large.

MINIMIZATION STRATEGIES OF EMISSION OF GREENHOUSE GASES FROM INTENSIVE AGRICULTURE

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ABSTRACT

Strategies to minimise emission of greenhouse gases (GHG) from intensive agriculture should aim at reducing gross emission and maximizing sinks. On the consumption side, the first priority is to control population growth and life styles which encourage excessive consumptive. In the developing countries, diversification of rice based diets would reduce the demand for rice and in the developed countries partial substitution of dairy products by vegetable proteins would minimise sources of methane. On the production side, energy consumption and biomass burning should be controlled, and mulching, composting, and green manure, and integrated pest management should be vigorously pursued.
Agricultural subsidies in developed countries and international trade are also important sources of GHGs. Corrective measures should be taken.
Agroforestry systems with perennial trees as a dominant feature are important carbon sinks.

Introduction

Agriculture has been identified as an important source of GHGs. Minimization strategies should aim at minimizing the net emission by reducing the gross emission and maximizing the sinks. This should be done at both the consumption and production side.

Minimization Strategies on the Consumption Side

Population growth and excessive consumptive lifestyles are the major driving forces for increasing agricultural production.

Population growth

Because of the high population growth rates in many developing countries, the pressure for producing more agricultural products will continue to grow and, consequently, more energy will be used and more land will be cleared for agriculture resulting in ever higher emissions of GHGs. Obviously, it should be mitigated by more extensive and effective birth control in the developing countries. The problem is huge and difficult, but it is not an impossible task as has been demonstrated by many countries which have succeeded in substantially reducing their population growth rates.

Lifestyles encouraging excessive consumption

Excessive consumptive lifestyles drive up demands. It is primarily a problem in the developed countries and the "throw-away" culture causes much to be wasted. Food processing, storage, transportation, and marketing consume a lot of additional energy which leads to substantial emissions of GHGs. Very little, if at all, is being done to change this lifestyle. The problem is compounded by the fact that it is being used as a development model by developing countries. The developed countries should set the example for a thriftier, simpler and healthier lifestyle.

Agricultural subsidies and international trade

Agricultural subsidies and overproduction in developed countries are also a significant source of GHGs. Furthermore, they distort world trade which causes difficulties to the developing countries often leading to environmental degradation (WCED, 1987). Corrective measures should be taken.

Urbanisation

Urbanisation increases the distance between the agricultural production centers and the consumers. Hence, more energy is required to transport the products. The creation of employment in the villages, e.g by developing post-harvest processing in rural areas, would reduce the flow of urbanisation. This would lessen transportation of food to cities and hence, lowering emission of carbon from the combustion of fossil fuels. Other benefits would be the improvement of the living standard of the rural people, the reduction of population pressure and encroachment in the forests (Soemarwoto, 1985) which would lower deforestation rates and the release of carbon into the atmosphere.

Food diversification

Since rice paddies are an important source of methane, the promotion of food diversification, especially in Asia, would reduce the demand for rice, which in turn would reduce the emission of this GHG. The rice statistics of the International Rice Research Institute (1986) showed that, in many countries, the contribution of rice to the calorie intake was decreasing. Traditionally many people do not eat rice as their main staple food, but instead eat sweet potato, sago, corn and taro. This tradition should be preserved and strengthened. With improved living standards people also eat more fruits, vegetables and other food which would lessen the rice intake. Post-harvest processing to make non-rice foods more appealing should be encouraged, e.g easy storage and cooking, and better nutritional value and taste. If the rate of decrease of rice consumption could become larger than the decrease in the population growth rate, there should be a decrease in the demand for rice production. This would not at all be impossible. Japan, for example, has shown a very rapid decrease in rice consumption per capita.

Food diversification should be accompanied by vigorous efforts to mitigate the higher risk of soil erosion in the cultivation of upland crops. Preventive measures should also be taken in order that diversification would not be by substitution of rice by imported food, e.g wheat.

In the developed countries food diversification should reduce the consumption of meat and dairy products and an increase of vegetable protein.

Minimization Strategies on the Production Side.

To keep up with population growth agricultural production will have to be increased requiring additional energy inputs. From 1950 to 1985 agricultural energy consumption has increased from 276 million barrels oil equivalent to 1,903 (Brown, 1987). In the developing countries much less energy is used than in the developed countries, but it is increasing as more intensification occurs in which more machines, irrigation and higher doses of fertilizers and pesticides are used. Appropriate technologies, such as mulching and minimum tillage, would lower energy requirements and should be encouraged. Overuse of fertilizers and pesticides, which often happens, should be discouraged, since in addition to being economically wasteful, it is an unnecessary additional source of GHGs. Crop rotation in which legumes are used in the cycle, green manure and composting of agricultural residues would reduce the need for fertilizers. Green manure plants also sequester carbon and the composting of crop residues would eliminate the production of methane and CO from their burning. These practices should be encouraged. Composting of organic garbage should also be more forcefully pursued. This would minimise landfills which are a source of methane. Further reductions of GHGs can be achieved by wider applications of integrated pest management and biological control which have been shown to be able to maintain high yields with less pesticides (e.g Postel, 1988).

Another possibility for increasing yields is by reducing the losses between the field and consumption. The IRRI rice statistics (1986) showed large variations in losses which indicate that there are possibilities for reducing these losses in many countries.

Post-harvest processing with appropriate and energy efficient technology should be developed in the rural areas using, where appropriate, wood as the energy source, producing products which do not need to be refrigerated, e.g salted, sugared and dried. It should also endeavor to substitute natural products for foam rubber and plastics, e.g kapok from the kapok tree (*Ceiba pentandra*). These efforts would minimise emission of carbon and the consumption of CFCs, create jobs for rural people and thereby reduce the urbanisation flow and population pressure (see above). The trees would also sequester carbon from the atmosphere. The products should be aggressively marketed nationally and internationally as being environment friendly.

Developing countries should carry out experiments for the application of the research findings of reducing methane production from rice paddies by cultural methods. The same applies for the developed countries with respect to intensive crop and animal production.

Maximising Sinks

Agroforestry systems are important sinks of carbon. Home gardens, an agroforestry system found throughout the world, are known to be important sources of income, calories, proteins, minerals, vitamins, medicine and fuelwood (Landaur and Brazil, 1990). The staple foods produced include bread fruit, sago, banana, and sugar and flour from the sugar palm (*Arenga pinnata*) which play an important role in food diversification. Fuelwood has the advantage that the trees recycle the carbon. from the combustion of the wood. The agroforestry systems should be improved in order to satisfy the increasing demand of a growing population and to balance the harvest rate with the growth rate of the plants, so that they would remain sustainable. In many places the home gardens are highly diversified consisting of many species and varieties with a multilayered canopy structure. Consequently, they are a rich genetic resource and effectively protect the soil against erosion.

To increase the methane sink the production of CO from biomass burning should be minimised as was discussed earlier. Other sinks of methane are still poorly known.

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METHANE EMISSION FROM RUMINANTS IN SEMI-ARID REGIONS

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ABSTRACT

Methane emission in ruminants in semi-arid areas can be calculated from relationships that have been established between methane production and energy utilization. Methane emission per unit product such as carcass, may be three times as high with animals grazing mature tropical pastures as with those grazing more productive pastures. The calculations are even less favourable when

(a) nutritionally imbalanced forage diets are involved; and

(b) account is taken of methane emission from the breeding female plus progeny.

Two ways in which methane production may be reduced involve

. the development of anaerobic microbes that convert carbon dioxide and hydrogen into products other than methane;

. strategic supplementation to improve the efficiency of energy use and hence reduce methane emission per unit product.

Introduction

Animal production in semi-arid regions occurs through nomadic enterprises, extensive grazing or as by-products of agriculture. Productivity is low and there is little financial outlay on livestock care. The livestock owner has little or no interest in spending money to reduce methane emission. However, methane can be diminished by improving the efficiency of conversion of the available feed into beef, milk or work and through this means reducing animal numbers.

Herbivore animals, especially in semi-arid regions derive most of their nutrients from the anaerobic fermentation of plant fibre in the rumen and large intestine. This fermentative process leaves much of the potential energy of the diet as short chain (volatile) fatty acids (VFA) which form the major source of energy for the host animal. In addition part of the dietary energy is used to support the growth of the rumen microbes which supply the host with much of its protein. Finally part of the diet is converted to carbon dioxide and methane. with diets that are nutritionally well balanced for the microbes, reasonable predictions of methane emission are possible from knowledge of the digestive or metabolic characteristics of the diet. However imbalances of nutrients such as nitrogen, phosphorus and sulphur depress feed intake and fermentation and reduce our ability to predict methane production.

Prediction of methane production

The greatest amount of data on methane production in farm animals has been obtained in studies of energy balance, the difference between input and output. In these studies it is recognised that energy is first used to maintain the body weight of the animal with any energy surplus to this need devoted to productive purposes. These concepts have been incorporated in the United Kingdom into the Metabolisable Energy (ME) system where ME is the energy remaining after allowance for losses in faeces, urine and methane.

At a maintenance level of feeding, methane is equivalent to about 15% of ME, whereas at feeding levels above maintenance this value declines to 10-12% of ME. There is limited evidence that with forages from semi-arid tropical regions, methane may form a slightly higher proportion of ME at both maintenance and supra-maintenance feeding levels. despite this, the general relationships between ME and methane are valuable, because from knowledge of ME needs of given classes and breeds of livestock for maintenance and production, predictions can be made of methane emissions. An extensive data base on energy transactions has been composed for European breeds of ruminants, those fed forages generally found in temperate regions. although fewer data are available for semi-arid regions and for the cattle adapted to life in such areas, it appears that similar nutritional principles apply. However the inability of these cattle to achieve high intakes of ME with such forages restricts production to 40% or less of that achieved by their temperate counterparts and, as annual methane production per animal is approximately the same, production per unit carcass weight may be three times as high. This situation is exacerbated with nutritionally imbalanced diets with which energy consumption may not be adequate even for maintenance. The correction of such deficiencies permits the animal to eat more and to derive energy sufficient not only for maintenance but also for production. Methane production rises per animal but falls in relation to the production of saleable product.

Reduction in Methane Emissions

Improvement in the efficiency of conversion of feed into saleable products by correction of nutritional deficiencies is probably the most feasible option in attempting to reduce methane emissions in semi-arid grazing systems. However methane emission can also be attacked more directly by modifying the population of rumen microbes responsible for production. Two possible ways revolve around the development of new microbial strains or the substantial modification of the rumen ecosystem. The first of these methods involves bacteria with enzymes capable of diverting nutrients away from methane towards VFA; such systems offer the possibility of transfer by genetic engineering techniques to bacteria capable of survival in the rumen, and hence of converting currently wasted and harmful metabolites into valuable nutrients. The second possibility involves changing the rumen ecosystem by removing protozoa. by so doing it should be possible to reduce methane emission directly; further, removal of protozoa which act as predators for rumen bacteria increases the amounts of protein that reach the small intestine and hence improves the amino acid status of the animal. Suitable technology now being developed to achieve this defaunated state would thus benefit the nutrient balance of the animal, increase production and thus reduce methane output per unit product.

PRESENT CONDITIONS IN THE PATAGONIAN RANGELANDS, IN RELATION TO POTENTIAL IMPACTS OF A GLOBAL CLIMATE CHANGE

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In this presentation I shall try to offer a very concise view of the present conditions prevailing in Patagonia, a region of about 600,000 Km^2 located at the southernmost part of South America, and of the role those conditions could eventually play under the influence of a global climate change.

Different General Circulation Models (GCM) have been developed to simulate future climate changes resulting from doubling of CO2 atmospheric content. Predictions emerging from these models are of great interest both at the global and the regional scales. For the whole Southern Hemisphere a rise in temperature of 0.5°C has been estimated (Jones et al., 1986).

The Giss (Goddard Institute of Space Science, New York) provides predictions for changes in surface temperature (Ts) for the double CO2 scenario. According to this prediction, for the decade 2010's the increase of Ts in Patagonia would be somehow below 1°C, while for 2050's it would be 1.5°C for most part of the region and 2.5°C in the north west. (Burgos et al., 1991).

Several authors have pointed to the difficulties arising from the scarcity of historical meteorological data in South America, for instance, to estimate the temperature change over the last 100 years, in relation with the increase of atmosphere CO_2 estimated in 1.2. Another factor which contribute to the complexity of predicting global and regional climate changes is the impact of the modification of vegetation cover determined by direct or indirect intervention by humans. Deforestation and desertification are two current ways in which the climate may be influenced through changes in the optical properties of the surface, in the rates of transfer of mass and energy and in roughness of the surface (Verstraete & Schwartz, 1991).

Implications of deforestation in the Amazonas Basin for global and regional climate change has received much attention and has become an issue of public concern. Molion (in Burgos et al., 1991) has given a general description of the way the thermodynamic mesoscale process operates in the Amazonas basin and, on that basis, he has intented predictions for changes in climatological parameters such as surface temperature and rainfall, for the conditions of unmodified vegetation cover and after large scale deforestation. For this purpose, he used scenario B from GISS Model.

After this very brief account of some of the results of application of GISS to prediction of climate change in southern South America I shall try to present a short description of the ecological conditions prevailing in Patagonia, a region broadly characterised as a semidesert (Soriano et al., 1983).

In the arid climatic Zones map prepared by Peveril Meigs for UNESCO (1960) Patagonia appears as a desert characterised as Aa12, where A means arid, a without rainfall seasonality, 1 is the temperature of the coldest month, between 1-10°C and 2 is the temperature of the warmest month, 10-20°C. However available data show quite a clear precipitation seasonality. A high proportion of total rainfall falls in winter and generally in small events (Fig.1). For central Patagonia, isohyets are shown in the map by Barros and Rivero (1981) (Fig.2).

A high degree of vegetation heterogeneity is apparent in correlation with differences in rainfall (Fig.3). Six different vegetation units have been recognised (Soriano, 1956). Besides the differences in floristic composition, these units show differences in the proportion of the dominant life-forms: shrubs, tussock grasses and cushion plants and in bare soil, in response to various degrees of aridity.

NOA/AVHRR satellite imagery has been used to study the heterogeneity of central Patagonia (Aguiar et al., 1988). With the aid of satellite sensor images some aspects of the dynamics of vegetation were analyzed, using the Normalised Difference Vegetation Index (NDVI) (Soriano and Paruelo, submitted). Several studies by different authors have shown that spectral data were highly correlated with the aerial net primary production (ANPP), a key functional aspect of the ecosystem (Goward et al., 1985; Tucker et al., 1985; Box et al., 1989; Hanan et al., 1991). The NDVI dynamics during the growing season in central Patagonia allowed the recognition of different patterns related to differences in maximum NDVI and in seasonality of NDVI change (Fig.4). Monitoring NDVI dynamics may be considered a useful tool in relation with the severe and rapid changes to which the vegetation is being and could be submitted in the future.

Changes already undergone by the Patagonian ecosystems can be traced to human intervention. The original, rather poor mammalian fauna showed clear predominance of the guanaco (Lama guanicoe). The horse, introduced by the Spaniards was rapidly adopted by the Indians. At the end of the XIX century sheep were introduced from south to north and sheep farming extended to the whole region (Soriano and Paruelo, 1990). In the 40's there was no place in Patagonia which had been free from sheep grazing and only a very small proportion, in the more arid areas, remained unfenced. Very soon after sheep introduction attention was paid to symptoms of desertification (Bailey Willis, 1914). Increasingly, evidences have been shown of various forms of soil erosion: as sand tongues, many kilometers long, micro- and macro-accumulations and barkans. Other symptoms of desertification are: decrease of vegetation cover, increase of xerophytism, as well of shrub invasion, decrease of forbs and floristic changes (Soriano and Movia, 1986).

Several factors and processes can be identified as causal or promoting agents of desertification acting at different spacial and temporal scales, from the regional or the landscape level to the vegetation patch or the bare soil gap and from the hour or day to a decade or a century.

Important factors in desertification are the strong winds that sweep the whole region during most part of the year, generally from west or south west, the large valleys and lakes dissecting the Andes parallel to the wind direction and the extended plateaus that facilitate the development of high wind velocities. Friable soils are increasingly exposed to the wind force under the double effect of overgrazing and trampling.

Age of erosion tongues has been estimated in about 70 years on the basis of its progression rate and length of its longitudinal axes (Castro, 1983; Castro et al., 1980; Gargantini and Movia, 1989). On the other hand, sand microaccumulations leeward of the grass tussocks become evident after a few strong wind days, while heavy grazing is going on in the site. Area affected by distinct signs of erosion in Patagonia was estimated in 40, 000 Km^2 (Monteith, 1970). Using Landsat images, the rate of increase was estimated and accordingly, eroded areas in Patagonia in year 2000 will be 60, 000 Km^2, 10% of the area of the region. An indirect indicator of the changes occurring as desertification goes on is the decline of sheep numbers during the last decades (Fig.5). Wool production per animal, in a 200,000 Ha in north west Patagonia showed a clearly declining trend (Fig.6).

Several kinds of positive feedbacks, both physical and biological are thought to contribute to maintaining or enhancing desertification (Schlessinger et al., 1990; Sud and Smith, 1985; Sud et al., 1988). An example of a positive biological feedback may be mentioned for the central-west part of Patagonia. There, soil bare gaps, about 30 cm in diameter appear with very high frequency interspersed in the matrix formed by two types of vegetation patches: scattered grass tussocks and shrubs encircled by a ring of grasses. (Soriano et al., submitted). Several characters and forces operate in the system against the establishment of new individual plants in these gaps. Most of the species in the community reproduce sexually and their disseminules exhibit plumy awns, pappuses or wings that favour winged dispersion. Thus, they are swept over bare gaps and piled up at the border of grass tussocks. A model of new individuals recruitment has been developed (Fig.7) (Soriano and Sala, 1986; Aguiar, 1991). The amount of seeds rapidly decreases from the border of tussocks into the bare gaps. Soil water availability for successful seedling establishment increases in the same direction in correlation with adult plant roots distribution. In summary, seed distribution and competition for soil water determine failure of gap colonization. On the other hand, new gaps open under heavy grazing (Fig.8).

Several biogeochemical processes in deserts may be exacerbated with desertification, and still more under conditions of a temperature rise, predicted by several Global Circulating Models as a result of doubling of atmospheric CO_2 content. It has been suggested that one-third of the gaseous loss of N to the atmosphere from terrestrial ecosystems comes from deserts (Bowden, 1986). Processes involved would be ammonia volatilization, denitrification and wind erosion. All of them may be encouraged by desertification. contribution of dust from desert erosion to the tropospheric aerosols might have complex and opposite local and regional effects on climate. according to some authors, absorption by soil dust of infrared reradiation from the earth's surface may determine local warming (Wang et al., 1985).

The more severe conditions scenario for a region like Patagonia would include, besides a general trend to temperature ruse due to greenhouse gases, a decrease of the amount of CO_2 fixed by a progressively decreasing vegetation cover and an increase of gaseous N losses and tropospheric aerosols. These, and other climate-driven vegetation changes would eventually manifest in NDVI dynamics as mentioned before. Monitoring of trends of: a. the number and height of biomass peaks, b. the duration of the biomass, and c. the rate of biomass change, both during increasing and declining periods, should provide valuable information on vegetation responses to climate fluctuations or consistent trends (Soriano & Paruelo, unpublished).

Along the north-south strip where the steppe contacts the forest of Nothofagus and Austrocedrus, this forest has turned into brusch or bushy steppe as a result of human intervention. Since the 30/s, several authors supported, on different grounds, the hypothesis of a consistent trend towards a drier climate in Patagonia and Tierra del Fuego (Auer, 1939, 1951, 1965; Kalela, 1941a & b). They interpreted the floristic and ecological changes occurring in that strip, as the result of a long-term aridification trend, resulting in a westward expansion of steppe and desert, into the forest zone. Recently, Veblen and Lorenz (1988) reconsidered this issue, approaching it through the analysis of tree population age and photographic comparisons of the forest/steppe margin over the past century. Both types of analysis indicated an expansion of trees into the steppe. Frequent burning of the steppe by the indians before 1900, overgrazing by sheep and cattle and forest fires occurring since the Europeans settle definitely in the region are, according to the author, the interventions which determined the current vegetation . This ecotone, 50-100 km wide extend at least between 40° and 43° S of latitude, representing a deforested and desertised area which could eventually be brought again to forest. As Vitousek (1991, p.349) has stated, "Deforestation has contributed substantially to the increase in atmospheric CO_2, and reversing this process through reforestation would reverse the effect as well". To reach this substantial change in land use, as well as to stop or reverse desertification in the whole region require political strategies to face North-South inequalities within the country. As well as, in earth global terms, a few countries in the north account for 38% of annual fossil-fuel CO_2 emissions, in Argentina, the humid pampas region and especially the megaurban Buenos Aires area surely account for the highest proportion of the nation's emissions.

Victor (1991) has proposed that any cooperation policy regarding climate change should take into account two essential criteria: political acceptability and long-term flexibility. For the case of Patagonia desertification, the suggestion has been made (Soriano, 1986) of channelling funds to directly modify or alleviate the mechanisms leading to overgrazing or undesired fires, instead of sterilizing them as occult or explicit subsidies every time an emergency or a catastrophe occurs, be it an exceptional dry period or an extremely cold winter.

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Figure 1

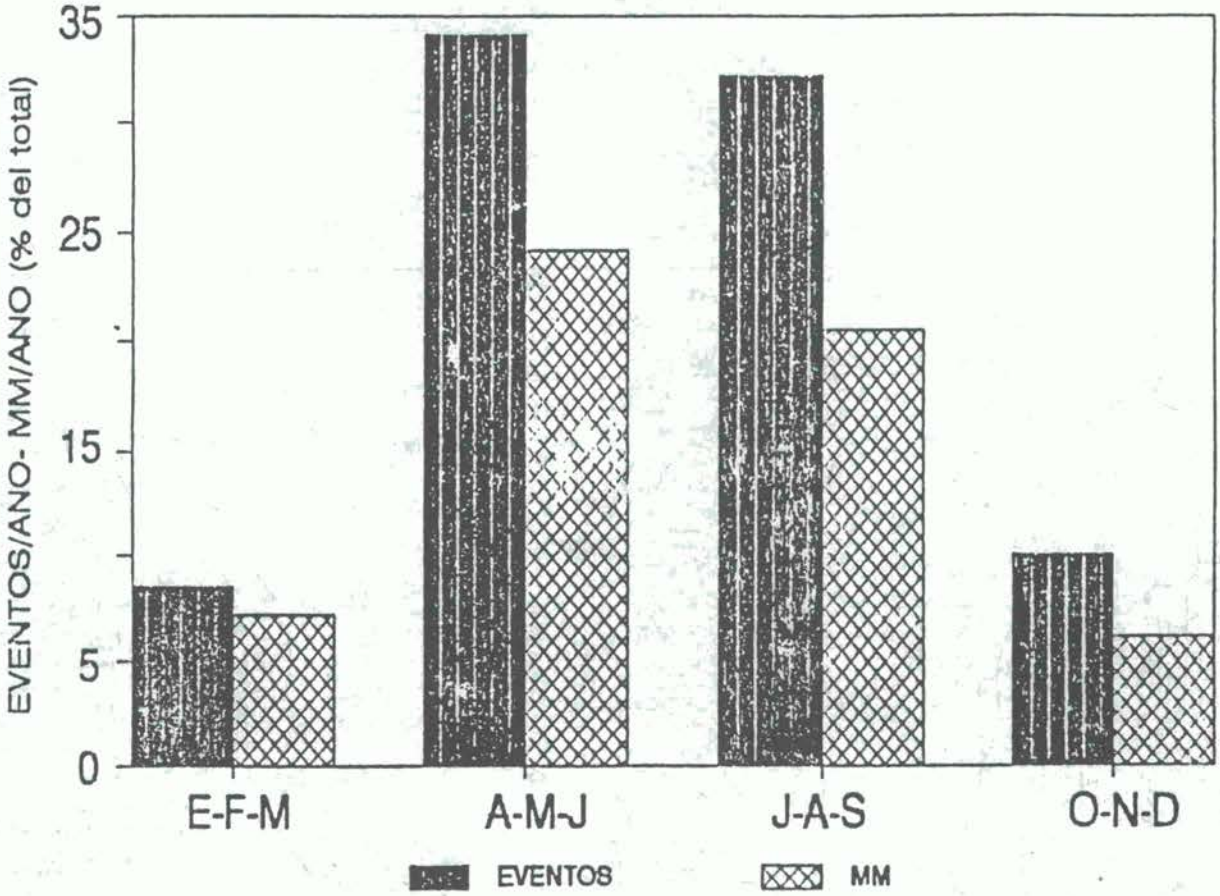
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Figure 2

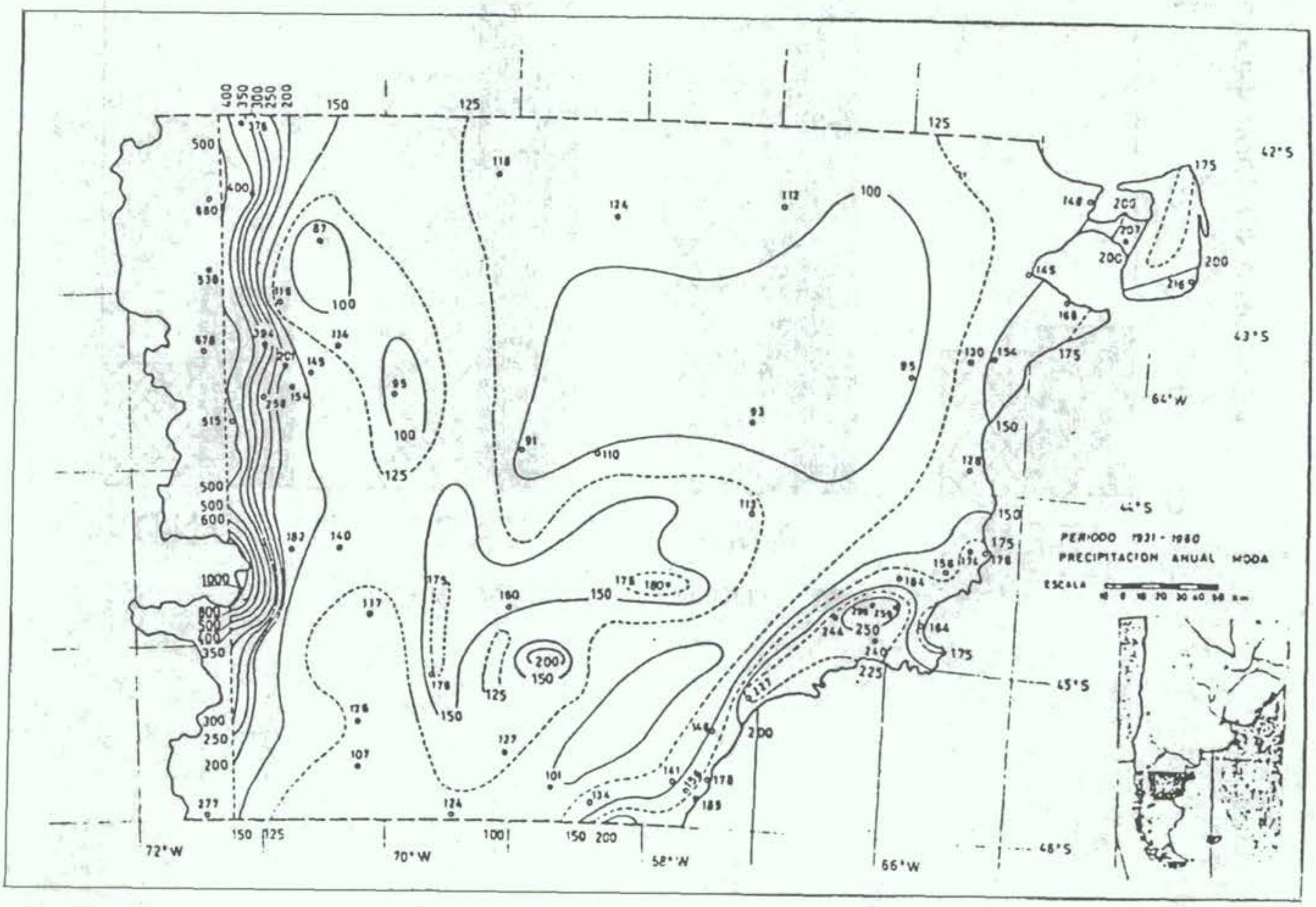
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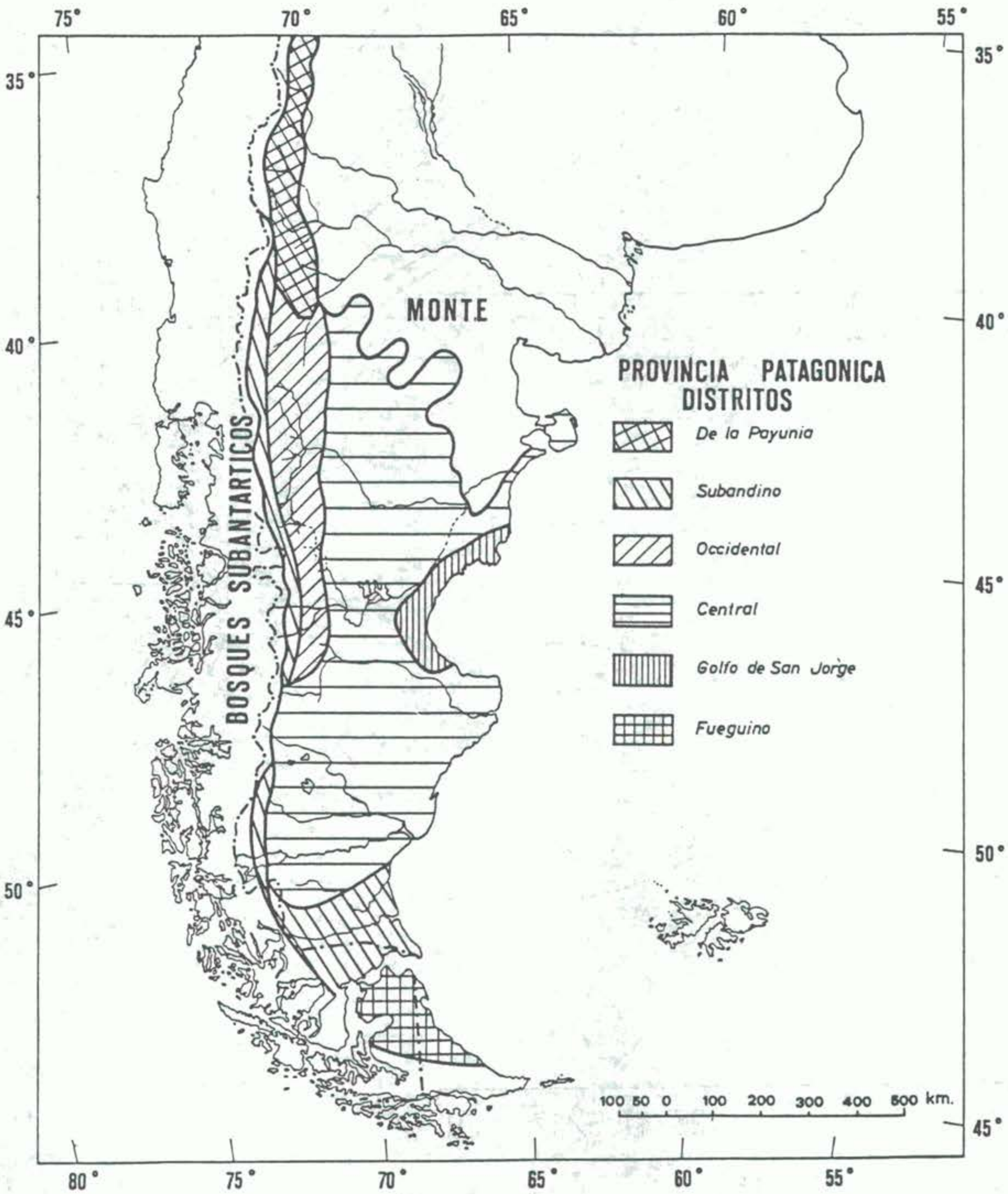
Figure 3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MONTE
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PROVINCIA PATAGONICA
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De la Payunia
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80°
75°
70°
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55°

Figure 4

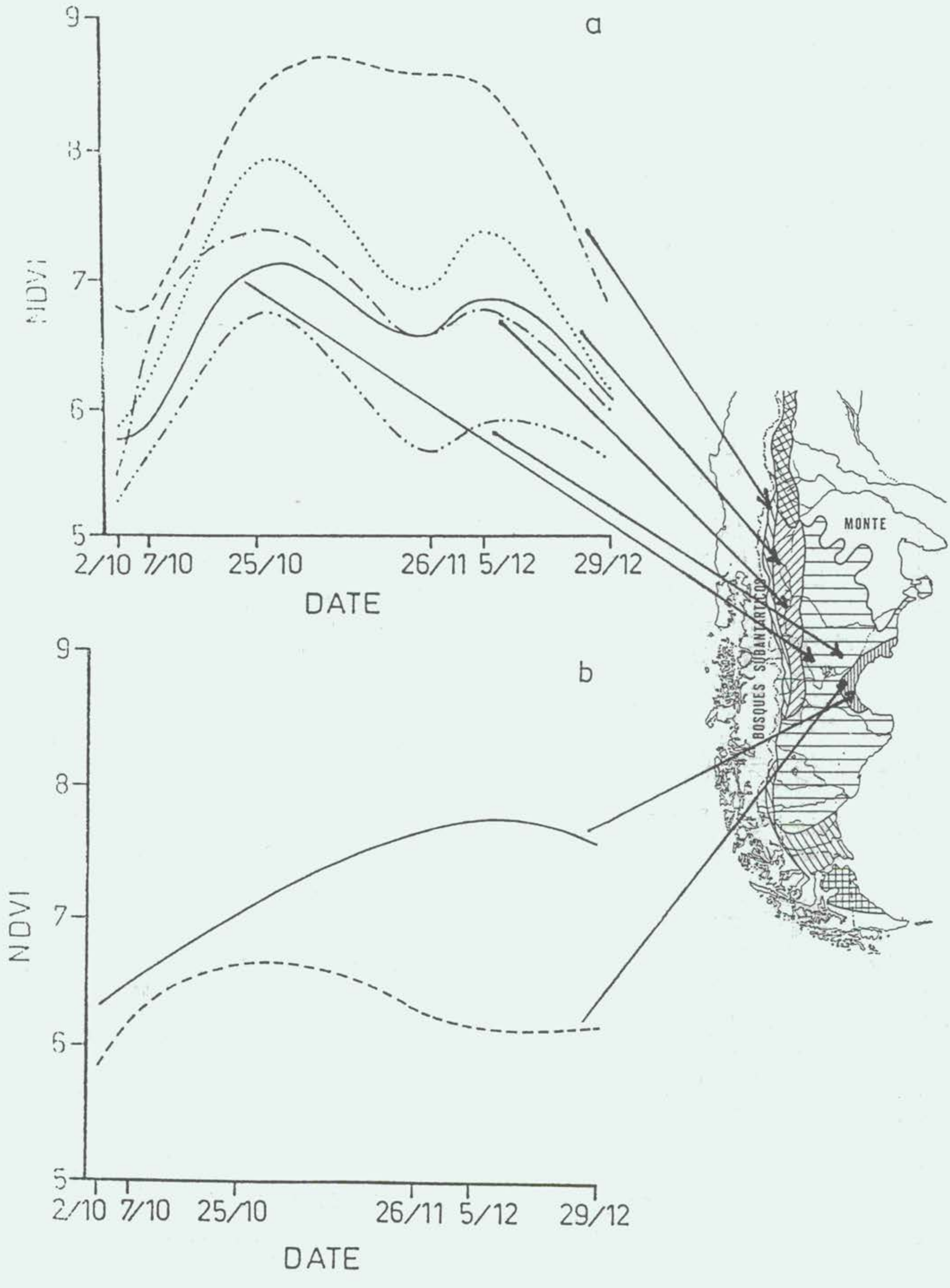
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Figure 5 and 7

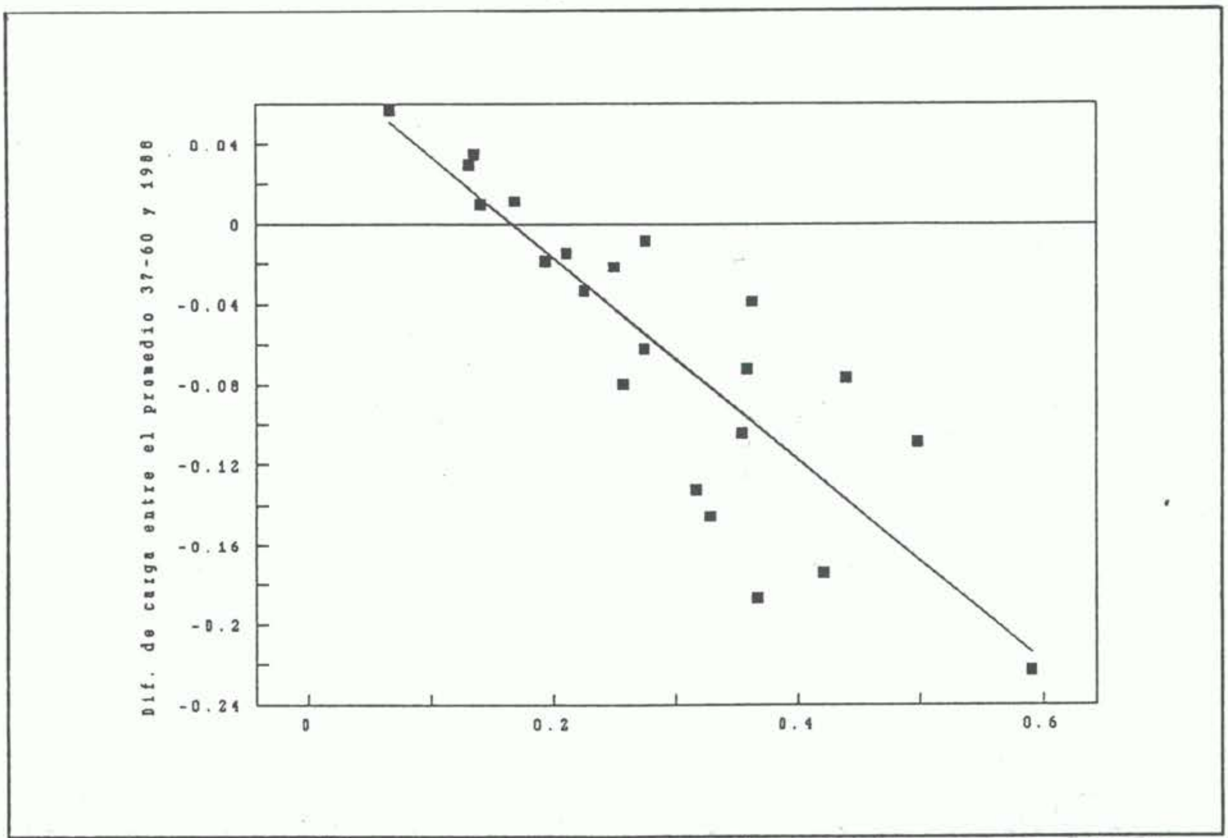
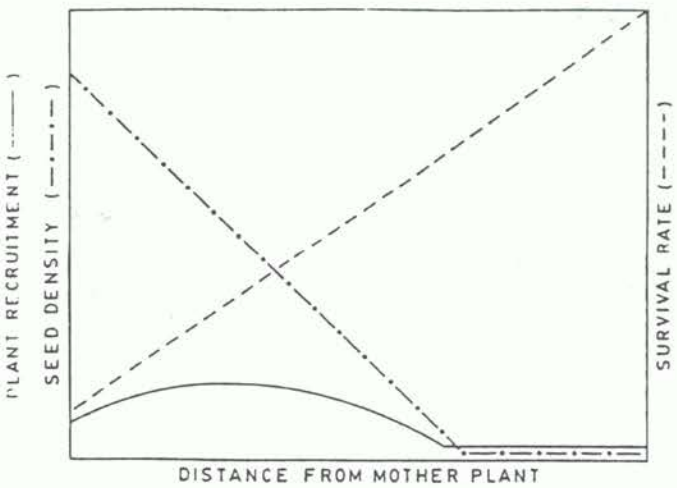


Figura 5 Variación de la carga entre el promedio 37-60 y 1988 en los distintos departamentos de Chubut y Santa Cruz en función de la carga media del departamento.

A. SORIANO AND O.E. SALA Isr. J. Bot.

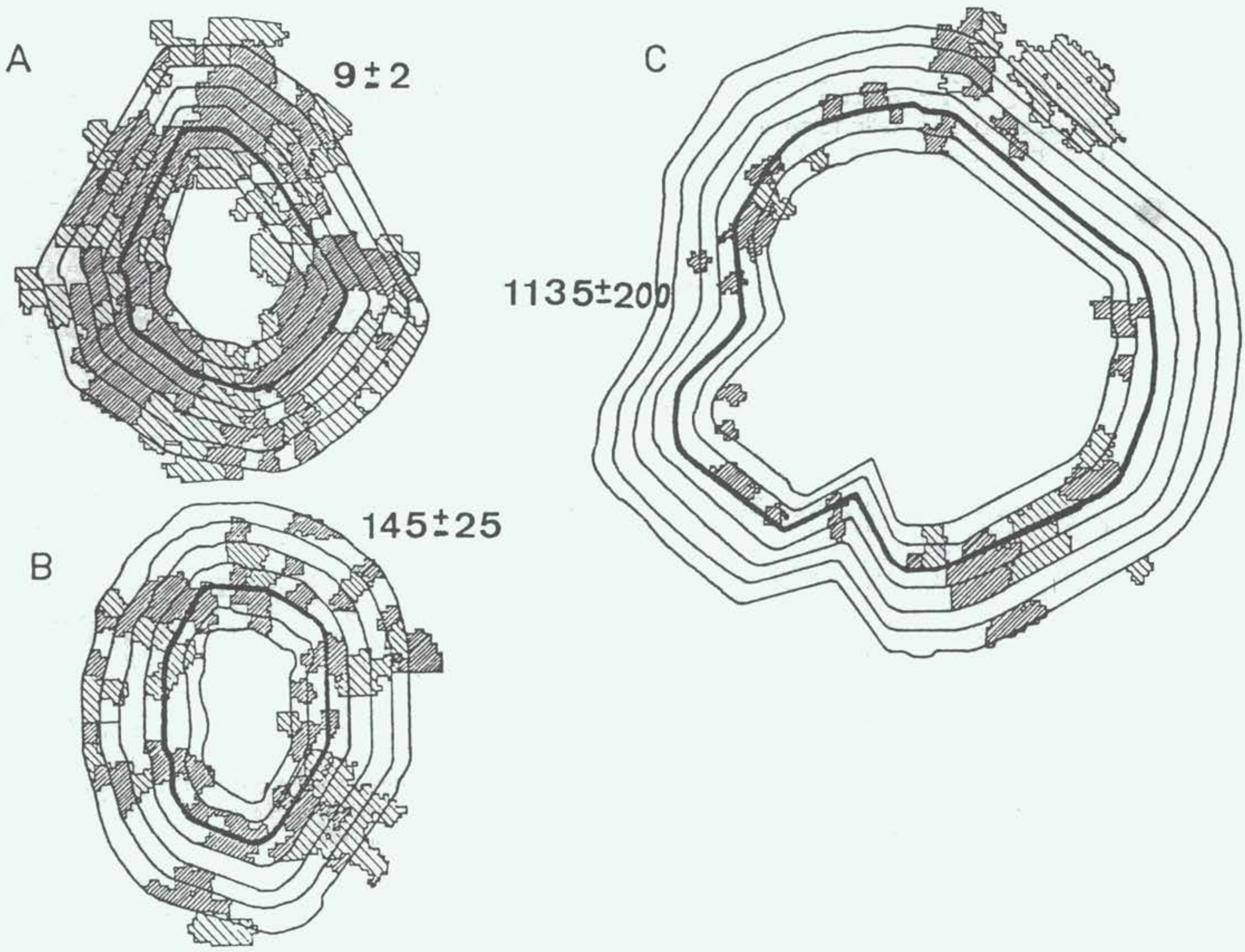


A hypothetical model of plant recruitment as a function of distance from the mother plant. Seedling recruitment is the result of the product of seed density and survival rates. The shape of the seed density and survival curves was suggested by observations and experimental results.

Figure 8

Grass Rings around Shrubs

(Numbers: Fecal pellets/m^2)



EXTENSIVE AGRICULTURAL RESPONSE STRATEGIES: OVERVIEW

(Abstract)

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In terms of trace gas emission and interaction with the atmosphere, the extensive agricultural regions are of less significance than the high rainfall and intensive regions. Because of their extent, however, they do account for a considerable annual flux of CO_2, due particularly to the amount of biomass burned in the more humid regions. It is unlikely, however, that burning results in a net loss of CO_2. It does result in a loss of CH_4 and N_2O, but the quantities of these emissions on a global basis still need to be determined: and the semi-arid regions may well act as a net sink for CH_4 owing to soil uptake. Net change in C storage in the rangelands is primarily a consequence of, firstly, the balance between tree clearing and woody plant encroachment and, second, the decline in soil C under prolonged heavy grazing. In terms of global environmental change the effects of extensive agriculture will exert their most significant influences through changes in the energy balance (resulting from a change increase in albedo) and, perhaps, changes in evapotranspiration through latent heat exchange associated with changes in vegetation structure (roughness).

Management options in the rangelands include clearing woody vegetation, use of fire and varying the number and type of livestock (which requires introducing watering points). For most managers, economic and technological constraints limit the possible response strategies. Three recommendations that would be in line with reducing atmospheric trace gas concentrations are i) reducing grazing pressure where stock levels are such that soil carbon is declining and net primary production has been reduced; ii) halting the clearing of woody plants; iii) where extensive farming includes small-scale cultivation of crops (usually subsistence level), adopting minimal or zero tillage practices. Changing fire regimes (reducing fire frequencies) is also a possibility, but fire as a management tool is governed by other priorities. Adopting these same recommendations would also prevent increases in albedo.

Given the relatively small contribution from the extensive agricultural regions to trace gas emission and climate change, coupled with the very limited range of possible response strategies and the strong constraints on the managers, it is best to concentrate initial efforts on the intensive, high rainfall and irrigated regions. In the rangelands, the priority is to determine how the people living there might be able to cope with the consequences of any future changes in climate and atmospheric composition, rather than how they might prevent them.

DETERMINING THE CLIMATIC REQUIREMENTS OF TREES SUITABLE FOR AGROFORESTRY

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Abstract

After fossil fuel burning, clearing of forests for agriculture is the major factor increasing levels of atmospheric carbon dioxide. Replanting trees on previously cleared land around the world could significantly reduce greenhouse gas emissions. However, forests were usually cleared to grow crops or graze animals, so there is no possibility of completely restoring forests on most cleared lands. There is a need to develop agroforestry systems, which include both agricultural activities and trees.

One of the key problems in developing successful agroforestry systems is identifying which trees can be successfully grown in different areas. This problem will become even greater as tree breeding produces a wider variety of genotypes available for planting. General methods are described to identify where a particular tree (species, provenance or clone) with potential for use in agroforestry systems can be grown. The methods also help to identify locations where particular trees are growing under relatively extreme climatic conditions for that taxa. Conditions at these locations should be carefully evaluated as more reliable future climatic scenarios are developed. In the meantime they could be monitored to provide early warning of the effects of climatic and atmospheric change.

Introduction

Establishing new areas of agroforestry systems could have a modest, but significant, effect on reducing net greenhouse gas emissions. This paper outlines general methods to identify where a particular tree with potential for use in agroforestry systems can be grown. Grevillea robusta A. Cunn. ex R. Br. is the species used to illustrate the methods. Harwood (1989) has noted that it "is used as a agroforestry tree in boundary and row plantings and within cropping areas, where it produces firewood, poles and sawn timber without seriously interfering with adjacent crops. In some countries, G. robusta is used as a shade tree for tea and coffee plantations."

Methods

Estimates of where tree species can be grown are usually initially based on where they grow naturally. As trees are often growing far from the nearest meteorological stations, these estimates have often been unreliable in the past. In the last few years methods have been developed to provide reliable estimates of climatic conditions at natural sites. These methods make use of developments in interpolation techniques, which allow mean climatic conditions to be reliably estimated for locations which are some distance from meteorological stations (Hutchinson et al. 1984). For example, interpolation relationships have been developed by Hutchinson and Busby (pers. comm.) using data from more than 1 000 temperature and more than 14 000 precipitation recording stations in Australia. Given the latitude, longitude and elevation of any site in Australia, mean monthly values of maximum temperature and minimum temperature can be estimated with an error usually well below 0.5^{o}C. Precipitation is more variable, but mean monthly values with an error of less than 10 per cent can be obtained over most of the country.

Using these interpolation relationships Nix, Busby and Hutchinson developed the BIOCLIM program (Busby 1991) which takes in geocoded data (i.e. latitude, longitude and elevation) for specific locations in Australia. It outputs estimates of mean climatic conditions at each location, as well as information summarizing the range of climatic conditions. Data for 25 locations within the natural distribution of G. robusta in the eastern Australia were run through the BIOCLIM program and the following ranges of climatic conditions were obtained:

Mean annual rainfall	720 - 1720 mm
Rainfall regime	Summer
Mean max. temp. hottest month	25.0 - 30.5°C
Mean min. temp. coldest month	2.0 - 8.0°C
Mean annual temperature	14.5 - 20.0°C

This information provides a preliminary estimate of the species climatic requirements. In the case of lesser-known species, which have not been widely tried outside their natural distribution, descriptions such as that given above are extremely useful. However, an analysis of the natural distribution is only the first stage in determining a species' climatic requirements. Many tree species can grow successfully in conditions somewhat different from those within their natural distribution.

It is necessary to examine results from trials outside the natural range to improve the description of a species climatic requirements. In the case of agroforestry species an extremely useful database of information has been compiled by von Carlowitz et al. (1991). Their Multipurpose Tree and Shrub (MPTSYS) Database contains both summary and individual site information for over 1000 multipurpose tree and shrub species suitable for the tropics and sub-tropics.

For example, the entries in the database for G. robusta contained four site specific references from Guatemala, Kenya, Rwanda and Costa Rica. The climatic data from these successful sites, rounded to the nearest 0.5°C or 10 mm, were used to modify the description derived from the natural distribution as follows:

Mean annual rainfall	720 - 2130 mm
Rainfall regime	Summer/Uniform
Mean max. temp. hottest month	25.0 - 31.0°C
Mean min. temp. coldest month	2.0 - 18.0°C
Mean annual temperature	14.5 - 22.0°C

If a species is successful at other sites not included in the database, these results can be used to further modify the description. In many cases the location of a successful site is known, but details of climatic conditions are not available. The ICRAF database contains interpolation relationships for Africa, Asia and Central/South America, which can be used to estimate the mean maximum temperature of the hottest month and the mean minimum of the coldest month for any location. Though the interpolation algorithm is not as good as the spline procedure used by Hutchinson et al. (1984), it does provide very useful first estimates for a large proportion of the world.

In the above example the climatic limits were extended to include successful sites outside the natural range. In some cases the limits will also need to be contracted. For example, Acacia mearnsii grows in plantations around the world in conditions which are considerably wetter and warmer than those under which it grows naturally in Australia (Booth and Jovanovic 1988). The data from the natural distribution provides just a starting point for developing a description of climatic requirements. As more data from successful trials are collected the description becomes increasing dependent on these data and less and less on the natural distribution information. For example, the analysis of A. mearnsii provided data from 60 successful trials, so a description of climatic requirements could be based entirely on these data.

Unfortunately, there is usually very little trial data for agroforestry species. So it is important to check the accuracy of the description of climatic requirements. One very effective way of doing this is to produce maps showing where climatically suitable environments exist (Booth et al. 1989). For example, Figure 1 shows areas of Africa which satisfy the description of climatic requirements of G. robusta developed from analysis of its natural distribution and the data contained in the ICRAF database. Showing numerical descriptions of species requirements to experts seldom produces helpful information, but maps like Figure 1 generally prompt experts to suggest areas which should be included or excluded. The effects of changes to descriptions of climatic requirements can be quickly mapped. The PC-based programs have proved so useful that a series of programs have been produced to examine different regions including Australia, Central/South America, Southeast Asia and Zimbabwe, as well as the whole world (Booth 1990).

Maps, such as Figure 1, show where particular tree species might grow, but they do not suggest how well they might grow. It would be useful to provide at least a semi-quantitative prediction of how well different species or provenances might grow in different areas. A program called GROMAP has been developed for this purpose (Booth 1991a).

Fig.1. Dark-shaded areas are climatically suitable for Grevillea robusta according to description of requirements included in text.

Discussion

This paper has outlined general methods which can begin to indicate the environmental requirements of particular trees suitable for agroforestry systems. In comparison to the dozen or so well-known species which dominate agricultural production, there are a vast number of species with agroforestry potential. The MPTSYS database contains entries for 1093 species, but very little is known of the environmental requirements of these species. Though some may be dropped from future editions of the database, it will become necessary to know the environmental requirements of particular provenances and clones of the more successful species.

For the moment, high priority should be given to developing descriptions of the climatic requirements of the more successful species and provenances. There is little point in using our present tentative descriptions of species climatic requirements, together with unreliable regional climate scenarios, to attempt detailed predictions of future impacts.

Instead, we should use the scenarios together with the climatic analysis methods outlined here to identify particularly hot and/or dry locations, which are likely to be further stressed by future climatic environments (Booth 1991b). Selected locations should be monitored to provide early warning of environmental changes. Such monitoring will be particularly important with trees. It is not practical to carry out increased ambient CO_2 experiments either in the field or in phytotrons for the hundreds of tree species used in agroforestry systems. Unless some breakthrough is made in relating seedling response to the growth of mature trees, careful monitoring will provide the best indication of the impacts of changing environmental conditions.

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AN OVERVIEW OF THE AGRICULTUTAL SYSTEMS IN ZIMBABWE AND STRATEGIES FOR MONITORING THEIR EFFECTS ON THE ENVIRONMENT.

(Abstract)

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Zimbabwe has five Agro-ecological Zones, generally termed Natural Regions I-V. Natural regions I-III are basically suitable for intensive crop production, while Natural regions IV-V are for extensive agricultural development. However for historical reasons about 80% of the population lives on Natural regions IV and V. This disparity in land distribution has resulted in the development of a dual agriculture system - the Large Scale Commercial Farms and the Small Scale Farms. The small scale farms are located in regions IV and V. About 5500 large scale commercial farms occupy farms of an average of 2200 ha while some 6 million people occupy small scale farms of about 10-12 ha in size. This has meant pressure on the marginal areas and development may be in the wrong places, such as cultivation on steep slopes or using inappropriate techniques such as deep ploughing on fragile soils or simply becoming insensitive to environmental factors. Such environmental insensitivity has resulted in the extensive devegetation of Zimbabwe, soil loss due to erosion and actual reduction in food production in the country.

It is against this background that it has become imperative that monitoring techniques that are reliable be used in order to be able to plan appropriately the most environmentally sound land use practices in Zimbabwe. Remote sensing and geographic information systems have now been introduced in most development institutions in the country.

POLISH FOREST ECOSYSTEM CO2 BALANCE AS INFLUENCED BY CHANGING ECONOMICAL SYSTEM OF THE COUNTRY

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ABSTRACT

An inventory of CO_2 sources and sinks was made for forest ecosystem in Poland. The inventory was based on governmental data on commercial wood production, use and forest fires. These data were recalculated to obtain whole tree biomass results.

Such an inventory was repeated for basic years 1988 and 1990. A trend of increasing CO_2 fixation as well in absolute values as per annum rates was found.

The trend is related to changing economical system of the country, i.e. the switch from communism to free market economy. The economical crisis and increasing price of timber decreased demand for it resulting in lower cuttings. On the other hand, an apparent food overproduction caused worse economical conditions for farmers resulting in more abandoned arable land subjected to reforestation and secondary succession.

Introduction

Last three years have remarkably differed from previous about fifty years in the Eastern Europe. Decay of communism and emergence of new political and economical system created new options and limitations to the environment. Greenhouse gases balance is among many affected. An inventory of these gases sources and sinks in Polish forest ecosystem was prepared for a basic year 1988 and repeated for a year 1990. The year 1988 is (at least for Poland) the last year of communistic system while the year 1990 is the second year of new economical system. Thus, results of these inventories may reflect the influence of political and economical change on greenhouse gases emission and absorption by Polish forest ecosystem.

Method

A general assumption applied in this paper is that an idea of stationary state is applicable to Polish forestry at least in the period of one year. Thus, all processes discussed herein are represented by means of differences between their intensities in the beginning and the end of a year. these differences may be equal to zero for cyclic processes.

The assumption of stationary state is applicable if a stable forest economy is hold and there is no natural or caused by people large disasters of duration shorter than one year. this is valid for Poland in 1988 and in 1990.

The analysis in this paper is confined to carbon dioxide released or absorbed in biological processes only. Other greenhouse gases (perhaps except methane) are produced in negligible quantities due to rather extensive nature of Polish forestry.

Numerical data

This paper applies data published by the Central Board of State Forests (Anonymous 1989a), the Bureau of Forest Inventory and Forest Economy

(Anonymous 1989b), Central Bureau of Statistics (Anonymous 1989c, 1991a,b) (see Table 1).

Data concerning wood increment were expressed in volume of commercial wood with no consideration of other biomass of tree, eg. foliage, small branches and roots. Correction coefficients (calculated according to Vyskot's (1983) data for coniferous forests and Ellenberg's (1971) data for deciduous forests) were applied to calculate total production and decay (ie. CO_2 accumulation and emission) in forest ecosystems.

An estimation of CO_2 emission resulted from natural processes of consumption and destruction in forest ecosystems was avoided by decreasing the primary absorption of the ecosystems to their net absorption as approximated by wood volume increment. On the other hand, CO_2 emission from after-logging tree biomass decay was calculated separately.

Results

- A balance of absorption and emission of CO_2 in forest ecosystems.

This study confines to main CO_2 fluxes and storage processes, namely:

Sinks of CO_2 (absorption):
1.Increment of biomass resulted from primary net production of ecosystem

Sources of CO_2 emission:
1. decay of biomass destructed during logging process
2. Biomass burned during forest fires and decayed after forest fires; usage (besides forestry) of fire wood and match wood

Balance equation $$\frac{dMCO_2}{dt} = A - E$$

where:

M CO2	-	amount CO_2 accumulated in forest ecosystem
t	-	time
A	-	absorption of CO_2 by forest ecosystem
E	-	emission of CO_2 by forest ecosystem

Absorption and emission terms were obtained by recalculating wood biomass into CO2 equivalents (detailed calculations are not shown here). The following coefficients were used:

p - carbon density in m^3 of wood (Larcher 1975)
a - coefficient converting C to CO_2 (Larcher 1975)

Results are shown in Tables 4,5 and 6.

Discussion
Last three years (1988 - 1990) were remarkable in Eastern Europe because of substantial political and economical changes. The political changes are not discussed here and some statistical indicators of economical changes in Poland are shown in Table 7.

Polish economy suffers crisis causing about 15% decrease in national product, investments and electricity production. The decrease should affect CO_2 production by Poland. No precise data are available at this moment but one can guess that Poland produces now about 10-15% CO_2 less than three years ago.

The crisis in agriculture may be expressed by about 8% decrease in production and about 40% decrease in real incomes from agriculture. The last feature causes a general trend to abandon marginal lands. The abandoned marginal lands are subjected to secondary succession. Thus, CO_2 absorption increase with increasing area covered with bushes and woods.

Decreasing people's real incomes (about 40%) caused a decreasing internal demand for timber while making Polish currency internally convertible increased export offer prices for timber and decreased purchases. These changes resulted in a 22.4% decrease of large wood logged and 17.7% increase of forest wood resources.

All the above mentioned changes affected CO_2 balance of the forest ecosystems. Emission was reduced by 10.3% while absorption was increased by 3.7%. The balance absorption was increased by 12%. These changes resulted mainly form substantial (by 13%) decrease of CO_2 release form logging residues.

The release is a main factor involved in CO_2 production by Polish forest ecosystem and constitutes 86.1% and 82.5% of the whole CO_2 emission in 1988 and 1990, respectively. On the other hand, forest fires are responsible only for about 2% of the emission for both years.

The efficiency (per unit area) of net CO_2 accumulation increased by 11.5% during the covered here period while CO_2 retention in forest trees increased by 17.7%.

The above shown tendencies of improving the CO_2 balance of Poland seem to be caused (at least until now) by an economical play alone. However, some processes (eg. afforestation of abandoned land) need more active government control while others (ie. implementation of more environmental friendly techniques) need more substantial investments to make the improvement permanent. The international interest and advise related to economical and environmental changes resulted from the unusual experiment on the whole country scale may enable Poland to contribute better to the global greenhouse gases balance improvement.

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Table 1.
Entry data for calculations in this paper.

Symbol	Description	Unit	Value for year 1988	1990
Sc	total area of coniferous ecosystems	1000ha	6990	6789
Sd	total area of deciduous ecosystems	1000ha	1781	1904
Sp	total area of forest fires	1000ha	3	5
AGc	average annual increment of large timber in coniferous forests	$m^3/ha/a$	3.50	3.50
AGd	average annual increment of large timber in deciduous forests	$m^3/ha/a$	3.44	3.44
Pc	coniferous large timber logged	$1000m^3$	17698	13774
Pd	deciduous large timber logged	$1000m^3$	4997	3843
W	large wood resources in forest ecosystems	$1000000m^3$	1238	1457
F	fire wood volume	$1000m^3$	2434	2642
M	match wood volume	$1000m^3$	32	16

Table 2.
Original data published by Vyskot (1983) for Scots pine stand (age 26 years) and correction coefficients. Wood resources data expressed in Mg (dry weight)/ha and wood increment data expressed in Mg (dry weight)/ha/a.

	Orig. data	Correction coefficients	Symbol
Needles	5.325	0.092	a(1)
Large timber	57.886	1.0	a(2)
Other above ground biomass	27.974	0.483	a(3)
Total above ground biomass	91.185	1.575	a(4)
Roots estimation	13.914	0.240	a(5)
Total biomass	1.5.099	a.816	a(6)
Net annual increment Mg dw/ha/a			
Large timber	2.226	1.0	a(7)
Other above ground biomass	1.006	0.452	a(8)
Total above ground biomass	3.232	1.452	a(9)
Roots estimation	0.474	0.213	a(10)
Total biomass	3.706	1.665	a(11)

Table 3.

Original data published by Ellenberg (1971) for Scots pine stand (age 26 years) and correction coefficients. Wood resources data expressed in Mg (dry weight)/ha and wood increment data expressed in Mg (dry weight)/ha/a.

	Orig data	Correction coefficients	Symbol
Foliage	3.2	0.031	b(1)
Large timber	102.9	1.0	b(2)
Other above ground biomass	52.2	0.507	b(3)
Total above ground biomass	158.3	1.538	b(4)
Roots estimation	24.0	0.233	b(5)
Total biomass	182.3	1.772	b(6)
Net annual increment Mg dw/ha/a			
Foliage	3.33	0.464	b(7)
Large timber	7.17	1.0	b(8)
Other above ground biomass	2.14	0.299	b(9)
Total above ground biomass	12.64	1.763	b(10)
Permanent above ground biomass	9,31	1.299	b(11)
Roots estimation	1.26	0.176	b(12)
Total biomass	13.90	1.939	b(13)
Permanent total biomass	10.57	1.475	b(14)

Table 4.

Annual net accumulation of CO2 by trees in Polish forest ecosystems (ie. the annual increment of tree biomass expressed in CO_2 equivalents - ΔB_{CO2}) as divided among various parts of these ecosystems. Data are expressed in 1000 Mg CO_2/a.

	Above ground		Below ground	
Ecosystem/Year	1988	1990	1988	1990
Coniferous ecosystems	23536	25500	3467	3597
Deciduous ecosystems	5373	5569	728	754
All forest ecosystems	29009	30069	4195	4351

Table 5.
The annual net emission of CO_2 from Polish forest ecosystem. Data expressed in 1000 Mg CO_2/a

Source/Year	1988	1990
Emission from logging residues of coniferous forests	9892	8226
Emission from logging residues of deciduous forests	1235	1434
Total emission from logging residues	11127	9660
Emission from forest fires and after fire decay of biomass	131	257
Emission from burning fire/match wood	1665	1794
Total emission	12923	11711

Table 6.
Annual balance of CO_2 emission and absorption in Polish forest ecosystems in years 1988 and 1990. Data are expressed in 1000 Mg CO_2/a.

Process/Year	1988	1990
Absorption	33204	34420
Emission	12923	11711
Balance net annual absorption	20281	22709

Table 7.
Selected data on economical circumstances in Poland for year 1988 and 1990. The numbers are relative. It is assumed that each value for the year 1988 is equal to 100.

	Year	
Feature/Year	1988	1990
Population	100	100.8
Gross national product	100	84.9
Investments	100	87.7
Electricity consumption	100	86.3
Agricultural production	100	91.9
Consumer prices	100	3007.7
Average salary	100	1765.7
Real incomes in agriculture	100	56.8
Real incomes besides agriculture	100	58.7

ON THE RESPONSE STRATEGIES TO CLIMATE CHANGE IN AGRICULTURE IN VIETNAM

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Main Considerations
In [1] the authors have made an assessment of the potential climate change in Viet Nam. The study projects a number of potential changes in Viet Nam's climate from 1990-2010:

- A possible increase in the frequency or intensity of typhoons
- A likely increase in monthly summer temperatures
- A potential increase of both droughts and floods in a great number of districts.

The climate of Viet Nam is monsoonal and tropical, and is influenced by three centers of action:

- The Siberian center
- The North Pacific center
- The Bangal sea center,

therefore

- The time variation of the climatic factors is disturbed by many quasi-periods (3 years, 5 years, 12 years etc ...) and random fluctuations,
- It is difficult to identify the correlation between the temperature and the rainfall.

In this study we focus on the assessment of the trend of the winter season temperature and the possible changes of the rainy season.

Assessment of the Trend in the Winter Season Temperature
For this purpose we have used the

- Time series of the monthly temperature of January and February.
- Time series of the running mean (running period : 5 to 10 years) of the winter season temperature (mean of January and February) of the three climatic stations

  LANG SON 21° 50' N, 106° 46' E
  CAO BANG 22° 39' N, 106° 14' E
  HANOI 21° 01' N, 105° 51' E

The results are displayed in Fig. 1a,b,c.

We note that,

- In general the variations of the January temperature and February temperature are not in phase, that is to say if the January is cold the February is warm, and the contrary is true. However, from 1978 to 1990 the process of the variation of January temperature and February temperature shows an in phase behavior.

- It is likely that from the time series of the data we may see the quasi period of fluctuation of 3-4 years, 12-13 years. In order to eliminate these quasi-periods we have calculated the running means with running periods 5 and 10 years of the mean temperatures of the January and February for the assessment of the trend variation of the winter season temperature.

We fitted the linear variation to these running mean time series:

$$Y = Ai + b$$

Y :Running mean temperature of January and February corresponding to running periods k = 5, 10 years

i : Order of the years

The results showed that

1. HANOI
   $k = 5$ $Y = 0.0194i + 13.1714$ $(r= 0.3514)$
   $k = 10$ $Y = 0.0201i + 13.1470$ $(r = 0.5330)$

2. LANG SON
   $k = 5$ $Y = 0.0227i + 9.1875$ $(r= 0.3945)$
   $K = 10$ $Y = 0.0240i + 9.1641$ $(r = 0.5671)$

3. CAO BANG
   $k = 5$ $Y = 0.0318i + 9.1448$ $(r= 0.5134)$
   $k = 10$ $Y = 0.0410i + 8.5961$ $(r = 0.7615)$

The warming rate of 0.2° C - 0.3° C / 10 years is in accordance with that of the Scenario A.

Assessment of the Change of Rainy Season Lengths
The shortening or the lengthening of the rainy seasons has a serious impact on the rice cropping.

According to [2], we defined the decade with forward accumulation of the 200 mm of rainfall as the decade of the onset of the rainy season and the decade with backward accumulation of 300 mm of rainfall as the decade of the end of the rainy season.

We may calculate the lengths of the rainy seasons for two stations

1. HANOI
   Mean length of the rainy season : 13.8 decades
   Standard deviation from mean : 0.99 decade

2. SOC TRANG (09° 36' N, 105° 58" E)
   Mean length of the rainy season : 14.3 decades
   Standard deviation from the mean : 0.50 decade

We see that there are no obvious change in the length of the rainy season. However, the activities of the typhoon, the dry/wet spells during the summer monsoon season are still worthy to investigate in the following years.

Response Strategies in Agriculture

From the above assessments, the study projects the response strategies in the following domains :

- The northward shift of the line of demarcation between the tropical and subtropical climatic zones.

- The response strategies in agriculture planning and in improving of the cropping systems to adapt to the possible changes.

Fig.2 represents the geographical distribution of the mean temperature of the January. We can distinctly separate 4 zones:

Zone 1 : Mountainous	:$T < 12°C$
Zone 2 : Hills and small plains	:$12°C < T < 14°C$
Zone 3 : Coastal and delta	:$14°C < T < 16°C$
Zone 4 : Coastal and small plains	:$T > 16°C$

For each of the above zones we propose the following recommendations in order to adapt or to mitigate the possible climate changes

Zone 1 :

- For the plants having a wide ecological range as : maize, soybean, tea, sorghum, eucalyptus, no problem in planning of the cultivation.
- Due to the potential warming for the fruit trees originated from subtropical climatic zone as : apple, apricot, mandarin, orange, etc ..., we need choose the species in order to improve the quality of the fruits.
- For the medicinal plants, the subtropical vegetables, the warming may effect on quality of the product.
- Climatic conditions may be appropriate for the coffee plants.

Zone 2 and Zone 3 :

- Development of the plantation of coffee is possible.
- For the rice cultivation, due to the warming, we ought to survey the fast elongation of the rice plant tube during the winter-spring rice crop.
- Potential development of the silk-worm, subtropical vegetables.

Zone 4 :

- Extension of the cultivation of the tropical crops : peanuts, sesames, sweet potatoes, mungbean, blackbean etc ...

To mitigate the impacts of the climate change in agriculture, we must undertake the investigations on :

- Modification and improvement of the present crop systems.
- Selecting efficient species.
- Development of the various patterns of the rotating, intercalating, overlapping cropping technique.

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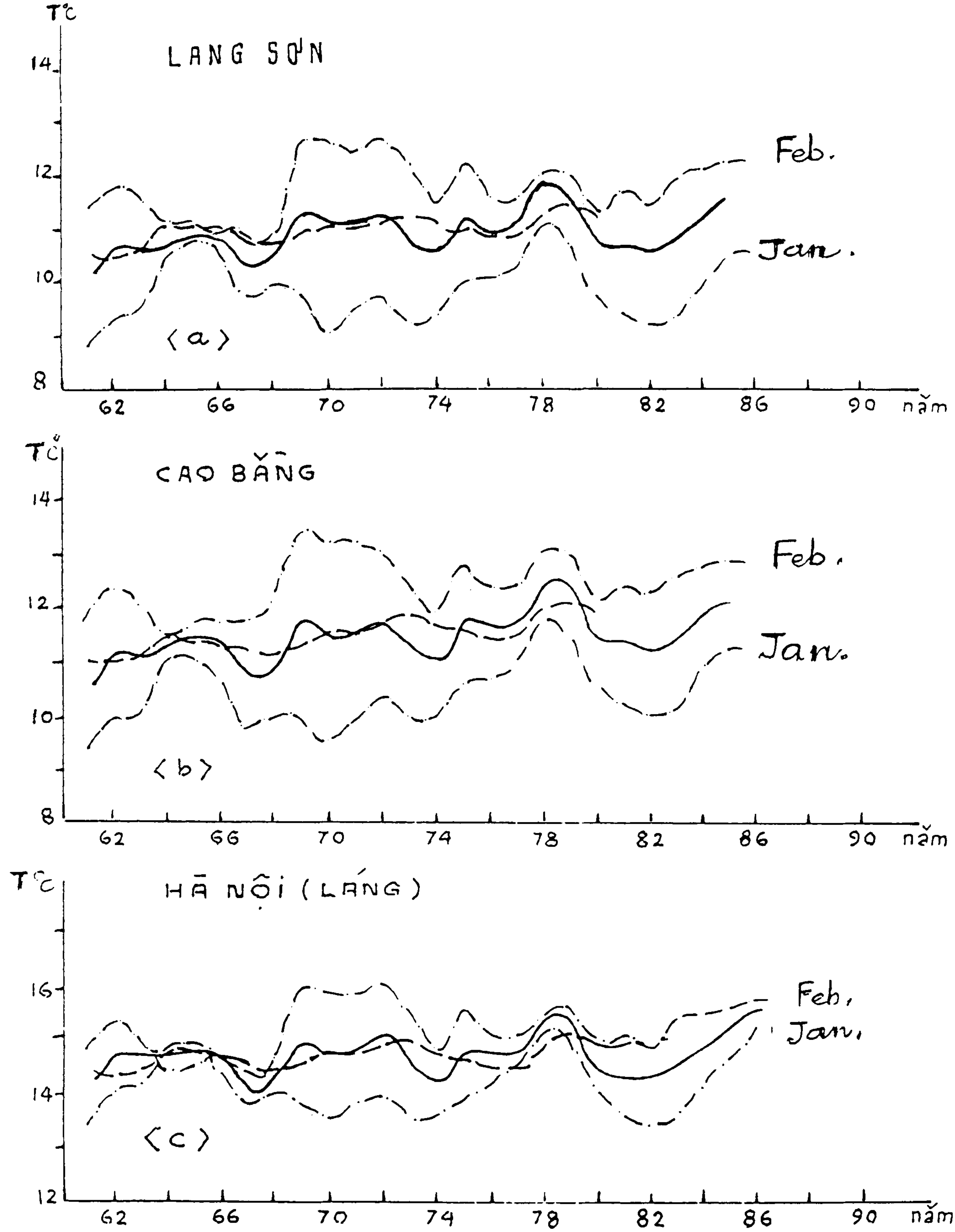

Fig 1a, b, c: Monthly temperature of Jan and Feb
Running mean of the winter season temperature
(mean of Jan + Feb)

_ _ _ _ _ _ _ Running period k=5

-------------- Running period k=10

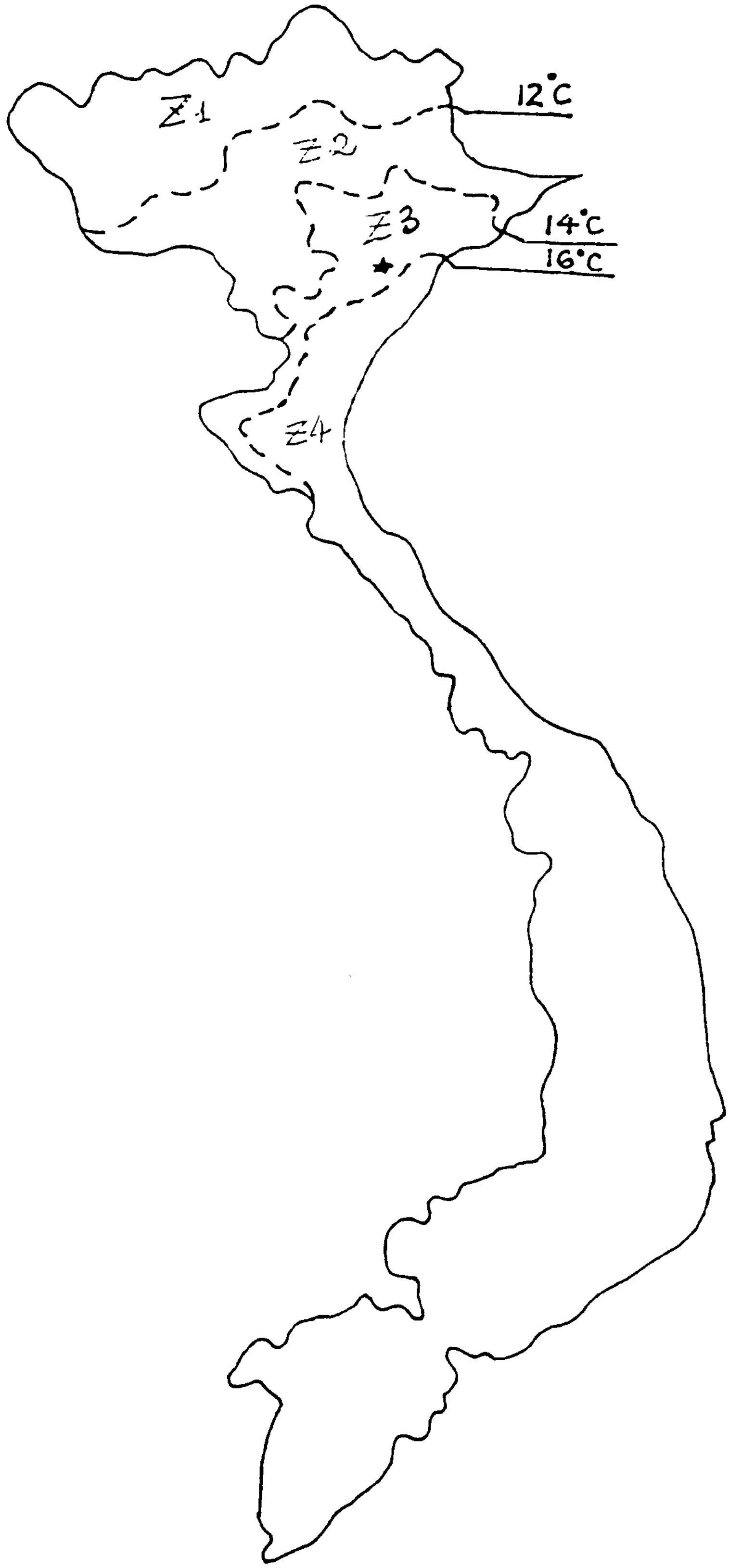

Fig.2: Geographical distribution of monthly temperature of Jan

ECOLOGICALLY SUSTAINABLE DEVELOPMENT AND FORESTRY: AN AUSTRALIAN PERSPECTIVE

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ABSTRACT

Sustainable forest use implies optimising the tangible and intangible social and economic benefits which forests can provide to the community, with the goals of maintaining the functional basis of forested land, biodiversity, and the options available for future generations. This requires policies and land-use decision-making based on an understanding of ecosystems, consideration of all forest values and the removal of institutional, structural and cultural impediments. Conflict resolution procedures are necessary to minimise adverse impacts on different users.

Use of Australian forests has resulted in less degradation than other land uses. There have been no known extinctions of Australian native flora and vertebrate fauna as a result of timber harvesting. Significant improvements in timber management have taken place in the last twenty years, but sustainability may not yet have been achieved.

The Resource Assessment Commission is developing a number of scenarios for the future directions for use of Australia's forests. A set of objectives which need to be followed in choosing a scenario for achieving ecologically sustainable forest use are reviewed and discussed.

Introduction

Sustainable forest use implies optimising the tangible and intangible social and economic benefits that forests can provide to the community whilst maintaining, and where-ever possible improving, the ecological functions, option values, bequest and existence values associated with most forests. This requires policies and land-use decisions based upon an understanding of ecosystems, the consideration of all forest values, recognition of the interdependence of the forest and other sectors and other ecosystems and, also, the removal of institutional, structural and cultural impediments to change.

History and present status

Generally, Australia's forests are characterised by much less degradation than other land uses. No extinctions of Australian native flora and vertebrate fauna as a result of timber harvesting are known. Significant improvements in timber management have taken place in the last 20 years but the industry may not yet be operating within harvest rates that are less than the regeneration rate.

In many ways it is inappropriate to talk about Australia's forests in isolation from the rest of the world, other ecosystems and other parts of the global economy: as part of the global commons, all systems are interlinked and interdependent. The issue is really about the most appropriate form of land use and development at the local, regional, national and international level. By its nature agriculture, for example, has generally been far more intrusive on many ecosystem processes and functions than forestry, but public attention is more heavily focussed on the impact of the timber industry (Australia 1991). This reflects increased community concern for environmental quality and, in particular, on the non-market value of native forests. While these are not easily quantified, it is clear that there has been a shift in community attitudes.

Climate change

The prospect of climate change adds another dimension to the management of Australia's forests and its wood industry. There is a need to allocate wood harvesting rights; design conservation systems; and control forest clearing and the establishment of plantations in a way that can adapt to new rainfall and temperature regimes. At the regional level, we are still almost totally ignorant about the nature of changes which could occur.

Ecologically sustainable development

Australia has just completed a major review of future policy directions necessary to promote ecologically sustainable development. There is a considerable difference between the term ecologically sustainable development and the more general term, sustainable development.

As a working definition, Australia's recent working group on the ecologically sustainable development of Australia's forests considered that "*ecologically sustainable forest use implies optimising the tangible and intangible social and economic benefits which forests can provide to the community, with the goals of maintaining the functional basis of forested land, biodiversity and the options available for future generations*".

Major issues

Australian woodland and forest policies are in a transitionary phase that is forcing the nation to grapple with a host of complementary and conflicting situations. Of all the issues, two stand out above the rest. The *first*, is the question of how to identify which forests should be periodically harvested and which forests need to be protected from harvesting, clearing and other exploitative land uses. This question applies to forests that are state-owned and, those that are managed privately under a variety of freehold and leasehold titles.

One of the biggest problems in forest conservation is that we still do not have cost-effective methods of valuing biodiversity and, in many cases, still find it very difficult to estimate the impact of changes in biodiversity on ecosystem processes and functions.

The *second* issue relates to the most appropriate way to develop Australia's wood harvesting and processing industry. Questions here relate to the long-term impacts of different harvesting strategies on biodiversity values and possible trade-offs with timber production objectives.

Strategic directions

Australian forest policy is in a transitionary phase. Usefully, the Resource Assessment Commission (1991) in its "Forest and Timber Inquiry Draft Report" has put forward a set of five possible scenarios that could be developed into a national forest strategy. They range on a continuum from the total cessation of all logging within Australia's remaining native forests through to one where an attempt is made to maximise timber production from native and plantation forests. The scenarios are

1. total reliance upon plantations for all timber production and no further logging of native forests;

2. heavy reliance upon plantations but some highly selective logging still permitted within native forests;

3. status quo;

4. no increase in the areas reserved for conservation purposes, coupled with an attempt to make the wood harvesting and processing industry as efficient as possible and a substantial increase in the area under softwood and hardwood plantations; and

5. 85% of the total forest area is logged, there is rapid growth in hardwood plantations, and intensive forest management is phased in.

The full implications of these scenarios are still being explored. Neither the first, nor the last scenario are considered appropriate and their purpose is to illuminate the boundaries between the central three scenarios. The thrust of the Ecologically Sustainable Development Forest Use Working Group recommendations suggest that the most likely scenario is one that mixes the second and the fourth strategies in a way that, whilst maintaining ecological functions and processes, seeks to maximise net market and non-market resource values and returns to the community.

Future challenges

Recognising that the stage is not yet set and that most land-use decisions are made at the state rather than the federal level, the challenge now before Australia and indeed the international community is to ensure that any policy initiatives encourage transition in sustainable directions.

Science and technology

Forest ecosystems are complex and both the available information base and our understanding of it are far from complete. We are still struggling to develop the technologies necessary to estimate sustainable yields.

There is also a need for much more effective monitoring and assessment techniques. We are beginning to explore the implications of developing highly "managed" forests which, using sophisticated silvicultural practices, aim to increase yield without depreciating the ecological capacity of the forest ecosystems. Hardwood plantations are another area where there is much more need for research and development.

Institutional arrangements
Conflict resolution arrangements are poorly developed and the social technologies necessary to achieve these objectives are still in their infancy. One approach is to develop plans that are optimal from viewpoints of different stakeholders and then couple computerised decision support system with standard mediation procedures to derive a final balanced plan. SIRO-MED offers one such methodology and it has been our experience that the resultant plan is much more consistent with sustainability goals than those derived by conventional processes.

There is also the need to recognise that, as yet, we have a very incomplete understanding and inventory of our forest and that the prospect of climate change is a reality. Moreover, shifts in the values that communities assign to forests must be expected. Thus, with attention to equity considerations and investment incentives, decisions about forests will have to be reviewed periodically.

Another challenge is to develop much more effective systems of accounting for the way we use and conserve resources. The evidence available so far suggests that such natural resource accounting systems will need to use economic and ecological modelling techniques to fill in the many data gaps that exist and then present the data in an integrated spatial and temporal framework that can be linked to the conventional models used for policy analysis.

Policy instrument choice
Assuming that land-use planning mechanisms will be used to identify the most appropriate way to distribute and redistribute forest and agricultural land into a variety of permitted uses, there is considerable opportunity to introduce a much stronger market-orientation to forest management. Possibilities include the more complete specification of rights so that licences become fully mortgageable and transferable.

Attention also needs to be given to the development of licence systems that encourage silviculture and logging practices that enhance biodiversity and other non-market values.

International considerations
While this paper has concentrated on national issues, there is also a set of international arrangements that require careful attention. Two areas are particularly important. *First*, there is an urgent need for the removal of the many production subsidies and tariff policies that reduce the opportunity for countries to compete with one another. Countries that use selective tariff barriers and subsidies deny everyone the investment opportunities necessary to take pressure off many of the world's most precious natural resources. Tariff barriers for furniture but not unprocessed timber, for example, prevent countries from value adding and change the logging systems that they use.

Second, there is a need to organise international trading arrangements and resource-related agreements which prevent countries from exporting sustainability problems to other nations less fortunate than themselves and which encourage environmental improvement across the global common. Amongst other things this will require developed countries like Australia, to provide market incentives for countries to improve resource management at home.

Concluding comment

Finally, and perhaps of most importance, it must be recognised that in most areas of forest policy we still work with value judgements. Until there is a dramatic improvement in natural resource accounting methodologies and the research is done to enable us to predict the impacts of different silvicultural strategies on wood yield and forest-ecosystem processes with much greater confidence, it will neither be possible to place absolute values on the wilderness or aesthetic characteristics of forests, nor their potential to yield timber.

At some stage in the future, objective techniques of placing value weightings that account for social, equity, and cultural considerations may emerge along with models that enable us to predict timber yields with a high degree of confidence. In the interim, however, we will need to recognise that many individuals and interest groups will make different judgements about the status and value of the same resource.

Recognising this, it is critical that such decisions are made with the best available advice, that all stakeholders have an opportunity to express their views, and that the ecological constraints to forest resource use and investment are recognised. Ultimately, the decision, possibly aided by conflict resolution mechanisms, will have to be a political decision.

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SUSTAINABLE DEVELOPMENT AND AGRICULTURE/FORESTRY IN EUROPE

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ABSTRACT

Agricultural production in Europe is characterised by a high level of intensity, with regional differences due to the climatic conditions. The efficiency of the input factors is markably higher in western Europe than in comparable regions in the Eastern countries. In western Germany for example the yields of the main crops were higher than in the former GDR although the input of fertilizer were the same.

To reduce the intensity of production and the pollution of the environment various measures were adopted in the past. They covered improvements of the advice of farmers and governmental regulations as well as support of extensification measures and the price policy of the EC. The effect in general has only been small up to now. As a result of the new price and subsidy strategy of the EC, which leads to higher cost benefit ratios, an area-wide impulse for lowering the input can be expected. In general reduced prices will have a smaller effect on intensity than taxes on the input factors, which lead to the same cost benefit ratio and the same reduction of farmers income.

Present Situation

Agriculture and forestry in Europe are characterised by a great variability due to different ecological, social and economic conditions. The following discussion will be focussed on the situation in the EC-countries.

In tables 1 and 2 some informations are given about land use and animal production in the EC-countries. the area covered by forests varies from 5 (Ireland) to 44 Percent (Greec). The variation of the agricultural area is much less, but the use of the agricultural area is also very different from country to country. In Ireland the agricultural area is nearly completely used as permanent grassland while in Denmark almost arable land predominates. In the Mediterranean countries a relatively high proportion of the agricultural area is under permanent crops like fruit trees and grapes.

The animal husbandry (tab. 2) is highest concentrated in the Netherlands, belgium and Denmark with respect to both, cattle and pigs. In the average of Germany the total amount of large animal units per hectare is only half as high as in these countries, but more then twice as high as in the others. Additionally one has to consider that the animal husbandry, specially the pig production, within Germany is also concentrated in the north-western part near the border to the Netherlands and Belgium.

One result of this ghigh concentration of animal husbandry is a high pollution of the air with amonia (see fig. 1). due to the main wind direction the ammonia is transported to south-east and increases the native pollution in other regions and countries.

The high concentration of cattle and pigs results also in large amounts of animal wastes, which lead to additional problems with respect to pollution of soil and ground water with nitrate and emissions of nitrous gases in case of denitrification. As can be seen from table 3 in the countries with large amounts of animal wastes simultaneously the input of nitrogen is very high, specially in the Netherlands. Although the productivity is also high in these countries (eg.

yield of wheat) one has to expect that the nitrogen balance between input and removal results in high surpluses.

The application of pesticides differs also very widely. Main reasons for that are differences in the production intensity and land use (higher proportions of fruit trees and grapes in the Mediterranean countries, vegetables and potatoes in the Netherlands).

Sustainable Development and Adaptation
To reduce the ammonia and NOx emissions from agriculture and also the production intensity the following measures on national and EC-level were taken:

- Governmental regulations
    - To reduce problems which occur from animal wastes their application is limited by the amount/ha and the time of application. Farmers have also to prove the area where slurry will be applied.
    - In protected areas for drinking water organic and nitrogen fertilization is limited and the released nitrogen after harvest is controlled. A listed number of pesticides are not allowed to use.

- Governmental supports for:
    - Non use of farm land
    - Extensive farming incl. organic farming
    - Production of energy-crops
    - Reforestation

- Quotas for milk and sugar beets

- Reduction of the prices for main crops. Although the prices were reduced to the half or lower the changed cost-benefit ratio led only to a small effect on the production intensity and the input of nitrogen and pesticides. As has been shown much higher effect could be obtained with the same loss of farmers income if taxes on nitrogen would be collected.

- Improving farm management practices to reduce the input of fertilizers, pesticides, energy and labour.

- Breeding of more resistant varieties.

On the other hand advances in breeding lead to higher yield potentials which increases the cost-benefit ratio and makes higher inputs of nitrogen even profitable. Up to now the economic frame work enables the farmers to produce with profit on a high intensity level and there is no indicatio visible that this situatio will change rapidly on an large scale in the near future. In the eastern european countries one has even to expect that the production intenisty will increase due to the shortage in the past and the better availability of fertilizers and pesticides in the future.

Table 1: Land use in the EC-countries 1988

Country	Total area 1000 ha	Forest % of total	Agr. Area % of total	P.Grassl. % of Agr. Area	P. Crops % of Agr. Area	Arable L % of Agr. Area
EC-12	225830	24	57	38	9	53
B	3052	20	46	45	1	53
DK	4309	11	65	8	0	92
D	24869	30	48	37	2	61
GR	13196	44	44	31	18	51
E	50476	23	49	25	18	57
F	54912	27	57	38	4	58
IRL	7028	5	81	82	0	18
I	30128	21	57	28	19	52
L	259	34	49	55	2	44
NL	3980	8	51	54	2	44
P	9207	32	49	17	19	64
UK	24414	9	76	63	0	37

Agr. area - agricultural area
P. grassl. - permanent grassland
P. crops - permanent crops
Arable L. - arable land

Table 2: Animal husbandry per hectare in the EC-countries 1988

		Large Animal Units			
Country	Total	Cattle	Pigs	Sheep + Goats	Poultry
EC-10	1.1	0.7	0.2	0.1	0.1
B	3.1	1.7	1.1	0	0.2
DK	3.1	1.2	1.4	0	0.1
D	1.6	1.0	0.5	0	0 1
GR	0.5	0.1	0.1	0.2	0.1
F	0.8	0.6	0.1	0	0.1
IRL	0.9	0,8	0	0.1	0
I	0.7	0.4	0.1	0.1	0.1
NL	4.2	2.1	1.6	0	0.5
GB	0.9	0.5	0.1	0.2	0.1

Table 3: Yields of wheat, use of nitrogen and pesticides in the EC-countries

Country	Wheat 1988 [t/ha]	Nitrogen 1985 [kg/ha]	Pesticides 1985 [kg/ha]
EC-12	5.34	74	3.9*
B	6.64	126	-
DK	6.73	135	2.8
D	6.84	126	2.5
GR	2.69	80	5.2
E	2.78	33	-
F	6.29	77	3.0
IRL	7.86	57	0.3
I	3.68	62	8.9
L	4.10	-	-
NL	7.23	247	9.8
P	1.34	30	3.1
UK	6.24	86	2.2

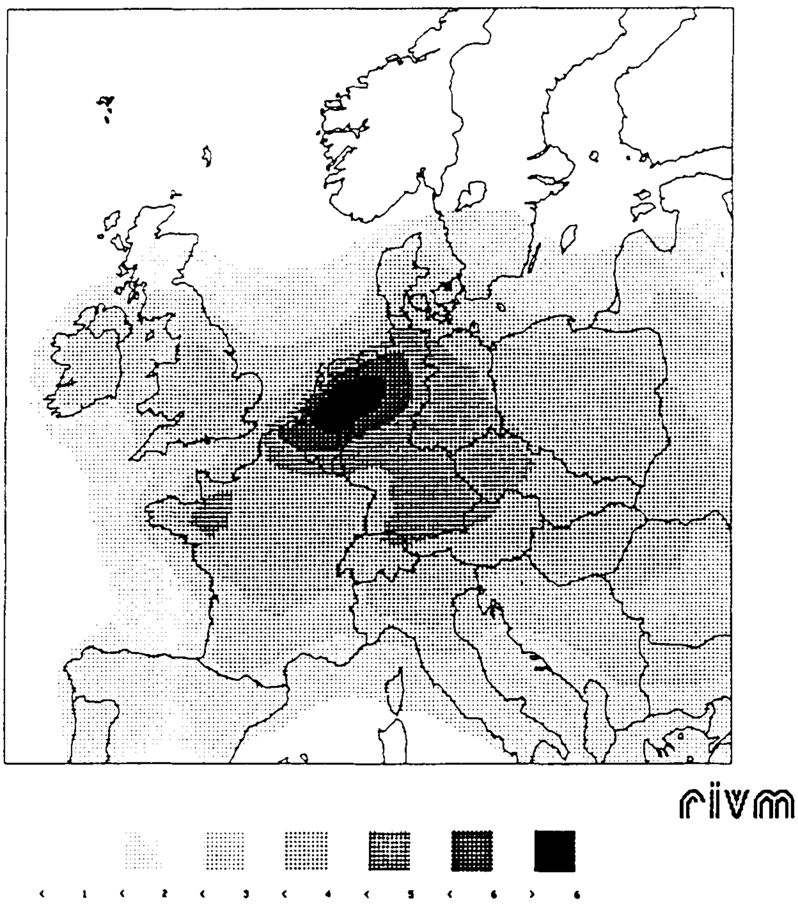

Fig. 1: Distribution of the calculated NH_4^+-concentration in Europe ($\mu g/m^3$)
(Source: Asman W.A.H. and van Jaarsveld, 1990: Regionale und europaweite Emission und Verfrachtung von NH_x-Verbindungen. In: KTBL-Schrift: Ammoniak in der Umwelt. Verl. Hiltrup, Münster)

INTEGRATED MANAGEMENT STRATEGIES - Summary

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ABSTRACT

The problems of greenhouse gas emissions and of future climate change discussed at this workshop are not likely to be solved efficiently by a piecemeal approach. This is very likely true of all environmental problems. It is not just that in solving one problem you have to be very careful not to be creating another; longer-term ecological sustainability has to be achieved without putting at risk the shorter-term livelihood of the world's people, especially those who are severely impoverished already.

The most economical solutions are likely to require a combination of changes to existing cropping and grazing practices and of changes to where those practices are pursued - on which part of the farm or catchment, where in a region or even a continent (some examples will be quoted). Likewise, the effective conservation of natural ecosystems and biodiversity in agricultural regions is likely to require a combination of changes to current production practices and of not cropping and grazing in some places. Forestry must be fitted into the land management system too.

This need for integrated management strategies poses an immense challenge to researchers and the community. The agricultural research profession has had some difficulty in coming to terms with an integrated farming systems approach, including all the farm operations as well as the farmer, and calling on both the natural and social sciences for understanding. Now those same people are being asked to think also about the environmental consequences of all the production processes and of fitting various forms of land use (not only cropping and grazing, but also production forestry and conservation) more closely to land capability.

Has such a comprehensive and systematic approach to the management of agricultural lands been achieved yet on a significant scale anywhere in the world?

The problems for agriculture and forestry of greenhouse gas emissions and of future climate change are not likely to be solved efficiently by a piecemeal approach. It is not just that in solving one problem you have to be very careful not to be creating another; longer-term ecological sustainability has to be achieved without putting at risk the shorter-term livelihood of the world's people, especially those who are severely impoverished already.

The most economical solutions are likely to require a combination of changes to existing cropping and grazing practices and of changes to where those practices are pursued. Production will need to be concentrated on the best (most productive) and safest (least environmentally susceptible) types of land.

In Australia, opportunities exist for improving the fit between land use and land capability through:

- partial reforestation of overcleared crop and pasture land (more than 90% of trees removed) in the south
- avoiding similar mistakes in developing the largely uncleared grazing lands of the tropical north, and
- relocating wheat cropping towards the safe and better watered parts of the nation's cropland.

There are also alternative forms of land use for beef cattle production (natural vegetation, sown pastures, feedlots) that vary widely in greenhouse gas emissions.

This need for integrated management strategies poses an immense challenge to researchers and the community. The agricultural research profession has had some difficulty in coming to terms with an integrated farming systems approach, including all the farm operations as well as the farmer, and calling on both the natural and social sciences for understanding. Now those same people are being asked to think also about the environmental consequences of all the production processes and of fitting various forms of land use (not only cropping and grazing, but also production forestry and conservation) more closely to land capability. Such a comprehensive and systematic approach to the management of agricultural lands probably has not been achieved yet on a significant scale anywhere in the world.

RISK MANAGEMENT AND CLIMATE CHANGE
(Abstract)

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The technologies available to assist in risk assessment and management for crop and pasture production are briefly outlined. The paper illustrates that these technologies, originally designed to deal with climatic variability which is a feature of Australian agriculture, have many of the attributes appropriate for the examination of the impact of global climate change on agricultural sustainability. It is proposed that anticipated climate change lies well within current climatic variability experienced by agricultural producers. It follows that some existing risk management tools should be more widely adopted in view of projected climate change.

CLIMATE CHANGE, SUSTAINABLE ECONOMIC SYSTEMS AND WELFARE

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ABSTRACT

Research on the effects of climate change on US agriculture and world grain markets suggests that adaptation will occur with relatively small effects on total production. Additional research shows that reducing emission of greenhouse gases from US agricultural production is relatively expensive compared to encouraging reforestation as an offset to emissions of carbon dioxide. Nevertheless, continued population growth and the increasing inequality of income across countries are likely to exacerbate the adverse effects of climate change. Concepts of sustainability should be expanded to cover industrial as well as agricultural production, and promote the efficient use of fossil fuels in general. Dealing with climate change effectively will require international cooperation and a willingness to address population growth and the divergence of incomes between rich and poor countries.

Introduction

The overall conclusion of this paper is that climate change is one component of a more general set of problems that will affect the future well-being of people throughout the world. Growth in population and the increasing inequity of the distributions of wealth and income among and within countries underlie many environmental problems. The effects of climate change may exacerbate these problems, but solutions to climate change must involve social as well as technical components. Technical options are necessary for developing solutions but are not sufficient for success.

There are many scientific uncertainties about the physical relations that affect climate. More research needs to be done to understand these relations better, but other sources of uncertainty are important. They include how people will react to changes in climate, and how their behavior affects emissions of greenhouse gases. These issues correspond to adaptation and mitigation which have been the focus of research in the US over the past few years. It is in these areas that the economic and social sciences play an important role. In simple terms, the physical sciences define a range of options, but social behavior determines which choices are made.

Effects on Agriculture

A major limitation of most existing models of agricultural production is that the effects of weather variables are not explicitly represented. Most published analyses of the effects of climate change on agriculture modify the mean yields of major crops based on results from yield models developed by crop scientists. Results are compared with and without the changes of yield in a comparative static framework [e.g. Adams et al. 1990 and Kane et al]. A more realistic analytical approach has been developed by Kaiser et al. by linking a model that generates weather patterns to crop yield/soil models to a management decision model. For a given region, this framework makes it possible to focus on adaptability over time, responses by farmers to variability of yield as well as changes in average yields, and the adoption of new crops and cultivars.

An important component of adaptation is the response of markets to changes in supply. In general, markets provide a self-regulating feedback mechanism for farmers, and help adaptation to occur smoothly. In this way, market systems can adapt in an active way without direct interventions by governments. Research on the adaptive capacity of US agriculture to climate change [Adams et al. 1990] suggests US agriculture can adapt to climate change without major adverse effects.but there are still substantial gains and losses in different regions of the U.S.

Research on world grain markets [Kane et al.] suggests that the overall effects of climate change will be small, but regional differences may be substantial. Some countries will benefit but others will not. To date, little research has been published on the effects of climate change on agriculture in subsistence economies. The tentative conclusion is that rich countries can adapt to climate change but poor countries may take it on the chin.

Turning to mitigation strategies, research by Adams et al. [1992] shows that the costs of reducing or offsetting emissions of greenhouse gases from agriculture in the US are relatively high The most promising strategy is to offset emissions of carbon through reforestation. The analysis shows again the importance of tradeoffs between winners and losers. Increasing the area for forests reduces the land available for agriculture, and higher prices for agricultural products are partially offset by lower prices for lumber products.

Sustainable Economic Systems

The existence of technical solutions to environmental problems is necessary but not sufficient for policies to work. Success requires that a policy is also feasible from an economic and social perspective. This same argument holds for sustainability. The continuing divergence of living standards between rich and poor counties is probably the primary obstacle to finding effective solutions to global environmental problems such as climate change.

Published projections by the United Nations imply that the current population of 5384 million will increase to 8645 million by 2025 The rate of growth of population is much higher in poorer regions, such as Africa, than in rich regions, such as Europe Comparing the projections of population between the years 2025 and 2010, Europe is the only region to show a decline, and the average annual growth for Africa is double the corresponding rate of growth for total world population..

As a first step to understanding the economic implications of increasing income per capita on the need for resources such as energy, it is useful to estimate demand models that explain how income is allocated to the purchase of different commodities. Expenditures in food correspond to two thirds of total expenditures in a poor country like Tanzania but less than a quarter in a rich country like Japan. Policies that decrease income inequality will tend to increase the demand for food. Currently countries with the potential for expanding agricultural production stand to gain from policies that reduce income differentials in the world.

Sustainability should not be interpreted as keeping things the same.

Conclusions
The magnitudes and complexities of problems associated with the growth of population and income inequality are daunting. These problems can not be separated from the environmental problems of climate change. The use of fossil fuels is the major contributor to greenhouse gases, but is also an important factor in determining levels of income. Agriculture and forestry are the most important economic activities that could be adversely affected by climate change. These sectors are the primary sources of well-being for a majority of the world's population. If food is expensive, the effect on the cost-of-living is much higher for poor people because the proportion of their income spent on food is larger than it is for rich people.

There are no simple solutions for dealing with the interrelated problems of climate change, economic inequality and population growth, but five issues should be considered as a basis for establishing general objectives among nations for future environmental policies. These issues are obvious to many people but are not yet reflected adequately in government policies in the US. The issues are:

1. Limiting the growth of population is essential.: A common assumption is that higher levels of economic growth will automatically result in lower rates of growth of population. However, the population problem is important enough to warrant more direct policies, such as improvement in the status of women.

2. More handouts are not the solution: There should be a return to traditional goals of providing economic opportunities for the majority of people. It is the responsibility of rich countries to see that these principles are applied globally.

3. Sustainability is not just for poor people: Developing sustainable economic systems will require that industrialised countries become less extravagant in the use of resources as well as encouraging poor countries to manage environmental problems better.

4. Fuel prices should include environmental costs: Prices paid for fuels should reflect environmental costs as well as the direct costs of extracting, processing and distributing the fuels.

5. Uncertainty is inevitable: Policies adopted now to deal with climate change will affect the next generation more than the current one. This means that uncertainty can not be avoided in making policies even if scientific knowledge was perfect.

The basic requirements for social and economic research relating to climate change are to recognise the global and long-run nature of the problems, and the interdependencies that link agricultural production, energy use and economic welfare. These issues justify research regardless of whether or not climate changes are substantial

Objectives for social and economic research are:

1. Better spatial data are needed on commodity flows and the resources that place limits on economic production, particularly agriculture and forestry.
2. Economic models of production should be linked explicitly to physical resources as well as to economic variables such as prices.
3. Economic models of demand should consider the distribution of income because of its importance for measuring welfare effects and determining the aggregate demand for necessities such as food and energy.
4. Better estimates of environmental costs, such as adverse health effects, are required to understand how to internalise these costs in market transactions, and to evaluate the benefits of different policies that affect climate change.
5. The role of energy in generating income should be understood more completely to measure and evaluate the effects of energy conservation. Better data should be collected on how efficiently fuels are used [see Mount 1991].
6. New methods are needed to understand dynamic adjustment processes in economics. Most of the existing analyses use comparative statics.
7. New methods are needed for developing policies that recognise the uncertainty surrounding climate change and other environmental problems.

Considering these seven topics, the first is probably the most important from a practical point of view. Good research on complex environmental problems requires good data. Even when suitable data exist, they are often not available for research due to institutional restrictions orinadequate documentation. These data should reflect research needs in the social and economic sciences as well as the physical sciences. If the importance of the interdependencies linking energy use, agriculture and the environment to population, income and welfare is recognised, there is achance that new policies for climate change will emerge.

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INTRODUCTION AND WELCOME

DR Stuart BOAG (Department of Primary Industries and Energy, Canberra): On behalf of the Department of Primary Industries and Energy, the CSIRO, the Rural Industries R&D Corporation and the Department of Arts, Sport, the Environment and Territories, who are co-sponsors of this Workshop in Australia, I welcome you all to Canberra.

This IPCC Working Group III Workshop will address technologies and management systems for agriculture and forestry in relation to global climate change. We anticipate that some 100 delegates from 41 countries will participate in the Workshop. Thank you to you all for coming so far. To those who are still in the air - and there are many of them - I wish a very safe journey.

I now have the pleasure to introduce Professor Dr Klaus Heinloth, from Bonn University. Professor Heinloth has a long-standing association with the IPCC and with the subject of climate change. He is an adviser to the German Government in the area of its investigations into the likely impact of global greenhouse gas emissions on the agricultural sector and the strategies which might be developed to limit those emissions. His address to us today is a plea for sustainable agriculture.

OPENING ADDRESS

DR Klaus HEINLOTH (Germany) Chairman of the Plenary Session: Distinguished delegates, experts on agriculture and forestry from all regions around the globe, ladies and gentlemen, on behalf of the AFO co-chairs, Zimbabwe and Germany, I would like to welcome you to our Workshop, **Assessing Technologies and Management Systems for Agriculture and Forestry in relation to Global Climate Change**. This Workshop has been prepared by our Australian colleagues and I would like to thank them heartily.

Let me start this Workshop with a brief opening address. Looking forward into the near future of the next decades - the next century - we must increase the carrying capacity of planet Earth from about 5 billion people at present to possibly about 10 billion.

Bearing in mind the present severe shortage of food, which imposes hunger on 10 to 20 per cent of the present world population, we must wonder whether the call for an increase of our productivity in agriculture by roughly a factor of two poses an almost unrealisable challenge for us.

But looking back at the history of mankind, we find some facts that may encourage us.

By inventing agriculture and improving its methods, mankind has already increased the carrying capacity of the planet Earth by about a factor of 1000. This has been done in a number of steps, each time by roughly a factor of 10.

Until 15,000 years ago Earth could carry only about 5 million people, those making their living by primitive hunting and collecting fruits. But then in the later part of the Stone Age, after inventing agriculture and domesticating animals, mankind was able to increase his numbers from 5 million to about 50 million.

By gradually intensifying agriculture, making use of irrigation and fertilisation and by improving breeding of plants and animals, mankind was able to further increase his numbers, up till a few hundred years ago, to about 500 million - another factor of 10. Since then the productivity from agriculture has been increased with breathtaking speed - mainly since the last century; indeed in the last decades - by introducing agroindustry, making heavy use of improved breeding of plants, or artificial fertilisers, herbicides and pesticides, thuse enabling mankind's population to explode to the present figure of more than five billion.

But, for instance, as a result of doubling food production within only the last few decades, world population has grown rapidly, thus shifting the average age of living people to smaller and smaller values, and simultaneously increasing the average lifetime of people. This factor would now make any further rapid change of the future growth rate of the world population rather harmful to mankind.

While in the past, with the world population not exceeding a few hundred millions, some spots on planet Earth were ruined by man's activities, the activities of five to six billion people at present, and most likely some more billions in the near future, threaten nature on a global level.

The rising world population (Fig. 1), which calls for rising production of food, rising production of many industrial goods, and increased use of natural resources, endangers the environment, and nature as a whole, by polluting air, water and soil; by deteriorating and reducing the amount of land to be used for agriculture and worldwide forests; and by reducing the multitude of natural species - our precious gene pool which enables nature to adapt to changing life conditions.

By behaving in this way, mankind threatens the survival of at least a major fraction of itself. And this may become obvious pretty soon.

In the last decades mankind has been able to raise food production at the same rate as the increase in world population. You can see this in the graph (Fig. 2), which compares the development of world population with the growth in the rate of food production. At least within the last few decades, food production did increase at the same rate as the population growth.

But despite the annual surplus of average worldwide food production of about 20 per cent, still 10 to 20 per cent of people in this world suffer from shortage of food. As you can see from the graph, within the last few years the further growth of food production slowed down. Nowadays we may face an annual loss of land up to one per cent of all land worldwide available for agriculture by erosion and aridification due to intensive agriculture and overgrazing.

If this trend continues, a gap between the expected growth of world population (disregarding a possible increasing shortage of food) and the food available for mankind could open up pretty soon and dramatically. Of course we have to avoid this opening of the gap, this danger to mankind. Also, we have to surmount this problem of the rapidly increasing shortage of food.

This poses a challenge of a completely new kind. This time we have, for instance, to raise food production by making better use of present techniques and by inventing new ways. However, all this must be done under rather severe restrictions. These include the fact that there will be no additional land for agriculture, because we need to protect our forests; no additional irrigation (this envisages possibly an increasing shortage of fresh water due to changing climate); less use of artificial fertilisers in order to protect soil, water and air - air of the troposphere as well as the stratosphere; and less use of artificial herbicides and pesticides in order to avoid pollution and to halt the decline in the multitude of natural species.

To surmount the problem, we have to think globally, but we have to act locally. Let us try to open up new possibilities. Let us try not just to suffer from climate change, but rather to make best use of this change. It is likely that the carbon dioxide level of the atmosphere will double from the preindustrial level of about 285 ppm within the next century. This is likely to occur even under severe restrictions on further anthropogenic carbon dioxide emissions.

Under a doubled CO_2 level of about 570ppm (keeping all other relevant parameters fixed), the rate of photosynthesis should increase by 10 to 15 per cent, thus leading to a corresponding increase in the annual turnover of biomass and the annual increment of standing biomass, mainly wood and possibly also soil organic matter, as shown in table 1.. You can see from that that the CO_2 level 100 years ago was less than 300 ppm. By 1990 it had increased to 355 ppm and it is likely that it will reach 570 ppm by the end of the next century. The increase in the annual rate of photosynthesis and of standing biomass for the period 1860 to 1990, as given in the table, is a rough estimate, which is supported by the observed increase in the annual fluctuation of the CO_2 content of the atmosphere as measured since 1958 of about 20 per cent. Therefore, we may assume that photosynthesis may have risen by about 20 per cent in this time, and standing biomass may have been increased by about 10 gigatonnes of carbon, assuming a 10 to 15 per cent increase for doubling CO_2 content. The numbers for the increase next century are a simple guess - no more than that. All I wish to point out is that we may assume that the annual rate of photosynthesis will increase further, as will standing biomass. I have not the slightest idea to what height it may go.

To realise and make full use of this most likely increase in bioactivities, we have to adapt agriculture and all our forests as well to climate changes, as to be foreseeen for the doubling of CO_2 in the atmosphere. We must assume a rise of temperature on global average by about 3 degrees Celsius and a corresponding change in the precipitation pattern and of soil moisture - especially as a result of the increase of temperature and of wind speed. Such a climate change could shift the climatic zones - arid zones as well as agricultural zones - by about 1000 km towards the poles within only 100 years.

Nature on its own could not adapt fast enough to such a climate change, thus causing a major breakdown of most of the ecosystems. So we have to support nature to adapt fast enough. To achieve this extraordinarily ambitious goal we have to learn more quickly how to manage agriculture and forests in a sustainable way, even during rapid change of climate. And we have to spread this knowledge more quickly.

This will certainly not be a one-way process from highly industrialised countries to others but, fortunately, an interchange of knowledge, experience and methods in all directions, between all countries. We all have to learn from each other and we all have to help each other. This interchange should lead to improved living conditions in all countries; in this way it could also strengthen self-esteem and pride of any nation.

We certainly should not try to equalise our rather different societies with our rather different backgrounds of tradition. But all nations should be enabled to find their best way for their future living conditions in their countries.

Ladies and gentlemen from all regions around the world, I hope that this Workshop will bring us a bit closer to the ambitious but necessary goal of avoiding the opening of a gap between the growth of world population and the production of sufficient food for mankind.

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Address by the Minister for the Arts, Sport, the Environment and Territories, **Mrs Ros KELLY**, on behalf of the Australian Government

Ms Monthip TABUCANON (Office of National Environment Board, Thailand) presented a paper entitled "Report on Bangkok AFOS Workshop to Explore Options for Global Forestry Management".

Dr Graham PEARMAN (CSIRO Division of Atmospheric Research, Australia) presented a paper entitled "Agriculture and Climate Change - A Physical Perspective".

Prof. Snow BARLOW (University of Western Sydney, Australia) presented a paper entitled "Agriculture and the Greenhouse Effect - A Biological Perspective".

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DISCUSSION

Dr Greg McKEON (Dept. Primary Industries, Queensland): I direct my question to Graham Pearman. We have heard about the satellite measurement of temperature being different from what is recorded in land-based measurements. Could you comment on this - especially on the accuracy of those satellite measurements?

Dr PEARMAN: The satellite record is very short - only about a decade long. If you look at the satellite record and then look at the ground-based record, you will see that, if anything, the satellite record supports the idea that the ground based record - even though it is based on only several hundred stations - is a good one. It is a positive result. It is really telling us that variability spatially in time is such that 10 years is not long enough to detect the kind of changes we have seen recently. The satellite record you are talking about is the one that senses the tropospheric temperature changes. There are other satellite records - for example, there is one that is looking at the stratospheric temperature change. That clearly also shows cooling which is consistent with what one might expect to see from a greenhouse point of view.

CHAIR: Thank you for that answer. Perhaps I could slip in a little more information here concerning the most recent climate change, and the debate as to whether we have already seen temperature change. In addition to this one sees a clear indication of a change in the water vapour content above the tropical oceans. During the last few decades water vapour has increased there about 15 per cent or so, and this accords exactly with what one would expect with a temperature change of about half a degree.

Moreover, one has now clear evidence that during the past couple of decades there has been a measured increase in the average wind speed around the globe, both close to the surface and at considerable heights. There has been an increase in wind speed of between 5 and 10 per cent, which means an increase of wind energy by 10 to 20 per cent. That has all come from just half a degree rise in temperature. This could be due to the greenhouse gas emissions of the early 1960s - 30 years ago - and we can imagine what the result will be with temperatures changes of not half a degree, but a couple of degrees.

Dr Naveen PATNI (Department of Agriculture, Canada): My question is for Dr Barlow, who mentioned that there are uncertainties with methane and N_2O emissions, but he did not mention CO_2. There is some talk in our country about the soil organic carbon oxidation being a big source of CO_2 release. How does that compare with the fossil fuel emission of carbon dioxide?

Dr Snow BARLOW: Obviously I had chosen not to talk about the CO_2 argument. The reserves of carbon in the soil, especially in the peat areas, are enormous. At this point we do not have data to determine whether there is an accelerated release of those reserves due to increases in temperature. One speaker mentioned the decrease in carbon in soils as a result of higher temperatures and, perhaps, cultivation. That is what one would expect. Perhaps Graham Pearman can shed some more light on this question. Perhaps there is some isotopic aspect to the release of carbon from soils, but I am not aware of that at this point.

Dr PEARMAN: I think there is uncertainty about the extent to which carbon content within a number of reservoirs of the standing biomass and soil biomass is changing. A lot of people have tended to emphasise the standing crop and deforestation. Certainly, there is a large amount of carbon in the soil organic compartment, and also in peats and so on. All I can say at this point is that if one looks at the isotopic changes in the atmosphere, one sees that historically those are consistent with what we expect from fossil fuel pollution and not the result of large amounts of carbon going in which bear relatively modern isotopic signals. There does not appear to be any great signal from that point of view. Secondly, if it is high latitude, the gradients in the atmosphere do not seem to support that. In the case of methane, it has been proposed quite strongly that part of the increase may have been due to the release of methane from high latitude tundra regions as those regions start to warm up. Again, the gradients in the atmosphere do not indicate at present that there are large releases from this particular source. We are talking about changes resulting from a few tenths of a degree; if we talk about what might happen with a few degrees change, the picture would be totally different and I do not think we could make any predictions.

Dr Peter COSTIGAN (Ministry of Agriculture, Fisheries and Food, United Kingdom): I would like to ask Dr Pearman about the revision to the methane greenhouse warming potential. The removal of the indirect effects will of course reduce the greenhouse warming potential from about 21 to about six times that of CO_2. Is that seen as a reflection of the actual real effect of methane or is it just an acceptance of uncertainty? Following on from that, does he think that perhaps in a couple of years when uncertainty is slightly reduced, we would go back to having a GWP of 21 or thereabouts?

Dr PEARMAN: My understanding of the situation is that because of the number of questions that were raised about the basis for calculating the indirect effects, it was decided not to include them. This is a policy decision rather than a scientific decision in the sense that we may go back to where we were and we may not because we do not know how to treat the problem properly at this stage. You are right; it will reduce the global warming potential, but not by so much as you have suggested, partly because, as I understand it, there was a small error in the calculation of the warming potential for the first volume which tends to cancel out some of the effect. But certainly I raised it very specifically because I felt that policy makers find one of the important questions is, 'How do we trade off between the various gases? Is it more important to reduce the emissions of one gas more than the other and what are the costs of reducing one gas more than the others?' These are the sorts of things that need to be debated. Obviously, the first thing we need to know is how relatively important the gases are. The answer at present in relation to methane and CO_2 is that we do not know too well. I have just been informed that the calculation error means that the GWP is 11 - about half the figure that you mentioned.

Dr Kenneth ANDRASKO (Environmental Protection Agency, USA): I have a question for Dr Tegart. If we are reducing the methane global warming potential and by extension increasing the importance of CO_2, and we are also talking about potential climate impacts on soil carbon storage as higher temperatures increase decomposition, I wonder whether we should consider in AFOS in our mitigation scenario work and estimates, mitigation options with climate change and without climate change because at the moment virtually all our estimations have been made in isolation without considering climate change impacts, which might be significant.

Dr TEGART: I feel a bit like McEnroe coming up against Sanchez - walking up and down a bit to delay the serve! This is a difficult question and one that I hope Working Groups II and III can get together on. Clearly we have not had time to assess the effects of this reassessment of the GWP and the relative contributions of gases, but it does seem to me that the whole question of the relationship between impacts and responses will need much closer interaction between the two groups. I realise that I am not answering your question at all, I am giving a political response. It is an interesting question.

Dr SAUERBECK: My answer will also be somewhat disappointing. There are new calculations trying to quantify the potential impact of global warming by 0.3 deg. in one decade. There is a very interesting publication by David Jenkinson stating that if we have this warming of 0.3 deg. per decade, then within the next 60 years the overall soil organic matter content in arable soils will drop. He did not quantify exactly the extent to which this would happen; it depends on all the conditions which determine soil organisic matter content regionally and locally, but he believes that the overall drop will result in an amount of CO_2 released which is about 20 per cent of what we have to expect from fossil fuel burning releases with the same period. This is quite something - 20 per cent of the six gigatonnes, which we have at the moment per year, over 60 years. This again is only one side of the calculation because once we have this global warming we also have the CO_2 increase and the CO_2 fertilisation effect. If this results in only a slight increase in plant residue returns into our soils, this may fully counteract the drop in soil organic matter. Again, it is a matter of equilibrium, and there are some indications in the most recent literature that once we have a 5 or 10 per cent increase in plant or animal residue returns into the soils, this may balance the additional losses due to the warming effect. We are still dependent on guesses and we cannot say anything precise.

Professor Henry NIX (Centre for Resource and Environmental Studies, Australian National University, Canberra): Following comments from Dr Noble, it seems to me that we need some creative accounting from our political leaders. We clearly need more funding for both research and monitoring of global environmental change. One obvious source of funds would be the defence budgets. I am quite serious about this. We have a changed world order. One has to question, "Whom are we defending?" We are defending the world against attack by human beings. Just 1 per cent of the global defence budget would have an enormous impact in this whole area. I recommend that we might think about this matter during the next few days.

(Luncheon adjournment)

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TRACK ONE: INTENSIVE AGRICULTURE

Chair: **Dr Gary EVANS** (USA)

Dr Suresh K. SINHA (Indian Agricultural Research Institute) presented a paper entitled "Methane Emission from Intensive Agricultural Systems".

DISCUSSION:

Dr David WHITE (Bureau of Rural Resources, Australia): Dr Sinha said that rice by itself does not produce methane. He pointed to the different emission rates from the two varieties, and then talked of relating methane emission to the amount of biomass. Could he clarify how this relates back to the methane emission per se? How is the biomass being translated into the different emission rates?

Dr SINHA: I thought that someone would ask that! The answer, I think, is simple. What you need in the soil is a source of carbon. This should be converted either to acetate for the purpose of bacteria, or the carbon dioxide that is present is reduced. What is important is the source of that carbon. When plants grow they usually leach out some organic acids and leach out other carbohydrates. The possibility is that the membrane permeabilities may be different in the roots. There may be leaching out of the substrates, and then the differences will arise. In regard to biomass - and I do not have any direct evidence of this; we will be working on this in the next couple of years - the larger the biomass produced the more likely is there to be leaching into the riceosphere. That is why it can become related to biomass.

Dr Dieter SAUERBECK (Federal Research Centre of Agriculture, Germany): Did I understand you to say that the methane formation is not temperature-dependent?

Dr SINHA: It is not only temperature-dependent. That was made out earlier.

Dr SAUERBECK: I suppose the redox potential in rice in a paddy soil is also non-uniform, and I would like to learn something about the differences in redox potential in the riceosphere as compared with a non-riceosphere soil. I would expect that in the riceosphere the redox potential would be low enough for methane formation. If this is true, acetates will certainly not come under redox conditions which would result in methane formation, but they may just be used up by the micro-organisms living next to the root. I am not convinced that this results in methane formation.

Dr SINHA: You are right. Data on the redox potential is available. It so happens that this was not recorded in relation to methane. It has been recorded as a routine in different parts of India as well as in China and maybe elsewhere. I have a table on this which I would be prepared to show you. and which shows redox potential in different kinds of soils in China as well as in India.

You can imagine a situation where there is irrigation in alluvial soils of the kind that we have in North India, starting from Punjab and going up to the eastern parts of the country. One has to give up to 40 irrigations in about 90-95 base, which means that you put water in, it goes out and alternately again. So there is so much oxygenation that that kind of reduced potential is not generated as a result of irrigation. As to all the soils that are heavy or alkaline the depopulation rates are very poor, and that is where the methane generation becomes higher. Somehow that got related to alkaline conditions. It is a question of generating much more redox generation rather than alkalinity of the soil per se.

Dr Heinz-Ulrich NEUE (International Rice Research Institute, Philippines): If I may seek to clarify the matter of biomass, increased biomass in rice means increased tiller number and increased tiller number produces more yields. To make it simple, if you put in more chimneys to the rice paddy, you get higher emission rates; it is a major pathway.

The differences with regard to the varieties are related in a major way to the diffusion from the root to the shoot. This is different depending on whether you have higher or lower restrictions.

The subject of redox potential is a very difficult one. The only reliable redox potential measurements are done in soil solution, not in the soil. That makes a very big difference. Therefore, one has to be careful where this has been done. Most redox potential in the soil directly becomes very deep, but no one knows how to interpret it. The thermodynamics are purely based on soil solution, not on soil redox potentials. So there one would have to differentiate as to what happens.

Finally, your estimates are based on pure emissions via the rice plant that have been measured. You haven't taken into account other factors. Eighty per cent of all methane that is produced is normally not emitted if you do not disturb the soil, but rice farmers if they go once into the soil walk 50 kilometres, even if they weed through the soil. So you are at the lower end with regard to undisturbed rice paddies. I acknowledge that you are putting emphasis on differentiations in different soil regimes and growth regimes that are at the lower end, but we should be careful in making any claims in this respect.

Dr SINHA: I will try to answer your questions. In the first place I think someone will have to show that the biomass per se would have no relationship to the exudation. Increase in biomass, whether as a result of fertilisation or growth, wouldn't give more exudation. I think in that respect there is literature available, not necessarily on rice but on other crops.

Secondly, some of the data on redox potential does come from the soil. I agree that it is difficult to interpret, but at the same time I think it is reasonable to say that in a soil where you are giving irrigation on alternate days, it is not having sufficient water at all. Under those conditions you are oxygenating the soil on alternate days, and thus to accept that you would have very low redox potential is difficult to take. I agree that these are the lower results, and that we need more. We need more studies.

I would make it clear that it is very difficult to accept whatever data has been obtained in Europe or in California and to extrapolate it to tropical conditions as they exist, because those experiments took into account the physical aspects of measurements. But from an agricultural point or view they are very poor experiments. In taking those data, one has presumed that the agricultural part was right. Nowhere in the whole of Asia - leaving aside probably China and Japan - do you get 250kg of nitrogen given to the soil.

What I am saying is that the values on which we are relying and on which the original IPCC report was based use data which are not necessarily to be extrapolated to the whole world. That is the major conclusion I am trying to put.

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TRACK TWO: EXTENSIVE AGRICULTURE

Dr Greg McKEON (Queensland Department of Primary Industries) presented a paper entitled "Management of Extensive Agriculture Greenhouse Gas Emission and Climate Change".

DISCUSSION:

Dr Snow BARLOW (University of Western Sydney): You said that inevitably the development of your native systems to highly productive systems involved the loss of carbon. But is that strictly if you go from a native savanna system into, say, a fairly intensive pasture system as one might in high rainfall areas? Do you still suffer a loss of carbon in those soils if you do that? In the southern area the characteristic of the buildup of the development of pastures has been the development of organic carbon in the soils. I was interested to know whether inevitably one loses carbon in that system as well.

Dr McKEON: In the woodland example I gave there are about 40 tonnes of carbon stored in above and below-ground trees. Probably you would get a decline of one per cent organic matter as well associated with the initial decline from the virgin country. That might be estimated, and a typical number is 14 tonnes per hectare, representing a change of one per cent organic material. They are the sorts of numbers you are trying to win back by storing carbon in the soil. By better pasture management, by having a greater amount of root biomass, we might win back one tonne of carbon per hectare just in terms of live roots.

We know from zero tillage in broadacre cropping that it is hard to win back much more than one or two tonnes with that sort of input of stubble into the system. Certainly legumes will raise the amount of mitrogen, and therefore the amount of carbon that goes with them. In the tropics though we have a lot of trouble getting the nitrogen input from our legumes that you have got in southern Australia, and as yet that is unresolved.

Also I mentioned the matter of legume potential. We even have problems of adoption of that technology in terms of its economics. I doubt that we can achieve that storage you are talking about in southern Australia.

Dr Mike MANTON (Bureau of Meteorology Research Centre, Australia): In countries like Australia where there is a high natural variability in the climate there is a particularly strong connection between management for climate change and management of the natural variability of the climate system. As you develop tools to understand the natural system and cope with that, then the climate change part will perhaps be much more straight-forward.

Dr McKEON: I think that is definitely so. In fact, we have stopped running scenarios in terms of what the GCMs produce in looking at the impact on agriculture. We would rather use the output of the GCMs in terms of their seasonal forecasting capability to try to make better decisions from year to year. This is certainly not a Dorothy Dix question, but the role of the Bureau of Meteorology in putting out those seasonal outlooks represents a very significant change in agricultural management in Australia and, because of the impact of the southern oscillation around the globe, could well also change management through the topics and in the savannas.

To explain that a little further, the Bureau of Meteorology produces every few months an outlook of what rainfall there is likely to be in eastern Australia based on the influence of El Nino and La Nina on those aspects. The year 1991 with El Nino represents the first time in our 200 years of European history where we have had the forecast well publicised through the media before it occurred, instead of being told after the event. This is the first experience that people, naturally sceptical of seasonal forecasting, have had of actually hearing the forecast and seeing the result. We have had a cultural change within the last year. We have gone from virtually no knowledge of the impact of El Nino on management to the Ministry of Primary Industries in Queensland explaining to journalists how it operated. The extension through the politicians and through to the producers has been very great.

We have been looking at how one might use that in adapting to climate change. If you tied management to a forecast based on seasonal change over the last 100 years, you would pick up about half the droughts and half the good years. If you used that in terms of, say, putting nitrogen on a crop you could have a more efficient use of that nitrogen. You would only put it on in those years where wet conditions are forecast. In terms of the impact of overgrazing, you have a warning of those conditions that are most likely to lead to the loss of perennial grass species due to heavy grazing in drought. So we think seasonal forecasting will play a major role. We are doing a major exercise with the Bureau of Rural Resources with David White's group to do that analysis in economic terms as well as the impact on land management. Perhaps you will produce a global impact statement one day!

Dr Miko KIRSCHBAUM (CSIRO Division of Forestry, Australia): Greg, is there any prospect of improving the fodder quality indirectly or directly through supplements and of that reducing methane emissions, while at the same time being profitable for farmers?

Dr McKEON: I will ask my colleague and joint author to answer that, if I may.

Dr Mark HOWDEN (Bureau of Mineral Resources, Australia): What usually happens in Australian systems, at any rate, is that when we supplement the feed, either through minerals or legumes, there is a reduction in methane over the lifetime of an animal. One can produce a kilo of beef with less methane.

The consequences in terms of normal management are that if you put that capital into legume pasture, you will increase the stocking rate; it is economical to do so. An increase in stocking rate will lead to an increase in net emissions from the system on a per hectare basis. On a per kilo product basis you improve the story; on a per hectare rain basis you go downhill.

Dr McKEON: To make that calculation you need good systems analysis, otherwise you cannot do a partial budget.

Dr Robert DIXON (US Environment Protection Agency): Australia has a long tradition of large germ plasm - múlti-purpose trees, with fixed nitrogen and a number of products associated with the trees. Your technology has been dispersed around the world, as has the germ plasm. It is interesting today to hear talk of the need to eradicate woody vegetation from your pastures. Are there types of value-added products - fuel, fodder, fibre - that could be derived from these woody crops to augment the farmers' or ranchers' incomes, or perhaps diversify the management of the portfolio, particularly in drought years when meat and crop prices are down? Are there other ways to make money?

Dr McKEON: That is a very good point, and I could have talked about the use of forest legume trees, leucaena, acacias and so on, that can contribute by storing carbon and increasing animal productivity. We have had problems in getting these adopted because of farmers' attitudes towards eucalypts. They transfer that anti-tree view to all trees. So we have various physical models to demonstrate the ability of those systems to fix nitrogen, produce more feed for cattle, but we have trouble getting them adopted. There are diseases associated with them which have prevented adoption of certain trees. There is certainly a role for those areas if we can educate people to use them and demonstrate their profitability.

In terms of the trees that are being burnt, in many of the western areas those trees have been identified as a source of exotic timber rather than the traditional uses of cabinet timbers, and are sold overseas in that sense. We have one acacia that is invading our treeless grasslands which has particularly been identified as being useful in that sense. In terms of export there is a freight problem in getting it to the people who are prepared to pay. In the United States I understand there is some impetus to get rangeland people to have woodlots and that sort of area.

Dr DIXON: I could speak on that subject for half an hour!

CHAIR: I am afraid I have to call "Time" now, but we will have time to revisit some of these matters. I would make a closing comment that both speakers in this session have made clearly. I refer to the need to keep in mind this multi-disciplinary approach to the problem. In every case as soon as we brought up an issue from one discipline, it was immediately countered by an issue from another discipline. I thank the speakers and discussants.

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TRACK THREE - INTEGRATED SYSTEMS

Dr Robert K. DIXON (Environmental Protection Agency, USA) presented a paper entitled "Integrated Systems: Assessment of Promising Agroforest and Land-use Practices to Enhance Carbon Conservation and Sequestration".

DISCUSSION:

Dr SAEURBECK (Germany): I found Dr Dixon's paper most exciting and interesting and it gives us many things to think about. Nevertheless, I would still like to repeat one of my statements this morning. All this carbon sequestration is most limited in time and extent. The thing I did not like in the presentation was the very slight emphasis which Dr Dixon gave on the timescale. I did not talk about abandoned land, land which can be returned into rangeland or even into forest. I talked about the most limited possibilities of carbon sequestration in arable soils which are under continuous cultivation.

I would like to have your comments on the statement that all this carbon sequestration is so much limited in time and extent. In principle I think that this is true of almost all the waste you have shown. It is something that you can manage just once, and once the system has reached its new equilibrium there is no carbon sequestration any more; it is the timescale that you showed in one of your overheads.

Another point which is most important to me is that one puts these figures - figures which are intoxicating if you just play with them - in relationship to the 6Gt which we all waste every year. I have met so many people who always point out how much we can do with this carbon sequestration. I feel it is almost negligible compared with the much more compelling and important need to reduce energy consumption. All the most important possibilities which you have shown should never be abused in order to distract people from the much more important and much more crucial obligation to reduce energy consumption. It is important to use all the tools that you have indicated, but it certainly doesn't solve the problem unless first of all we reduce our energy consumption.

Dr DIXON: I do not take exception to anything Dr Sauerbeck said. I believe, and the data shows, that storage of carbon in terrestrial systems is temporary - it is always temporary. The 100Gt of carbon which cycles annually in the terrestrial biosphere with the atmosphere is a process that has been taking place for a long time, and that will continue into the future.

The take-home message is that perhaps we have some opportunities to conserve carbon in soil systems and other places where we have not yet mismanaged. We have some opportunities to perhaps use these alternative land use systems to offset deforestation rates. I would like to emphasise the carbon conservation aspect.

Secondly, I would like people to think about these carbon sequestration issues as part of a larger portfolio. Within my own research shop we call it the series of five per cent solutions. I think energy conservation and reducing greenhouse gases is one part of that solution. We like to think that carbon conservation issues, carbon sequestration opportunities, might be a small part of that portfolio.

My third point is that it seems reasonable to reduce greenhouse gas emissions by achieving energy efficiency, but even if the globe had the resources we will not do that probably tomorrow or next year or ten years from now. It will take time. There are opportunities to store carbon temporarily in these systems to buy us some time over the next 30 to 50 years. If the predictions are as we have discussed this morning, perhaps there are some opportunities for temporary carbon sequestration. But certainly all trees eventually die, the carbon turns over and goes to the atmosphere. That is why I started with the slide of a global carbon cycle. It is a cycle and we should keep that in mind. We have a history of mismanaging that cycle. The message I would like to share with you is that as resource managers perhaps we have an opportunity to do a better job of that in future, and to manage it to our benefit to reduce greenhouse gas emissions. Your points are well-taken and I thank you for reinforcing them, because time is certainly a factor.

Dr McKEON: I believe that we should get our own house in order if we are to ask cities to reduce energy expenditure, so we should look at the oportunities. When you see figures like 70 per cent of extensive systems threatened by degradation, that is not a good emotional number for cities to have. They ask resource managers what they are actually doing in those terms. Even though we might only store another tonne of carbon on those systems, which is equivalent perhaps to two years of forest clearing, it helps to win the emotional argument that we can look after our own systems, and it behoves other industries to look after their systems.

Dr Birger SOLBERG (Norwegian Agricultural University): I have a comment and a question. My first comment relates to the last discussion. I think part of agroforestry is also connected to energy and the use of those trees will often be a substitute for other energy uses. So you have a benefit there which you haven't incorporated.

Dr DIXON: I agree that I did not make that point. I just touched on it. It is probably appropriate for another occasion. I believe there are papers on that topic later in the Conference.

Dr SOLBERG: That will just increase the attractiveness of investing in those issues. The second point is that you showed some internal rates of return that ranged from 9 to 100 per cent. This means that most of these projects or measures are no-regret measures, as the Minister pointed to this morning. In a way there is a synergism here that is important to keep in mind. If you can do that for 10 or 20 years that is a great benefit in this issue. I wanted to tone down a little the comment that was made in the first question.

Dr DIXON: I think there is a regret that we cannot store this carbon for longer. I think we have to be careful with "no regrets".

John CULLEY (Agriculture Canada): In Canada there is great concern about waste from urban areas. It struck me that throwing garbage into landfills and covering it up is a form of carbon sequestration. I wonder whether the EPA has looked at the potential impact of recycling waste back on to farmland, where again it becomes more rapidly oxydised as CO_2, so the mix would maybe change - more CO_2 and less methane in the landfill sites.

Dr DIXON: We are conducting research on that topic right now. I think there are EPA officers in this room who have done some work on that topic. I know Ken Andrasko has done some work in that area.

Dr Kenneth ANDRASKO (Environmental Protection Agency, USA): We have just started looking into the potential carbon cycle benefits of increasing the recycling of paper products in the US. The Forest Service in the US has done some runs in its RPA modelling process. We estimate at this point that they are of the order of 10 million tonnes per year as to the potential benefits of significantly increasing the recycling rate from its current rate of about 28 per cent up to about 45 per cent, which we deem feasible within about a decade or so. So there is some work going on.

One of the problems with landfills is the trade-off in sequestering carbon; by producing methane you are producing gas with a higher forcing factor. Those are the kinds of trade-offs that we have to go into in a little more detail.

Dr TIM MOUNT (Cornell University): As an economist I would like to ask you about the cost numbers for the United States. They look awfully low. A well-managed tree plantation in Minnesota used for a power plant would come out at $15 a tonne of carbon; your numbers were $1 to $6 a tonne.

Dr DIXON: I can share with you the source of that data. It is the report by Molton and Richards Forest Service 1990. Those were US numbers. This is a difficulty when this kind of data is presented. I did say these were numbers from land that is available on which we could plant trees. These were intitial establishment costs. You have to put bounds on what those numbers actually represent. Those are the initial establishment costs of planting trees and taking care of them for the first three years. There are certainly other costs associated with managing these systems to conserve and sequester carbon.

On the other hand, I am hoping that your paper will address the other side of the coin. Today we have talked about costs. That assumes that forests provide no other goods and services, which is not true. In fact, we are very interest in and will invest resources in the benefit side of the equation over the next several years. Some of these carbon conservation opportunities - I emphasise some - might actually pay for themselves - for the other goods and services that flow out of the forest sector. Researchers in the US have been working on these factors for some time, but I think we need to redefine our models.

Dr Heinz-Ulrich NEUE (Philippines): I wish to raise two matters, one relating to sequestering in arable land. It works fine only if you keep up your inputs as high as you have shown, and it is often a problem to produce that on this kind of land. Therefore, the calculation on that is a nice one, and if you do not keep it the degradation afterwards is just as fast. It becomes a very difficult system to manage and still get enough outputs that you may sell or eat yourself.

My second point relates to agroforestry, which all the world is now enthusiastic about. The problem is that I have hardly seen any of these wonderful projects that could be maintained when the umbrella of the project was taken off. There are many reasons for that because the input that you have to provide so that these systems can run is very, very high. Often an input has to be maintained economically. Finally, there is then the problem that any population pressure on these systems is much more sensitive than for well-established systems. Because of the population pressure in these systems, afterwards they break down because they are not good enough to provide for a doubling or tripling of the population. If you do not export people out of these regions, you find that the system breaks down. The socio-economic factors become very sensitive. Although biologically or physically you have a nice system, the socio-economic part does not work.

Dr DIXON: I agree, and I would not take exception to what you said, but if we consider the alternatives - continued deforestation and degradation - at some point in time we shall run out of these resources on this planet. There is an opportunity here, I think, to slow these trends or reverse them. I think at some point in time we might develop a set of social, economic and political conditions which would encourage us to do that. Perhaps we are coming closer to that point.

Dr HEINLOTH: I want to come back to the cost of sequestration of carbon in agroforestry. This will certainly involve some money towards sustainable development. Nevertheless, when you compare it with the cost of more efficient energy use, it is even cheaper, and we should not forget that.

Dr ANDRASKO: I would like to follow up Dr Neue's point and ask Bob Dixon to address whether part of the problem so far in getting long term sustainable agroforestry systems it that we have identified technologies, but have not focused on the economic benefits enough. We have developed the infrastructure of markets and so on to produce sustainable systems. The examples we have thus far of projects that look like they would not continue without continued inputs are because we have not solved the problem of marketing goods. We have a good example in the Amazon with extractive reserves and with brazil nut plantations. Once they have developed the markets and the ability to transport the products, some of those case studies have been far more successful. I suggest that perhaps for a few minutes we could focus on expanding the marketing side.

Dr DIXON: I agree. I would put forward the example of global trade in rattan. There is a $1.3 billion trade opportunity for exporting rattan products from resource-poor farmers within the tropical latitudes to various parts of the world, as well as within their own countries. Where markets have been developed, these programs have been sustained over a period of time.

I would also add to what Ken said. Agroforestry is not new. Folks were managing agroforestry long before we discovered the global carbon cycle, and did it quite well. They fed themselves, they provided shelter, the fuel they needed, and it was done on a sustainable basis for hundreds and hundreds of years. It has only been with recent environmental and demographic pressures that some of these agroforestry systems ceased to be sustainable, but with the technologies and our understanding of market systems, economic incentives, perhaps we will reach a point where all the projects can be successful, not just a few.

If we are asked to make choices, I imagine a body such as this is being asked by the citizens of the globe to offer technical advice with regard to what are the things that we can do today or 10 years from now. If we look at the list of ideas that we are considering and that were discussed by the Minister this morning, some of them have a very large price tag. They have a downside and may not pay for themselves. Some of the management options seem to be no-regrets in the broadest sense. They provide goods and services, employment and community stability. Indeed, there have been some tragic failures. I instance the overall failure of the tropical forest action plan, and the fact that global deforestation has doubled in the last 10 years while this plan is being implemented. Maybe we can do better.

There are market drivers in most of these situations. If resource-poor farmers are given credit, some minimal technology or perhaps if we just leave them alone without some of the pressures that they seem to be dealing with day in and day out, warfare being one, there are opportunities perhaps to manage these systems on a sustainable basis. I used an example where Pakistan had an influx of about 3 to 5 million refugees - nobody knows the exact number - from Afghanistan. It caused a major fuel and commodity crisis, but within a short time we were able to implement systems to deal with these immigrants. At the same time we were able to protect the resource base. But there are definitely some failures.

I would like to ask a question of our group, the group in Germany and the dozens of groups represented in this room. I think we have all worked very hard on the biophysical side of this equation. We have looked at the numbers, we have carbon budgets and a fairly good understanding of the global carbon cycle. We can certainly do better, but I would like to hear comments about the social, cultural and economic drivers as to ways in which we can focus our research to close the gap between the technologies we have on the shelf and those that we might implement. I am probably addressing people in the biophysical sciences. Perhaps it could be part of the Chairman's report, or a question that we could pose or whatever, I would like us to think about moving our resources in that direction so that we could answer some of these difficult issues.

CHAIR: That will be part of the charge to all three Working Groups. In addition to identifying the technologies that we have begun to discuss, we hope that we can have as part of the input from you what you perceive to be some of the social, cultural and economic barriers, as well as at least some perceived costs. If you do not have the hard data as to the costs, I am sure that many of you at least have some anecdotal information that will help us get started.

Perhaps this may be the moment to go to general discussion.

GENERAL DISCUSSION

Prof. Henry NIX (Centre for Resource and Environmental Studies, Australia): I am a biophysical scientist but a social issue that doesn't seem to be considered is global urbanisation. In fact, if present trends continue, within one or at most two generations subsistence farming and agriculture will be a curiosity. That has enormous consequences for the sorts of systems that people are talking about here.

I have not heard any discussion of the problem of global urbanisation. In Latin America already 80 per cent of the total population is urbanised. In Africa the figure is 40 per cent and rising swiftly. It has enormous consequences for the sort of agriculture that is carried out in a community.

CHAIR: That is a very valid question, Professor Nix, one I myself have had some concerns about and tried to get into some papers.

Dr DIXON: I offer a comment. I agree that we have not addressed the urbanisation issue, but as we concentrate population in cities around the world, that would also argue for the fact that some of the conservation measures that we have evaluated today might become even more valuable in future - valuable from the perspective of things that we can actually implement without social or economic trade-offs, or at least the trade-offs may not be as great as they are today.

CHAIR: Perhaps I may comment on that. The United States in the 1980s went through what can only be called an analog of some of the potential kinds of issues that we would be faced with in global urbanisation. It came in the form of a rapid drop in the value of agricultural land, which literally dropped 50 per cent in less than five years. This caused bankruptcy anmd a loss of 250,000 farms from a base of a little over 1.5 million farmers in the United States. This had many catastrophic effects within the rural communities. Some communities have virtually disappeared. We saw a loss of a total infrastructure in the way in which that system provided goods and services, storage, transportation and processing the products of agriculture and timber industries.

If we were to ask this question in areas where today we see a significant shifting from tropical forests to other land uses, many of them focused on the provision of some agricultural commodity, and there was no support system, no infrastructure being developed to enable those communities that are on what they call the frontiers to continue to survive, and reintensify those areas most suitable for agriculture and bring back or help stabilise some of the areas that were marginal agriculture and maybe suitable for some of the systems we have just been talking about, then we would see one of these major global urbanisations as a result of shifting away from some frontier type agricultural systems. In the US we have just seen the loss of a quarter of a million farmers who had to migrate into urban areas. They could have been productively employed in the US agricultural sector, but at that time we had no infrastructure in place to maintain them there. That is simply an anecdote. I perceive that we have some discussion available to us in the future here.

This might be a convenient point at which to ask each of today's presenters of papers to make any additional comments they may wish to address to the Plenary.

Dr SINHA: I would like to talk about the issue of population and the maintenance of food production to meet that requirement. While it is true that so far the world has maintained a better growth rate of food production, it should be said that that came in the West from very intensive use of commercial energy. Whereas in the East largely it has been through the use of non-commercial energy, using cattle, for example, as a major source of power.

The fact remains that we will have to meet the requirements for food, which reqiuirement will increase. It was argued at a recent conference I attended that agriculture has become a liability to the world. If agriculture becomes a liability to the human race, what are the alternatives for food? No doubt there has to be improvement in productivity, which means that intensive agriculture has to stay whether we like it or not.

While ensuring food production, we have touched on how to minimise gas emissions. That is where the efficiency of the system comes into play, whether by using fertilisers or cultivation practices or use of specific varieties. This of course has happened in the past. It is bound to happen in future because we have to be optimistic and should be able to meet these goals. To give a simple example, with an increase of temperature of 2deg, the fertility of the plant decreases. Germ plasm is available which is far more tolerant. It is a recognition of that which should be incorporated in the breeding programs. We should recognise genetic variability and make use of it in those programs.

Dr McKEON: The issue of management of extensive systems and how agroforestry might be involved is difficult, because we are concerned with production; those systems have to feed people. As has been correctly pointed out by Dr Sauerbeck, we reach a new equilibrium in terms of carbon and cannot return to the virgin state of a forest with its wood and its non-edible leaves. That means we have to live with a system that has less carbon stored in it, even though in terms of the products that we are interested in it is producing more.

Where you have an erosion of such a system, to use that word metaphorically, in the case of continuous broadacre cropping where we are exporting nitrogen each year, eventually you will get declines in yield and declines in the protein content of, say, wheat, which have both economic and dietary consequences. So there is a need for integration of systems which allow us to come back to that plateau of operation. One of them is nitrogen fertilisers, which we cannot keep doing in terms of their energy consequences. Therefore, we look to pasture legumes and perhaps in agroforestry we look to a leguminous tree phase where those options are available. In extensive systems we are not actually exporting that much in terms of the animals that are going away; perhaps phosphorous is one that people are worried about.

The export out of the system is probably the loss of carbon through soil erosion, and also perhaps through exposure of the soil, with higher soil temperatures producing a greater breakdown. Once again, it would seem that we are on a continuous rundown of that system and the functioning of that system. The integration that we will be looking for is something that is able to sustain the system at a level of operation over periods that are longer than our own generation time.

I take this opportunity to deal with Henry's comment about urban population. It may not be appreciated that Australia is probably one of the most urbanised countries, but the myth is that we are all somehow linked to the bush and the outback. One of the major problems we have had in convincing producers to use, say, seasonal forecasts is the fact that the effects are mostly in the bush and that droughts do not usually hit cities. Therefore, the media are not interested in pushing that out through the national newspapers. In 1987 you found El Nino reported on page 10. It is only when we have had a major drought in the city that you find El Nino described on page one of the newspapers.

One might say we cannot do much about energy expenditure; agriculture cannot solve the problem of energy use in the cities; we cannot compensate for it, so we will feel the harsh winds of climate change in agriculture. But we have a communication problem with Henry's urbanisation in that the city may not care, unless its food supply is directly affected. I would say that that is a problem that has already occurred due to urbanisation and is likely to get worse. We will have trouble convincing our city comrades to reduce their energy use and CO_2 into the atmosphere if we are wearing the effects of it.

Dr DIXON: One factor that is driving Track Three is that 70 per cent of the world's terrestrial photosynthesis happens in forest systems. Also two-thirds of the carbon stocks in the terrestrial biosphere happen in forest systems. Therefore, it is a significant part of the global carbon cycle, and the perturbations in that cycle are what brings this group together.

Secondly, I would argue that somewhere around 3 billion resource-poor farmers live essentially in tropical latitudes within or adjacent to forest systems. It is virtually impossible to separate production of agronomic or horticultural crops from tree crops in many of these systems. The way that we practise agriculture in boreal or temperate biomes is really quite different from the way we do so in some tropical latitudes.

Miko KIRSCHBAUM: Could I ask the speakers whether they can think in their respective areas of one very good example of a no-regrets option, if there is one - an option where you could reduce greenhouse gas emissions while at the same time having a profitable change? Could they also say whether such opportunities are being implemented at a rapid rate or give a typical example as to why it may not be, giving typical impediments to its implementation?

Dr McKEON: A very good question, Miko! On 20 per cent of our grazing lands, we could reduce the number of stock by 20 per cent, thus reducing the amount of methane. We would store perhaps another tonne of carbon per hectare as a one-off acquisition. That would probably increase the production from those systems. We are attempting to implement that at the moment. For example, in Western Queensland in our sheep country we are attempting to get producers to use lower stocking rates. Sheep are a very good example. Sheep continue to put on a product, wool, until they die. Therefore, what limits the number of animals, the stocking rate, is how long you can keep them alive. There are options there in reduction of animals per hectare, and we know that that will bring about more product and will have the system operating better. That applies to about 20 per cent of our grazing lands. So you can make that calculation for me if you like.

Dr KIRSCHBAUM: Then why don't farmers do it?

Dr McKEON: Good question! Why do systems degrade? If you had no year to year variation in climate, a producer would see the impact of what he does and would feel it in his wallet. He would say, "I am overstocked. I have not produced as much as I did last year. Therefore, if I have fewer animals I will come back to that optimal point". But instead each year is not constant and we have high year to year variability. Farmers cannot recognise the effects of year to year variability in climate as it affects their production from the effects that their management may have had on that production. That is our problem in extensive systems. It is a straight result of the climatic variability. Therefore, it is very difficult to win that argument.

In intensive agriculture - I am thinking of cotton pest management - where everything is controlled by the farmer, it is much easier to see the result of the implementation of a management strategy, in that case reducing pesticides. As a consequence it is much easier to get adoption in that form of intensive agricultural industry.

Dr SINHA: I would like to give two specific examples. Today we recognise that intercropping as a system provides advantage in terms of adaptability. The farmers have been using it for ages. Now we are working much more to justify it or improve it. That will not be the kind of technology that has any regrets. Secondly, we are working towards improving the efficiency of the inputs, such as fertiliser application. That is an objective in any case. So there won't be any regrets if we continue to do that.

Dr KIRSCHBAUM: Intercropping is one of those examples that I have never heard anything bad about, yet farmers in India and everywhere move away from it.

Dr SINHA: No, I think you will find they are already back to it, despite scientists saying that they should grow from one crop.

CHAIR: I close this session by thanking the three speakers. They have done an excellent job in laying the groundwork for the next two or three days. They have helped identify the tracks and have been willing to present some very difficult information in such a way that we can begin to assimilate it into what we need to do.

(END DAY ONE)

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DAY TWO PLENARY

TRACK ONE: INTENSIVE AGRICULTURE

CHAIR: Dr Gordon NEISH (Canada)

(Rapporteur: **Dr Tom DENMEAD)**

Dr DENMEAD outlined the discussion that had taken place during Track One on intensive agriculture.

He pointed out that its Chairman, Prof. Henry Nix, had suggested that the group had three purposes. One was to resolve some of the contentions about intensive agriculture as a source or sink for greenhouse gases, and the second was to arrive at some quantification of source sink strengths.Thirdly, the group would be required to recommend okay or adaptive strategies for sustainable agriculture, bearing in mind social, cultural and economic aspects.

The Chairman had urged the group to do some lateral thinking. He suggested that it might be fine to undertake an exercise in which existing systems were fine-tuned, but what was really needed were some new strategies.

Dr Denmead said he was not sure the group had addressed all those aspects, but at least it had had good advice from Prof. Nix at at the start.

The group had had an informal presentation from Michael Gibbs (US EPA) which bore on Professor Nix's advice. What was suggested was a framework for preparing and comparing strategies for minimising emissions, based on a concept of emissions per unit product. An example was given of its application to livestock production, but Dr Denmead thought it would apply to other agricultural systems. Systems were categorised and the impacts of various management practices were superimposed upon them. The framework seemed to have promise, but Dr Denmead had not seen a number at the end to say that it was or was not an okay system. Draft summaries of the approach were available to Workshop participants.

The main business of the session considered two case studies involve GHG emissions, one from an intensive dairy farming system, and one from intensive agricultural systems. The case study for the intensive dairy farming system was presented by Dr Steve Jarvis (UK), who dealt with emissions of methane and nitrous oxide from a representative dairy farm in South West England which has more than 1,000mm rainfall and a grassland production system.

Questions were asked about the representativeness of this. For instance, it was pointed out that more than 50 per cent of dairy cattle are located in India and Africa, so that perhaps this was not the total example. Comment was made that were this system not to be propped up by subsidies it might not exist, and the question was asked as to what was the future of such systems. How representative or indicative were they for future developments?

Dr Jarvis had pointed out that in the UK methane from agriculture is about 34 per cent - about a third of the national contribution - and most of that (some 70 per cent) came from animals. Dr Jarvis had pointed to how losses from ruminants occurred, as well as losses from dirty water and wastes which occurred when the animals were stored indoors, or where wastes were stored and then returned to the land. Some 60 per cent of the methane losses occurred directly from the animals, and about 40 per cent from the wastes. Unknowns were the contributions of soils and whether they were sources or sinks for methane? This raised technical questions which were unanswered and were worth pursuing.

Nitrous oxide emissions were also instanced by Dr Jarvis, who pointed out that grasslands made about 31 per cent of all UK emissions, and about 50 per cent of the total contribution from agriculture; the other half roughly came from tillage systems.

The group went through possible sources of nitrous oxide and the mechanisms of loss. Accounting was done for losses from the swards and from wastes. A figure of some 400kg of nitrous oxygen/nitrogen was lost from the swards, and about 138kg from the wastes, plus the mineral nitrogen that was applied.

Dr Denmead said that the group then considered control emissions, and Dr Davis had pointed to certain possibilities, bearing in mind that for methane 60 per cent of the loss is from animals and 40 per cent from the wastes. Dr Davis had discussed possible strategies concerned with dietary efficiency, feed formulations, feed treatments, bio-engineering to change the microbial balance in the animals' guts, and he had dealt with possibilities for controlling emissions from the wastes and from the dirty water.

The same exercise was undertaken for nitrous oxide. Dr Davis had pointed out that one could effect controls through the timing and amount of fertiliser application, and also through the type of such application. Nitrates produced a lot of nitrous oxide from denitrification and these were the biggest contributor in terms of fertiliser types to nitrous oxide losses. In trying to measure these losses, there was a huge day to day variation. This cried out for new techniques for people to get to grips with the problem. One wanted to know how much was occurring and what made it occur. Temperature, moisture, and nitrate levels were seen as important in this process.

Dr Davis had pointed to uncertainties in grazing and to a need to measure losses occurring while animals were grazing, requiring perhaps new techniques. There was a question about losses from other sources than the ruminants - emissions from the wastes and soils, and whether soils were sources or sinks.

There were problems to be researched on the effects of management, and a real need for new methodologies for direct measurement of gas fluxes in the system.

In regard to nitrous oxide, problems were seen to be the variability of these processes, and a way was needed to handle them. One technique in estimating nitrous oxide losses if not measured directly was to infer them from the total nitrogen loss during denitrification, but this assumed a certain constant ratio between nitrous oxide produced to nitrogen produced. The establishment of that ratio or the way in which it varied needed a lot of research. There was a need for appropriate methods for direct measurement of fluxes in such situations.

An interesting point in the group's discussions made by Dr Sauerbeck was that all the nitrogen added in agriculture eventually ended up in denitrification, with some nitrous oxide production. It may not be directly in the agricultural system where the nitrogen is applied, but sooner or later after its passage through various forms, including us, nitrous oxide would be produced as an end product. It raised the question of where the emphasis should be - should one look at processes of, say, nitrous oxide emission directly from agricultural systems, or at the fate of the end products of agriculture.

Dr Denmead said the second presentation to the group was from Dr John Freney, who dealt with GHG emissions from intensive agricultural systems, and mainly with nitrous oxide emissions. Dr Freney had pointed out that most of the nitrous oxide was produced in soils - about 90 per cent of the biospheric emissions were believed to come from microbiological processes in soils. He had outlined the courses of nitrous oxide production, and pointed out that it was produced during nitrification, the conversion of ammonia to nitrate, and in denitrification - the process of breakdown of nitrate back to molecular nitrogen, with some nitrous oxide produced in the process.

In cropping systems, Dr Freney believed that nitrification was as important as denitrification. Strategies to control nitrous oxide emissions had to deal with both these states.

Dr Freney had dealt with possible mitigation strategies for nitrous oxides and gave a number of examples. There were a number of possibilities, including using correct forms, rates and times of application of fertilisers; providing a continuous plant cover, so that nitrogen was not sitting around in the system waiting for plants to take it up. He gave a good example from cotton farming where nitrogen was applied several months ahead of the time that it was needed, mainly because of the cheapness of the product at that time and the farmer's availability to do the operation. But only a few per cent of that nitrogen remained at the time when it was needed.

Mitigation strategies included nitrification inhibitors, correct tillage and irrigation practices, reductions in biomass burning - not so much from nitrous oxide emitted in the smoke or plumes from such burning, but because of the subsequent mineralisation and nitrogen changes that take place in soil after burning. Dr Freney felt that this was a useful option to reduce nitrous oxide emissions.

Dr Freney felt that reducing animal excretion was one possibility, on which he did not elaborate; adding lime was thought to be another possibility.

A good deal of Dr Freney's remarks were devoted to the possibilities for nitrification inhibitors, particularly the use of coated calcium carbide as an inhibitor of the step involving nitrification of ammonia to nitrate. A number of examples were given from various crops, showing that this was potentially a very useful practice. It could be that all nitrification could be stopped with the process and virtually all nitrous oxide emission inhibited, but there were some difficulties.

Dr Freney made the point that by using such techniques the farmer could not only do everybody else a favour but could benefit himself. The approach was attractive because it saved nitrogen fertiliser costs because less needed to be applied, but at the same time it restricted emissions of nitrous oxide.

Dr Denmead told the Plenary Session that the point was taken up in discussion that in order to make practices for reducing emissions attractive to farmers, they had to see an economic benefit in them. The general feeling was that they were not particularly concerned with how much methane or nitrous oxide might be going into the atmosphere, but if it were economically feasible it would lead them to adopt new practices.

Dr Freney pointed to effects from volatilisation of ammonia as there could be losses of nitrogen as ammonia into the atmosphere. Eventually it returned to the earth as wet or dry deposition, and this could be nitrified and carried on. It was not a simple problem. Even if the formation of nitrate were restricted initially, it could still be formed from the disperson of nitrogen into the atmosphere and its subsequent return to earth.

The discussion raised a number of interesting points, some of which centred on the proposition as to whether one could devise a system that would minimise emissions, and perhaps even cut them out altogether. The answer is that probably one could, but it had to be done in consultation not only with farmers but also with fertiliser companies, which had some practices that militated against minimising emissions, and with agronomic advisers.

A final point that was raised was that there was a danger in taking technologies and transferring them from so-called developed agricultural countries such as the USA and Australia to developing countries. Examples given were practices involved in sowing rice, where it was thought that technologies operated here promoted a lot of nitrous oxide production and that it would be bad for these to be copied in Asia.

DISCUSSION

John CULLEY (Agriculture Canada): In our part of the world nitrification inhibitors have been singularly unsuccessful in any kind of economic or demonstrable value, except under irrigated dryland conditions. I am interested to know whether experience with such inhibitors elsewhere has been very successful, as it is a fairly high cost way to go.

Dr DENMEAD: John Freney pointed out that in terms of costs of using calcium carbide at present the coating cost about $30 per hectare and saved some $80 or $90 per hectare in fertiliser costs. He suspected that when the process was developed commercially costs might be different.

Dr John FRENEY: I think Tom has made the important points. In irrigated cotton we put on 30kg of coated calcium carbide per hectare. This along with a dressing of 60kg of nitrogen per hectare gave the same yield as a cotton crop receiving 180kg of nitrogren per hectare without the calcium carbide. In other words, the dressing of 30kg of calcium carbide costing 40c per kg saved 120kg of nitrogen costing 80c per kg. One has $12 per hectare for the cost of the calcium carbide versus $96 per hectare saving in nitrogen. But the calcium carbide has to be coated with wax, and we are not sure how much that will cost. One can bet that whatever manufacturer gets holds of the process he will charge so that the farmer will probably end up paying for the inhibitor what he would have paid for the fertiliser. This is a matter where the farmer and the fertiliser manufacturer could get together.

Dr SAUERBECK (Germany): I think there was also agreement in our group that in regard to N_20 releases from intensive agricultural systems we depend on an improved nitrogen budget in our systems. This means that we not only require a much more balance-oriented management but more cycle-oriented nitrogen management.

I gave an example of what we are trying in Germany at present. Our Government will probably issue something that can be translated into a fertiliser application directive, which enforces a rough nitrogen balance, either farm-based or even field-based, to be drawn up by the farmers themselves. It is not so much a control measure as an educative measure to teach the farmers to make them aware of the sometimes tremendous balance excesses which they produce if they compare the amount of nitrogen that is being removed with the produce and the overall amount of nitrogen that is being introduced by either mineral fertilisers or farm wastes. We hope this may help to improve the overall situation.

Another part of the application directive deals with the legal enforcement that nitrogen, irrespective of the source, be it farm manure or mineral fertilisers, cannot be applied any more at the farmer's own will, but he has to do this only at a time when it can be assumed that the nitrogen fertiliser is being used up by the growing or just-sown plant in order to reduce the losses.

I feel that this balance point of view should be implanted in the minds of our farmers, and that it should also be enforced, if there is no other possibility, that nitrogen fertilisers can only be applied once we have a reasonably good guarantee that it is used by the following plant crop.

Dr NEUE (Philippines): I think we should look at the total system. If we reduce the emission in the farmer's field but increase it in the households, it doesn't help globally at all. One has to calculate whether we can reduce it as a total budget, or whether we should distribute it differently, because then it doesn't make any difference where you lose it. The question is, can one really reduce nitrous oxide emission in total, or is it only shifting it from one source to the other?

Dr DENMEAD: This is something that needs more work. I do not feel able to answer the question, but somebody may volunteer from the audience.

Dr SAUERBECK: I would like to challenge the statement that 90 per cent of the N_2O comes from soils. This figure can be found in the literature, but I cannot believe that all the 90 per cent comes from the soils. It may result from the nitrogen applied to the soils, but a large amount of the N_2O enters the groundwater and is released somewhere else. And quite a bit of the nitrogen that we introduce into our agriculture is released later on from completely different environmental compartments, including the oceans. So I think the statement that 90 per cent of the N_2O formation results from denitrification in soils probably has to be reconsidered and changed.

Dr DENMEAD: I think the 90 per cent figure comes from Alex Bouwman's book. I suppose it should be said that while we know that nitrous oxide is increasing in the atmosphere, probably the sources of nitrous oxide are the most uncertain of all these greenhouse gases. For instance, the contention that tropical forest soils are the biggest contributors of nitrous oxide to the atmosphere is based on something less than a thousand spot chamber measurements, each of about 20-30 minutes duration. It is really not enough to build a global budget on. I take the point that there must be some uncertainty in that figure.

I should say that factors of uncertainty associated with these sources vary from 2 to 5 - this is quite common.

Gary EVANS (USA): In regard to the discussion of methane specifically from dairy operations, was there any discussion about use of some of the new rumen manipulation chelating chemicals, or even moving into the area of some of the naturally occurring hormones as a method for increasing yield per unit of production?

Dr DENMEAD: My memory is that those things were mentioned as options but were not discussed in any detail. Perhaps we should refer back to Steve Jarvis for the definitive answer.

Dr Steve JARVIS (United Kingdom): I may have to pass this one to Ron Leng, but certainly these were mentioned as possibilities. There are side issues that might divert the intention of using these as possibilities. There are all sorts of arguments against using extra hormones in food production, which might not go too well.

Prof. Ron LENG (University of New England): I think we have to take a much more global view. Each of us tends to express our own opinions from our own countries and our own intensive agriculture. If we look at where large ruminants are, the majority are in forage-based systems, large numbers are in developing countries, and they are relatively slow-growing and slow-producing. Although the technology we refer to of enhancing rumen fermentation is more easily applied in the intensive production systems, and while this accounts for a lot of product, they do not account generally for a lot of methane. It is much more sensible to go down the road of increasing efficiency of the slow-producing animals than it is to go for the high input areas, because we have a lot more potential if we are the worst scenario for methane production - that is, a grazing animal or an animal eating straw, with a highly inefficient rumen and a highly inefficient utilisation of that straw.

By putting those deficiencies right, we can decrease methane production by up to 75 per cent. We can't do that across all animals. When one comes to decreasing methane production in the intensive production systems, the potential is only perhaps 10 per cent or less. So most animals are in those low-producing system, and therefore in my opinion they should be the targets for any systems of amelioration of methane production, because we can get the biggest response. If we could just get the 80 million bullocks in India with an efficient rumen we could halve methane production from those animals. Those are the mathematics that I like to deal with.

Dr DENMEAD: Professor Leng made those points in discussion and I apologise for not including them in my summary.

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TRACK TWO - EXTENSIVE AGRICULTURE

CHAIR: Dr Gordon NEISH (Canada)

(Rapporteur: **Dr Will STEFFEN**)

Dr STEFFEN reported back to Plenary session on the discussions in Track Two (Extensive Agriculture), He referred to a presentation made by Dr Mark Howden of the Bureau of Rural Resources and a slide giving the results of work using a model called Grassman relating to productivity of extensive agricultural systems, primarily in Queensland. The model was modified to look at possible strategies and responses of the system for reducing GHG emissions.

The objective was to develop a system which allowed the identification of management options for the northern beef cattle industry which reduced GHG emissions while maintaining farm productivity. They focused on three possible management strategies for reducing GHG emissions

- stocking rate
- tree clearing method
- fire frequency.

The first looked at kg of animal per hectare per year, plotted against net emission of CO_2 equivalents of greenhouse gases. The aim was to get a rough estimate as to how to reduce GHG emissions simply by moving stocking rates down to optimum level. There was promise of a fairly simple strategy for reducing GHG emissions and one that should be popular as it also increased productivity and profitability.

The group also looked at fire frequency in extensive areas. Dr Howden had examined different fire frequencies from burning every year, second, third year and so on down to a system that is never burnt. Fire was an important management tool for a number of reasons, particularly for keeping down the unwanted woody species on a property. In practical terms there was little option for varying the position in terms of GHG emissions. The group agreed that such a proposition was not as promising as stocking rates in examining strategoes for GHG emission reductions.

Dr Howden also dealt with effects of clearing and the type of methodology used. Two clearing methods were compared involving uncleared land. One method involved mechanical clearing using a bulldozer to remove vegetation. The problem was that regrowth was relatively rapid, so one had to go back in after seven, nine or ten years and do it again.

Grassland and a chemical means of removing woody vegetation was far more efficient and long term, and resulted in fewer GHG emissions, because it was not necessary to burn it every so many years when clearing. There was also a marginal increase in productivity. Therefore, there was some possibility in varying clearing techniques for reducing GHG emissions. One caveat was that not much clearing of treed land took place any more, and secondly there was the problem of deadwood and how one should consider it. Should it be considered as storage, albeit temporary, or as potential GHG emissions some time down the track?

The general conclusion from the three strategies was that stocking rates seemed to be the most promising method of offering fairly quick and straightforward ways of reducing GHG emissions.

Gaps were identified by Dr Howden that should be looked at to improve the methodology and reduce the uncertanties in conclusions. A lot more measurements were required and discussion took place in the group on this aspect.

It was pointed out that if the sink strength of methane was varied by 50% it would result in only about 10 per cent change in the net emission of CH_4 from the system. There was some limitation but it was still worth looking at. A number of contributors to the discussion pointed to the quality of forage in determining the amount of methane emissions.

Dr Steffen referred to a contribution to the group by Philip Simms from work at the Southern Plains Research Station in Oklahama. This involved a case study of how to move to a sustainable extensive agricultural system and implications for GHG emissions. The objective of the work was to increase the efficiency of red meat production in range resource utilisation through integrated management of energy, flow, nutrient cycling and hydrologic dynamics in production systems in Oklahoma. It was a systems approach to looking at an extensive agricultural production system. It moved back a little to intensive systems in terms of being able to do a little more in the way of manipulation and adding more inputs.

Philip Simms' work took an interesting look at monthly forage production, which gave an idea of the great variability of extensive systems compared to intensive agricultural systems. Dr Steffen referred to a number of overheads illustrating the variability system employed at Southern Plains. However, variability could lead to boom and bust cycles, with good years followed by bad. This could be avoided by building systems that were far more resilient, moving towards sustainability and at the same time reducing GHG emissions. Philip Simms showed a good understanding of the systems and was seeking to devise a much more robust system that was able to withstand booms and busts in climatic variables.

Dr Steffen showed a further slide illustrating impacts on agriculture and referred to the difficulties of implementing mitigation strategies. As one moved to trans-scientific questions - those that were outside the realm of science - into realms of economics, politics and so on, certain things had been identified by Philip Simms. These included increasing environmental concern about what was happening to our production systems and our natural systems; increasing government regulation to make sure that we did not do the wrong things; and decreasing agricultural subsidies.

The group had dealt with the question of sustainability, in which there was a lot of confusion about definition. Dr Steffen drew attention to ecological sustainability as opposed to economic sustainability and the relationship to GHG emissions. The obvious question was whether there were net emissions from systems managed ecologically sustainably. The obvious answer was yes, because if a system were defined as being sustainably managed in that it had inputs equal to outputs, there should be no net GHG emissions, but that was not quite the case.

Dr Steffen instanced the Grassman model in which the carbon was in balance but there were still net emissions contributing to global warming. The reason was that the system took in CO_2 and pushed out CH_4 preferentially. Although one atom of carbon went in and one atom went out, there were gases with different radiative properties. The net effect was a net warming of the atmophere due to the replacement of CH_4 for CO_2. The rate of that warming depended on the equivalent value put on methane, and the number to be put on that was still a matter for discussion. It was subject to some uncertainty.

Another interesting question that arose was that some extensive agricultural areas may not be producing more GHG emissions at present than they produced in their natural state. Several participants from North American pointed out that in the natural state the prairielands of North America were grazed by large ruminants - by bison. Cattle had now been substituted for bison, and the interesting question was, what were the methane emissions from bison, and whether there were any significant difference in GHG emissions now compared with what they were before European-style grazing came to the plains of the USA and Canada. The question needed to be addressed.

Dr Steffen concluded by stressing the trans-scientific areas that would impinge on any proposed mitigation strategies. The first was economic. One would not get farmers and graziers to do anything that was not in their best interests. The Grassman simulations had identified a strategy which at the same time improved the productivity and profitability of a system, while reducing GHG emissions and moving to sustainability.

There were also social aspects to be considered. In the less developed countries economic arguments may not be so persuasive. There may be areas where the number of animals equals the status of the person who happens to own them. You may be able to prove that it is in his economic interest to reduce his number of cattle, but it may not be in his social interest to do so. That could also present a problem in reducing stocking rates.

The third matter was psychological. One did not need to go to less developed countries but had only to go to the outback of Australia. People in the bush did not like to be told by bureaucrats what to do. One had to worry about the psychology of how people changed and how one should approach such a change. Edicts from Canberra, Washington DC, Nairobi or wherever were not very popular, so one had to do one's homework to ensure that what was done was for the benefit of the people one was seeking to change.

It was important to identify these trans-scientific issues when talking about mitigation. One should know what one was talking about in terms of amounts and one should get quantititative. Secondly, one had to identify management strategies for emission reductions, and Dr Steffen hoped future speakers would bring up a few more for consideration.

It was important to look at the most promising management strategies and quantify the potential reductions. Once one had an idea of context and how much more it could be reduced, one would have a much better idea of just what extensive agriculture can do in the way of mitigation.

Dr Steffen emphasised that an effort had to be made to identify important social, economic and psychological barriers to change, and at least point to areas where input was required from social scientists. Finally, it was important to identify and rank critical research areas where more work was needed in order to reduce uncertainties. It was no good saying that more research was required before one could say anything. One had to do both. One had to propose strategies which could be done now, the so-called no-regrets stratagies, but Dr Steffen thought those present would be remiss in their duties if they did not identify what was needed to be done to reduce the uncertainties and to recommend even better strategies in future.

DISCUSSION

Prof. SAUERBECK (Germany): I did not understand the straightforward relationship between stocking rate and greenhouse emission. Perhaps that could be explained.

Dr Greg McKEON: The system that we are dealing with there is a big production system where the main product involves how much liveweight is put on a steer, a castrated male animal. As you increase the stocking rate on a pasture, that is, the number of animals per hectare, the actual weight gain per animal declines in a linear fashion. If you then calculate the weight gain per hectare, you get a quadratic relationship and we would say that the peak there is the maximum production of the system.

People use the term "carrying capacity" when what they are really referring to is the capacity of the grass base to withstand that level of grazing. What actually happens when you change the breed of animals is that you can get out of balance between the capacity of the grasses to take pressure and one's animals to gain or hold weight under levels of high utilisation. That is why one gets curvilinear or quadratic type relationships when dealing with production systems based on the live weight of animals. As a result, as you increase the number of animals the weight gain past that optimum point per animal declines, but one is still producing emissions because one is still converting grass through the animals and producing methane. Therefore, methane emissions continue to rise.

Dr DIXON (USA): Could you elaborate on any discussion you had this morning in regard to developing common methodologies to compare the biologic/economic options for mitigating GHG emissions? Do any models come to mind in discussion of that topic?

Dr STEFFEN: No, we have not yet done so, but that is a good point. We should do so in the future.

Dr DIXON: I am not sure that it is a job that any one individual could tackle. This IPCC/AFOS forum is probably one of the few forums where enough people from enough different countries and with different backgrounds and levels of expertise get together to develop these methodologies. I merely make the comment that I would encourage this body to take a close look at that aspect this week.

Dr NEUE (Philippines): I am still a little concerned about the subject of fire. One has just heard the comment that it has to be done otherwise the system cannot be maintained. Can you explain whether this is the case just because those concerned have to burn?

Dr Mark HOWDEN (Australia): In the systems that we are looking at here, fire has several purposes. The main one is to control the growth of shrubs and trees because more shrubs and trees mean less grass, which in turn means less production from the system.

It also has other purposes. One is to counter the effects of patch grazing. This is where animals go back to the same patch year after year to eat, and because they keep on grazing that area it becomes overgrazed very quickly. They keep on grazing that area because it has young, green growth, but with bad effects on the grass itself. Therefore, there is that sort of purpose.

One can also put a fire through grassland to increase the amount of green pick, so that is just young regrowth which has high quality and aids low-weight gain. It can also be used to move rank grass. In some tropical areas there can be large growths of grass which after a while loses quality and is effectively useless in terms of live weight gain for animals. By removing that one can get access to pastures and obtain more grass growth from that area. Therefore, it has multiple purposes. It is very much an integral part of the management of these areas. Apart from management fires, one has of course accidental fires. These might spread from a neighbour's property or might come from lightning strikes. Fire is part of these ecosystems and we are stuck with it basically.

Dr NEUE: Are you saying that fire is the only option you have and that there is no other option?

Dr HOWDEN: In different systems fire becomes a different priority. If one is dealing with forest systems in more tropical areas, the situation could well be different.

Dr McKEON: The grasses used in such native systems are well adapted to fire. That is why it becomes a self-fulfilling exercise to maintain those grasses by fire. If we wanted to step outside the system, we would have to say that it is some other form of production. It may involve grass species, such as silent pastures, which will require more inputs to put them into the system. It may be some form of fodder tree shrub where one would not want a fire going through. We would have to break out of the paradigm that has constrained us within that native pasture system.

Most of the time when we try to work those out in terms of experimental situations, we find that the economics are such that they are hard to implement because we are competing against a native system that already exists - a natural system which the farmer got for free or just for the price of taking up the land. A change in that system requires an economic input, if not other inputs.

Dr Tim MOUNT (Cornell University, USA): In the US there is a saying that if the country had been developed from west to east, nobody would have bothered to get to Massachusetts! Cornell is in an area where land was put into agriculture in the early nineteenth century and is going out. What sort of rules are used in Australia to determine which land is usable for agriculture and which land is not?

Dr STEFFEN: I do not know whether there are any.

Dr MOUNT: Well, should there be some rules?

Dr STEFFEN: There is growing agreement that there should be some rules, but there is still some controversy as to what those rules should be.

Dr McKEON: In our situation much of those lands we are talking about are held by the Government and used under leasehold. There is legislation regarding the number of animals that can be carried, and permits are required for tree clearing. Although our political forefathers had the foresight to put these things in legislation, essentially these things are untried in terms of people being constrained. It is only recently with the environmental awareness movement that we are beginning to use that sort of legislation. In fact, it does not have to be used because most people want to look after their land anyway.

There are always people who are innovative, so the margin of cropping will always go out to that low rainfall boundary. There will be failure and it will come back in. Sadly, because eastern Australia is dominated by the southern oscillation, as I said yesterday, there are periods of La Nina conditions where you get high rainfall. The 1950s would be an example. These tend to be periods of successful crop development or expansion of agriculture by sowing legumes or removing trees. During drier or more normal times these turn out to be failures. There are always people on the edge trying new ideas. They are successful in favourable climatic conditions, but are unsuccessful in unfavourable conditions. As yet we have not determined a way of linking that climate through legislation to enforce the view that "Thou shalt not plough past this isohyet".

CHAIR: It is fair to say that Australia is not the only country which does not necessarily have all the controls that might be appropriate as to where agriculture shoudl be pursued and where it should not. It is an ongoing concern in many countries as to whether land that is traditionally used for certain purposes is being appropriately used.

Dr SAUERBECK: Did you deal specifically with the problem of nutrient balance, especially nitrogen balance, in your extensive systems on the short, medium and long term timescale?

Dr STEFFEN: No. Nitrogen did come in to some extent in the simulations of Grassman, particularly in biomass burning. If, for example, you look at different types, there are different burning regimes. With no burning there are only carbon based compounds emitted. If burning starts, one gets nitrogen compounds. I think that it is a fairly small component compared with the intensive systems. We spent most of our time talking about carbon compounds. Very little attention was given to nitrogen compounds. I think that is perhaps a bit of a weakness because nitrogen compounds are important components of the emissions from biomass burning. I think that we will have to get a much better handle on what those compounds are and what are the concentrations. That is a big unknown, so Dr Sauerbeck has raised a good point.

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TRACK THREE - INTEGRATED SYSTEMS

CHAIR: Dr Gordon NEISH (Canada)

(Rapporteur: **Dr Miko KIRSCHBAUM**)

Dr KIRSCHBAUM, in reporting to the Plenary on discussions in the Track Three (Integrated System) workshop, said that the morning session had tried to derive a number of key statements that encapsulated the feeling of the group as to the importance of integrated systems, general greenhouse questions, and some main requirements.

The group discussed how much was known and how well one could quantify at this stage the potential contribution of agroforestry systems or integrated systems to mitigate greenhouse gas emissions. Although the group felt that there were in existence a number of reports, more information was requested. The process needed to be quantified in order to present to policy makers clear scenarios to be put into cost benefit analyses and present numbers as to how much carbon could be stored or the escape of carbon prevented by appropriate integrated systems.

To that end the group encouraged all countries to provide information available to them which could be comprised in appendices to the reports of the present meeting so that such quantification would be possible in future. Recognising that IPCCWGI was undertaking very similar work with a budgeting approach, Dr Kirschbaum said the morning session was conscious of the fact that there should be no duplication of effort, that the groups should not work at cross purposes, but that what was done should be coordinated.

Dr Kirschbaum referred in a slide to living systems that include woody perennial vegetation and generally sequester and conserve more carbon than systems consisting of annual species only. Recognising that there were shortages of data, he thought that the statement in general was true. Systems that contain trees or other woody perennials do contain more carbon, which was obviously true for the above-ground part. Also in the soil, an area that was much less well-understood, it was generally the case that more carbon was stored in undisturbed systems and the disturbance may be the most important aspect. As soon as soil was disturbed, that process then promoted a decomposition process in the soil in such a way that a large amount of the soil organic matter was lost and the carbon went to the atmopshere as CO_2.

Obviously soil disturbance was much more reduced in perennial vegetation for obvious reasons. In general, it was probably true to say that there was more scope for preventing carbon escape, preventing a drawdown in carbon-rich systems, than the converse - the buildup of carbon in carbon-poor systems, which came back to the question of soil disturbance.

A further important point stressed by Dr Kirschbaum was that integrated systems in general may be better able to adapt to a changing climate. That was derived from the general observation that complexity in systems led to greater stability in response to external forces that may cause the system to become unstable. The more complex the system, the more resilience systems in general appear to have. That appeared to be the case in agricultural systems as well. For example, with a variety of crops in a system in response to market forces, while one particular commodity may go through ups and downs and violent swings in price, the system was more buffered and farmers likely to have an income with fewer fluctuations. The same considerations applied to biological systems. Systems with a variety of species were likely to deal with a changed environment better than others. A monoculture was much more vulnerable. While recognising that that was probably true, Dr Kirschbaum said the group felt more information was warranted before such a statement could be made with certainty and generality.

It was concluded that agroforesty had a number of benefits - environmental, economic and social. Two were reductions in greenhouse gases and increasing the resilience of productive systems to climate change. Taking all these into account, it may be considered a no-regrets option. Basically one was trying to devise strategies to limit the emission of greenhouse gases. It had been said that no-regrets options should be the first ones to be pursued. So basically whether climate change was upon us or not, those no-regrets options were still a good idea. Agroforestry in the role of productive systems seemed a classical case, where there were so many benefits, many of them environmental. The system would be beneficial and implementation would be warranted in any case. Therefore, it was a prime target to be put forward to policy makers, since it did not rely on any assumptions or criticism from greenhouse sceptics.

There were a number of problems and Ros Prinsley had alluded to them at some length in the morning session. The adoption of integrated systems required a cooperative approach by farmers, scientists, extension officers and the population in general at all stages of design, implementation and refinement if they were to be successful. Such an approach was frequently missing and was seen as one of the major reasons why there had not been a greater adoption of agroforestry systems. The various stages in the link in the first instance from scientists who had conducted experiments showing that agroforestry is a good idea in particular systems to implementation at ground level were not all pursued with the same vigour. Therefore, the communication did not exist all the way along where it was needed, and implementation of the system did not always proceed.

Dr Kirschbaum put forward a plea that those present should concern themselves with that linkage all the way through. The message should be taken to the people who actually implement it on the ground, or the system would not be successful. In the case of agroforestry one needed to understand what were the driving forces for local people, why they do the things they do, why they may want to cut down trees, or why they may be reluctant to plant trees in their particular circumstances. The group's recommendation should be directed at those particular needs.

It was stressed that research and appropriate analytical tools were needed to identify appropriate integrated systems within developing and developed countries, with an emphasis on minimising greenhouse gas emissions. This was directed to the scientists and the policy makers in the first instance. It was recognised that more information was needed on how the systems could operate and on what was the most appropriate combination of elements. That was required to be addressed in each different environment and socio-economic group separately. Appropriate analytical tools were needed also, which referred to the development of models by which the information could be put together, and applied to a slightly different situation, possibly changing the relevant inputs. This effort needed to be channelled to different regions specifically. It was an area in which the cooperation between developing and developed countries could play a major role. There had to be two-way communication, directed at the needs of local farmers in their villages, combined with the most recent up-to-date scientific understanding. Only then would there be a chance of its being successful and of having an impact.

Recognising that integrated systems could respond to the threat of climate change, more research was needed to be able to make valid comparisons between various short term and long term response options. More research was needed in the relevant areas in terms of quantification. It was important to look at the matter over different timescales. It was important to take a long term view, and to look at what happened with carbon levels over 20, 50 or 100 years.

DISCUSSION

Dr Brian WALKER (CSIRO, Australia): While I agree that there will be integrated systems which will demonstrate an improved ability to withstand variations and changes under global change, I think that it is important not to make a statement that an increase in complexity per se will give you an increase in resilience, because that isn't true. There is a whole developing field of ecological theory which will debunk it. One does not want to underline what might be a good recommendation in general with recourse to slightly superficial ecological theory. I am sure that Miko is well aware of it, but simply to equate increased complexity with increased resilience is not true. Type of complexity is all-important.

Dr KIRSCHBAUM: Can you think of a way of rewording it in such a way that you would be happy with it? I guess it is true to say that on average at least the more complex a system is the more resilient it is.

Dr WHITE: No, that is not true. There is enough experimental evidence to show that you can increase the diversity of a system and increase its instability. It very much depends on the type of diversity and the type of complexity.

Dr KIRSCHBAUM: In certain specific instances I can see that that doesn't hold, but as a generalised statement?

Dr WHITE: I will give it some thought and come back to you on it.

Dr KIRSCHBAUM: Very well. I think that it is a very important area, and we need to get it right.

Dr SAUERBECK: I also was not completely satisfied with your generalised statements, Dr Kirschbaum. One of my remarks was similar to what Dr White said, but the other one involves the statement that systems which contain woody species would always sequester and store more carbon than other systems. So far as the storage is concerned, above ground and below ground carbon, both plant residue with roots or wood or soil organic matter, I agree, but carbon sequestration can be much higher in certain non-woody plant canopies. Maybe it is just a problem of mixing up terms, but at least carbon fixation can be much higher in some plant systems compared with perennials.

Dr KIRSCHBAUM: If you change a given environment to more or less woody species, can you think of instances where a system without the woody species would contain more carbon? If you compare a shrubby desert with a high productive, high rainfall grassland, I am sure the grassland would contain more carbon, but for the same environmental conditions and so on. And here we are talking about systems for a given environment, on a given farm or whatever.

Dr Peter COSTIGAN (UK): I would like to ask what is defined by agroforestry. You say that agroforestry could always be recommended as a no-regrets policy. That seems to be to be a rather sweeping statement. I accept that often growing trees may well be advantageous to a community in terms of fuel supplies and so on, and also sequestering more carbon, but how closely do the trees need to be integrated into the agriculture? The same benefits would seem often to come from having small woodlands associated with an area of land rather than having trees actually growing betwen cropped areas. It boils down to what you quite mean by agroforestry.

Dr KIRSCHBAUM: We were given two definitions this morning. One was very long and I can't remember it. The second one was very nice. It simply said: agroforestry means trees on farms for a purpose. I think that is a good definition.

I do not think one can say that in all circumstances agroforestry always is the preferred option. But in a very large number of circumstances, especially in lower input systems, it has so many other benefits that make it a preferred option.

According to my definition, a woodlot on a farm could still fall within the definition of agroforestry, but in general you get more benefits if you can integrate them. The soil protective properties of trees are only valid if you can integrate them physically more closely together.

Dr Daniel MURDIYARSO (Bogor Agriculture University, Indonesia): In terms of net primary production, I think the statement as to carbon sequestering in perennial terms is not quite clear. If one is talking of agroforestry, it should involve multilayer crops. In that case the net primary production can be very high and may sequester more carbon. But if it is a monolayer species, it is almost the same as annual crops.

Dr KIRSCHBAUM: We are not talking about annual primary production. Monocultural agriculture systems can have very high primary production, which completely turns over in one year, so nothing is stored anywhere, which in greenhouse terms is a major problem. It may not be a problem in any other terms. I cannot think of an example where it would not be true that an agroforestry system or a system incorporating perennial vegetation does not store more carbon than the equivalent system with only annual vegetation.

Prof. LENG (Australia): I would like to make a comment about agroforestry because I was unable to attend the agroforestry section. I think one of the aspects of agroforestry is that if you are to incorporate it into agriculture and increase productivity of, say, annuals, you have to have some radical and new thinking going into those systems. It is difficult to break down tradition in many of these areas. For instance, the utilisation of fodder trees has been pushed for many years, but very few areas of fodder trees have been actually planted, leucaena being the exception in the Philippines before it was wiped out.

I want to make people aware of the systems that are being developed largely in South America, and now in Vietnam where sugar cane with trees is being used in pig production, for instance, where the trees are providing the proteins and the cane is providing the energy in the form of sugar cane juice. This is radical new thinking, but 20 to 40 pigs fattened per hectare on sugar cane and tree forage is potentially possible. There is a tremendous opportunity there to use agroforestry, but it requires very radical new thinking.

The other new thinking that I believe has tremendous application is the system that is developing with prosopis in the more arid areas. The prosopis tree can produce more edible biomass than the savannas produce. Just a few trees per acre produce more edible biomass than the savannas produce themselves.

There is undoubtedly great opportunity in agroforestry, but it has to have radical thinking and it has to break away from traditional uses in agriculture.

Dr KIRSCHBAUM: Even though you weren't there, you very much mirrored what was said in this morning's session I think it is very true, and it partly inspired us to say that yes, we do need radical thinking but it cannot be arrived at by an august gathering such as this. It has to be arrived at by people working together at various levels who have some interest in the system. It does require radical thinking. One of the reasons giving to us today as to why agroforestry has not been incorporated more into Australia is that farmers traditionally see trees as enemies and cut them down when they see them. So it is a revolution in thinking for farmers to start bringing them back. It has made a lot of headway. According to Ros's figures, 25 per cent of farmers in Australia use agroforesty now in some form or other, which I feel is an encouragingly high figure. There is still 75 per cent to go! It requires a radical rethinking, there is no doubt about that.

Dr Karl VOLKMAR (Agriculture Canada): I am a little confused when I hear about this. I agree that agroforestry is probably an important component in improving the input of carbon in the soil, but then I hear people talking about burning as also being an optimal method of managing carbon, and there is very little flexibility in their talk. Is there any system in which agroforestry is less effective in sequestering carbon? Would a grassland system, for example, possibly be more efficient in the long term than an agroforesty system? Can you think of any environmental condition in which agroforestry may be less effective? I am just throwing out that question.

Dr KIRSCHBAUM: Certainly grasslands contain enormous amounts of carbon below ground. I do not want to be too categoric about it by saying that grasslands may never be able to match an agroforestry system. I know of no data in any comparison between pure grassland and agroforesty system to suggest that grassland was more productive, but I would not completely rule it out as a possibility.

If you make a comparison between what I am saying and what Greg and Mark were saying earlier, I guess there is one big difference. In agroforestry, as Professor Leng, was saying, we are talking in many ways about a revolution. We are thinking of farmers going to something totally different, totally at odds with what they have been doing in farming. It means a very different system. That is a major reason why we are not getting as far as we wish we could get.

I imagine Mark and Greg in the real world may be telling farmers to burn every three years instead of every two years, and there is a reasonable prospect of achieving that. Perhaps one could ask Greg and Mark if this would bring about a revolution in the grazier's thinking. Maybe then we would start talking about very different approaches, and maybe that is the real difference.

Dr McKEON: We haven't really compared our systems with what agroforestry could do. Let me give two examples. We have a large area of treeless grasslands called the Mitchell grasslands which are very fertile. The few measurements of roots that we do have suggest that there is certainly a large amount of root, perhaps 20 to 40 tonnes of dry matter, below the ground, and only a very small amount above ground, 1 to 2 tonnes per hectare. Into that system we have the invasion of an unwanted acacia, acacia nilotica, which was introduced as a shade tree. The two systems seem to be incompatible. The importance of the shade tree in that area is that it allows sheep to look after their lambs a lot better. It is a very hot part of the world so you can see some advantage in having a tree in that environment. But it spreads very rapidly and we lose grass, so we are worried that we cannot find a stable combination of a shade tree and our grassland. In preference we will take the grassland.

In the second case we have introduced leguminous fodder trees into the sorts of situation that Mark Howden was talking about into the spear grass zone. Because they are leguminous forage trees, not only do they benefit the animal directly, but also appear to put more nitrogen into the soil and probably store more carbon. Although we do not have the measurements, we do know that there is a shift in grass species to those species which are associated with more productive systems and also benefit from the shade provided by those trees.

We are re-evaluating our whole concept of tree-grass competition as a result of these trials. Perhaps there is a small proportion of trees that we can tolerate in our spear grass zone, which would increase production in terms of the grass but also offer a wood supply and all the other benefits one gets from trees. We are re-evaluating our empirical agricultural science in that regard.

To answer the question directly as to whether we could compare the two systems, we do not have those experimental methodologies yet. We have a lot of trouble in extending our forage legume systems because of the reaction people have towards trees, and also because of the investment required in setting that up in changing from the natural situation.

Prof. Vu Boi KIEM (Service Hydrometeorologique, Vietnam): We have no doubt that the adoption of the integrated or agroforestry system is a very useful sink against the greenhouse effect. I wish to comment that the agroforestry system is part of a wider conception, the system of cultivation. In our country we have a system of rice cultivation.

There have been many difficulties in implementing the cropping system for the peasants because of the technology. We need appropriate technology that is easy for the peasants to operate. It would be difficult to implement the agroforestry conception or cropping system within a big population of a developing country in the tropical and sub-tropical zones.

There are many problems to be faced for the future. In South East Asia we will be threatened by a rise in sea level. Many cultivated areas will be submerged by salt water. Our task for the future is to investigate an efficient and resilient cropping system to mitigate changes brought about by climatic conditions. The countries of South-East Asia must cooperate in future to improve the position and to investigate what can be done to assist the big mass of peasants in the region.

Dr KIRSCHBAUM: The Vietnam delegate told this morning's session about the more successful areas where agroforestry appears to have had multiple benefits, and Prof. Kiem appeared to be very supportive of the system. Perhaps others who were present at the Track 3 Workshop may like to add their comments.

Dr Gary EVANS (USA): I was not present for this morning's session, but I would like to ask whether most of the discussion focused on high canopy type tree composition with cropping systems, or whether you also discussed cropping systems where in essence you were using woody plants in a hedge or hedgerow combination. I was thinking of some work we did in Guam several years ago, where we used some of the leguminous shrubs, keeping them at a hedge level and using the clippings as one method of incorporating more organic matter on the surface with crops like cassava. We used the cassava primarily for swine production, but in this case we had the ability to retard a lot of the torrential rain problems by using the slower decaying wood from the clippings, as well as incorporating the leaves as another form of nitrogen.

Dr KIRSCHBAUM: We did not specifically address that in our discussion. It comes back to the question of having appropriate systems in appropriate situations. This morning Ros Prinsley gave a number of examples that span a wide range, from a few trees in a grazing area to a very intensive situation. One of her illustrations showed what looked like maize growing in a corridor with leucaenas growing on the sides several metres tall. It looked somewhat peculiar, rather different from the way in which we tend to think of agriculture. There is no doubt that agroforestry as a broad term can span a very wide range of different situations. But we did not specifically try to narrow the matter down.

Dr MANTON (Department of Meteorology, Research Centre, Melbourne, Australia): It would seem that the objective of agroforestry is to produce food, but with the primary objective of optimising the sequestration of carbon, whereas I assume the objective of agriculture is to produce food. But these days we want to produce food in an ecologically sustainable fashion, looking at the carbon and nitrogen cycles in particular. I would have thought that once you do that, the objective of agroforestry would be satisfied. If agroforestry is the solution to the agriculture problem, surely it should come out naturally. What is the difference between the objectives of agroforestry and agriculture in its own right?

Dr KIRSCHBAUM: You did not get a satisfactory answer yesterday and I am not sure whether you will get one today.

Dr MANTON: You are saying that the objective is really to sequester carbon? It is not obvious to me that setting it out as an objective is the way to generate food.

Dr KIRSCHBAUM: I think that there are three objectives in productive systems. One is to be productive, to produce food; one is to be sustainable, which I shall not attempt to define; and the third is to minimise the greenhouse global impact. With integrated systems I imagine that we are trying to find a compromise between those three. We try to integrate systems to make them more sustainable, which almost goes without saying.

Dr MANTON: What is "more sustainable"?

Dr KIRSCHBAUM: It is more sustainable if it degrades in 100 years rather than in 10 years. It comes down to a definition of what is "sustainable", and so on. If you slow the drawdown in carbon loss in the soil, that is a good thing, but it is not the final solution. It seeks to make the system sustainable while still being able to produce from it food and fibre. It is almost incidental that this also happens to be a system that seems to have nice greenhouse benefits. That is one area that this meeting can take up and say, "Yes, hooray, there is a system with greenhouse benefits and other wonderful features as well." That is the attraction of the integrated system. The challenge is to devise the most suitable integrated system and to get it adopted. In an integrated system we in this Track have to address the revolution. We have to introduce something new.

Dr MANTON: I thought that one of the constraints on the other two Tracks was that they look at sustainable systems. That is the first criterion.

Dr KIRSCHBAUM: Yes, it may be easier to change a system, be it intensive or extensive, into a sustainable one by turning it into an integrated system. Indeed, that may be the only way to do so. I do not want to be dogmatic, but that is certainly one way to make it sustainable.

Prof. LENG (Australia): I do not see why there should be any argument about this. For me the agroforestry system is relatively new in our thinking. Therefore, we have to give it a special place as an idea.

I take exception to the idea that these things should be done for food production. If our problem involves five billion people going to 10 billion people, population growth probably is our primary concern. We should stop thinking of food production and start thinking of income earning capacity, because it is only by income earning increases that we seem to get decreases in population growth. I would make the point strongly that particularly in aid programs income earning capacity should be the first priority and not food production. It is a very drastic thing to say, but it then limits population growth eventually.

Sustainability is the second priority. The third then, obviously, is the spinoff that it has in the greenhouse effect. Maybe in a future world that might become the primary consideration. The main point is that the slowing of population growth is much more important than slowing methane production in the world at the moment. We can only slow population growth apparently by giving people the means to do so - an income sufficient to enable them to rely on their own capacities.

Dr BOUMA (CSIRO, Australia): It strikes me towards the end of today's discussion that it is a little peculiar that forestry as such has been left out of the discussion. Is it because we did not put it in our charter for this Workshop, or is it just that forestry is not fashionable? Secondly, if our main aim still is that because of climate change we want to consider options for reducing greenhouse gas emissions, which is what I thought it was, then halting deforestation may be a much more effective way of ensuring further loss of carbon to the atmosphere and to try to regain it by agroforestry or any other method.

The third point relates to an earlier observation that woody species would be good at sequestering carbon. That is true only if you start from a degraded system. If you cut down a forest to start an agroforestry scheme, you would have a net loss. I think that the basic premise is somewhat shaky.

Dr Stuart BOAG (Dept Primary Industries and Energy, Australia): I would point out that two previous AFOS Workshops have dealt with forests comprehensively or extensively. They were in Bangkok and Brazil. Therefore, it was the expectation of the AFOS co-Chairs to drive discussion at this Workshop in the direction principally of agriculture and then to bring on board the issues associated with integrated systems. Therein lies the lack of discussion of forests.

Dr KIRSCHBAUM: I do not disagree with Dr Bouma. I think that to stop carbon loss from a system is a lot easier than to regain carbon. If that is ever the option, yes, we should stop the carbon loss in the first place. I do not see it in those terms. I see it as a system that has been put aside for food production because it is why a group of people live in a village or own a piece of land and want to make some money out of it. In whatever state of degradation it is currently, the options that we present to landholders at that point are either that they grow exclusively for food, with no perennial vegetation as part of it, or have such vegetation included in one form or another. That exclusively is the situation I am addressing and I think it holds then and only then.

Dr Ken ANDRASKO (USA): There is another very direct link between the question about forestry and whether it is included and agriculture on which we are focusing in this Workshop. In order to maintain standing forests, somehow we have to provide jobs and income, in systems that have relatively high yields per unit area. In thinking about introducing agroforestry or more sustainable agricultural systems, work carried out in Eastern Peru, in Amazonia, by Pedro Sanchez and others has shown that there is a ratio of five to 20 hectares of forest whose losses are weighted by introducing more intensive systems, including rice and other crops at the site, where they have about a 90-year database. There is a direct link between the two that we might wish to bear in mind. We cannot maintain standing forests without somehow in some systems providing more intensive production systems.

Dr McKEON: At the moment we are constrained by the trees that we have available to us in agroforestry. Has there been any attempt to design the type of ideal tree that would allow us to have both a forest and to meet the needs of food and fibre? I am thinking of what sort of biotechnology might be going on in relation to trees, similar to trying to design ideal animals in the most efficient conversion of forage into animal product.

Dr KIRSCHBAUM: I will ask Trevor Booth to answer that one.

Dr Trevor BOOTH (CSIRO Division of Forestry, Australia): I am not sure that I am the best person to answer this question, but I think we are a long way behind the agriculturists in genetic engineering with trees. It is only in the last year that the first gene has been spliced into a eucalypt here in Canberra. Some work is being done in other parts of the world with other tree species with genetic engineering, but it will be decades before we get to the designer tree stage.

Dr KIRSCHBAUM: I think that there is heaps of scope for using the natural variability and looking at the thousands of tree species that are there and seeing which ones can be made use of. I think that we will come to that biotechnology at some later stage.

Dr Gary EVANS: If I may make a further comment, there is a group in the University of Hawaii called the Nitrogen Tree Fixing Association. It is a deliberate attempt to identify leguminous trees with high qualities for fodder as well as nitrogen fixing. This group has worked together for about 20 years and has been looking at naturally occurring varietal groups of trees that can be provided in appropriate ecosystems to enhance them.

Dr DIXON: I think, as I said yesterday, that we are looking for a series of solutions to minimise greenhouse gas emissions. The answer probably is not agroforestry or intensive agriculture, extensive agriculture or forestry. It is a series of solutions and perhaps each sector can contribute a small amount to the larger reduction in greenhouse gases. If we focus on that, some of these questions as to whether it is agroforestry or agriculture may cease to be as important as they have seemed to be this afternoon.

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OVERARCHING ISSUES - OPEN PLENARY DISCUSSION:

CHAIR (Dr Gordon NEISH): We come to the subject of overarching issues, which will be very brief in view of the lateness of the hour. Indeed, what an overarching issue is will depend on your definition of the term. I see a few issues that arise time and time again in this meeting, whether they be intensive, extensive or integrated. I will throw out a few ideas and possibly someone else can say they are wrong and then suggest what we should be talking about.

What arises a great deal is the merger of the natural sciences with the social sciences. I see this as one of the overarching issues as to how we deal with some of the socio-economic and biological aspects. The development of appropriate technologies and their transfer is an issue that arises a good deal. International cooperation in research and development is a major issue and we are dealing with trans-boundary matters, such as greenhouse gases. I am not sure that we are doing a very good job in seeking better international cooperation in R&D on global issues.

Tied in with that is a subject that has often arisen in this meeting and in others, namely, methods development. How do we measure what we want to measure and how can we be sure that people are getting the same measurements in different parts of the world? Do we have good comparative data? There was a case in point yesterday in talking about methane production from rice paddies and so on in coming up with methodologies, approaches and extrapolations in broad areas. There are difficult questions that will involve modelling and the development of analytical tools and so on. How can we best do those things?

Overriding a lot of this is the nature and organisation of the global economy and reward systems. The question of agricultural subsidies came up at a meeting this morning in relation to distortions that had been caused. We dealt with how people can make a living off the land without abusing it, and what impact that will ultimately have on global population growth. It was said earlier that increased prosperity tends to lead to lower population, but also increased prosperity results in increased resource use. One wonders where the trade-off will occur. If everybody in the world were living a North American lifestyle, we would run this planet down very quickly! That again is a matter to be considered.

I throw out those suggestions in order to get a few people mad, upset or to cause them to jump and and down. Within the area of overarching issues, will somebody start the ball rolling?

Dr NEUE (Philippines): Although we have talked a great deal, I would point out that things are still very uncertain. Possibly we should seek to come up with methods by which to bring about more certainty. But to make something certain still means looking into the past. One can explain what has happened, but it does not help one very much to make things certain. Historians are always doing this, as are economists. They can always explain what has happened, but if you ask them what will happen tomorrow, they do not know the answer.

The main point that we are still missing - and this involves a very big problem of methoodology - is how to make predictable these certainties, if they exist. One then comes to modelling, where we always talk about local solutions to the global problem. But up until now there has been no model to help in the local area. Any solution that comes out of the existing model does not help any local person. How does one bridge that gap? If no solution is reached in the next 10 years, all that we do here will have no impact on what in principle we are trying to do.

CHAIR: Are there any other issues that participants wish to raise under this heading of overarching issues?

Dr DIXON: Perhaps we could take a moment to discuss possible ways to address these issues. You have identified a number of good ones. Perhaps there will be an opportunity within the Tracks to deal with them.

CHAIR: I hope that can be done within the next two days. I thank you all for taking part in this most interesting concluding session for the day.

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(END DAY TWO)

DAY THREE

CHAIR: Dr Chalapan KALUWIN (New Caledonia)

TRACK ONE - (Intensive Agriculture)

Reports to Plenary

Dr Tom DENMEAD (Rapporteur) told the Plenary gathering that the representatives of Track One had considered presentations on two general topics. One related to cropping systems and presentations were made by Drs Neue and Minami on methane emissions from rice cultivation, as well as a presentation from Dr Acosta from Cuba on the opportunities for reducing methane emissions by growing sugar cane.

The second part of the meeting concerned more mineral aspects, and involved presentations of philosophies of management strategies.

On methane emissions from rice paddies Dr Denmead reported that as the result of figures presented the group was probably getting closer to agreement on the contribution of rice to the total global inputs of methane. From a number of estimates presented by speakers to the group both on direct measurement with chambers and on model estimates, using such things as geographic information systems, the group seemed to be homing in on a figure of somewhere between 40 and 60Tg of methane per year coming from rice paddies. This was less than was put forward in the 1990 IPCC estimate. It was rather more than Dr Sinha was suggesting on Monday, but it looked to be a fair consensus figure.

The result was that the global contribution of rice paddies was reduced from some 20 per cent of all global emissions in the IPCC 1990 document to 11.8% currently, according to Dr Minami.

Both speakers in the group dealt with the bio-geochemistry of methane formation, which was most informative. In regard to trends, Dr Neue brought out the fact that the areas under rice cultivation were not changing very much at present, but were probably increasing by one per cent per year. The production had increased greatly - it had tripled over the last 40 years, and will probably need to double again by early next century. This was brought about by multiple cropping. improvement in cultural practices and so on.

Dr Neue anticipated that this would take methane emissions from the present 40-60Tg of nitrogen per year to about 80Tg by the end of next century. He made the further point that technologies to reduce emissions existed that could be put into practice, but to make these effective they had to be used in conjunction with the people who had to use them. There was a long lead time of some 15 years or so.

Discussion threw up the fact that differences existed between soils and their propensities for methane formation, between soil varieties, and between rice varieties.

Dr Denmead told the Plenary session that he felt there was now a reasonable understanding of the problem to suggest technologies. The problem was to get people to adopt them.

In his contribution to Track discussion Dr Neue made the point that in rice cultivation in the Philippines and probably for a number of other Asian countries soil is disturbed at least five times in the life of the crop. Since some 80 per cent of the methane was trapped in the sediments underneath, this could promote a great release of methane. It was a point that needed exploring. Use of production technologies that required minimum disturbance of the soil seemed to be a simple means of limiting emissions.

The discussion instanced a number of factors affecting methane production in soils. These included factors such as the redox potential, substrata nutrient availability, temperature, soil pH, plants, sulphate concentration, addition of chemicals, and absorption.

Speakers made the point that these factors could now be incorporated into models using information from geographic information systems to make fairly good predictions. It was probably that with a bit more improvement in mechanistic models, the predictions could be quite refined in a few years' time.

Dr Minami talked about means for reducing methane emissions from rice cultivation, which included things such as water control, control of percolation rates and drainage rates, fertilisation practices, selection of rice cultivars, soil selection, handling of straw and so on.

The general comment to be made was that probably processes and mechanisms were fairly well understood. Measurement techniques were not so well developed. Chamber systems were used currently. There was a need for systems that measure more extensively and integrate spatial variability particularly.

Dr Acosta addressed the Track on the carbon dioxide budget of sugar cane crops. He pointed out that with new practices in sugar cane culture, sugar cane could well be a net sink for carbon dioxide. He believed that there could be an accrual of between 1 and 2 tonnes of carbon per year to soils, using improved practices. They included reducing biomass burning and burning off; using green cane harvesting with trash blanketing and so on. He made the further point that alcohol production from sugar cane was a real possibility, which in turn would reduce reliance on fossil fuels.

Dr Denmead mentioned a contribution to the Track by Dr St-Yves (Canada), who raised a number of interesting issues. She made a plea for holistic approaches - for a long term vision for agricultural food systems versus greenhouse gas emissions. She stressed the need to consider economic, environmental and social factors involved, outlined the factors and examined some problems.

One point that was posed on Dr St-Yves talk was put by Prof. Nix. He said that we were now requiring farmers to do a great deal - not only to produce food and fibre, stimulants and euphorics, but also to have sustainable systems to conserve the soil and the environment. How to get farmers to do all this was a big social problem. How did one pay them to do this, and what sort of system could be introduced to envourage people to do all the things that we would like them to do?

It was also noted that we needed to consider problems of waste disposal too, which closed the cycle. Should we say that nothing more should be produced before we know how to handle the waste problem? This raised the issues of apportioning blame and whether the polluter should pay. An example was given of a well-known hamburger manufacturer and the fact that a quarter-pounder required the production of a quarter of a pound of methane. Most of the meat was produced in Central America rather than in the headquarters of the manufacturer. Where should the onus be put - on the farmers who produced the beef and who could not afford to pay, or on the larger producers and perhaps the people who benefit from this who operate in another domain? Questions were also asked as to people buying off their consciences by having trees planted in other countries and so on.

A contribution was made to the debate by Dr Soemarwoto (Indonesia) who spoke of strategies for limiting emissions of greenhouse gases from the point of view of an equation in which the net emission was the result of the total production less the sink. He considered in turn ways for reducing both the emissions and the sinks. This raised a number of nice socio-economic issues, particularly in elation to developments in developing countries.

DISCUSSION

Dr Gary EVANS (USA): I must speak on behalf of one of our most beloved export products, which is the fast food industry, at least to make a minor correction. The allegation that much of the hamburger utilised in the fast food industry comes from Central America cannot, in fact, take place because of the foot and mouth disease quarantine that is in place between North America and Central America. It does not allow the import of Central and Latin American beef into the North American arena. I think we should scotch that one very quickly.

Dr DENMEAD: Point taken! I'll say no more.

Kathleen HOGAN (USEPA): I want to comment on what perhaps is a nuance on something Dr Denmead suggested. He spoke of emission from rice paddies dealt with in Dr Neue's talk. I believe what Dr Neue presented in the emissions estimate of 40-60Tg from the paddies was Dr Denmead's suggestion of what the minimum estimates would be. As was pointed out, farmers going throught the rice paddies up to five times per season could add a significant amount of methane in addition to that 40-60Tg.

Dr DENMEAD: Yes.

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TRACK TWO (EXTENSIVE AGRICULTURE)

Dr Will STEFFEN (Rapporteur) gave the Plenary session a brief outline of the talks and discussions in Track Two. The Track heard three talks, two of which were on the lines of case studies, and the last a summary talk. The first was given by Dr Jim Hogan of the CSIRO Division of Tropical Animal Production in Brisbane.

Dr Hogan's emphasis was on the animal part of the animal vegation soil climate system, and looked at how methane emissions from animals could be reduced The short answer was improved efficiency of feed conversion or the slogan "More Beef from Fewer Mouths". Dr Hogan gave an analysis of the energy balance of the animal in terms of the energy input in feed and what happened to that energy as it went through the system. Fairly early on in the system there was a component of wastage in methane. If this wastage in methane could be reduced there were a couple of benefits - one, that greenhouse emissions would be reduced, and second there was more metabolisable energy left which eventually found its way into production. There was a multipurpose incentive for improving the efficiency in the energy balance system.

The trick was how to bring this about and several strategies were discussed in Track Two. One was to improve the nutrient balance, by changing the composition of what the animal ate; or by adding supplements to correct nutritional deficiencies. This could be appropriate in some places but not in others, but it offered an opportunity to change methane emissions.

Another strategy was to manipulate the rumen microbes. If genetic engineering could be used to develop bacteria which produced volatile fatty acids, methane emissions could possibly be cut. Another method possibly lay in removing protozoa.

A second case study centred on vegetation which animals must use for their source of energy and nutrients. It concentrated on the Patagonian region of Argentina. Dr Steffen showed a slide of biomass accumulation which changed for different biomes in that area. There were different patterns in biomass accumulation and it was an important component of the system and would have a large impact on eventual production.

Dr Steffen showed further slides illustrating how climate change impacted on systems and variations from year to year. He reiterated the extreme variability in climate with which extensive systems had to cope compared with intensive systems in general. There was a good example as to how the system was being run down over time, which had to be avoided in future.

Dr Steffen said that if one added supplements to increase the productivity or utilisation of forage, one may be able to put more animals on the system, and increase the use of the low quality forage by giving them supplements. But if it were pushed past a system where it was used sustainably, it would be degraded. Soil erosion and faster soil degradation may occur, which in turn may result in more greenhouse gas emissions through loss of organic soil carbon.

Dr Steffen said that what came out clearly from the discussion was that whole cascades of events could happen if one was not careful and did not look at the ecosystem as a whole.

In relation to increasing the diversity of herbivores, Track Two had concentrated on cattle, and did not talk very much about sheep or goats. It had been suggested that there were many other herbivores around, some of which were ruminants and some not, which could be used. In Southern Africa there were game ranches and mixed ranches using more traditional species such as wildebeest or zebra, and perhaps there was the possibility of using bison in North America. The Australian equivalent was kangaroos.

When one began to think about changing the systems to go to mixed or more native species, one had a lot more than simply scientific questions to grapple with. One had questions of culture, social systems and so on. Certainly the use of kangaroos in Australia was fraught with much controversy. It was perhaps a possibility for the future and Dr Steffen said he was not advocating we all go off and use native species tomorrow. However, it was worth thinking about and could have a big impact on greenhouse gas emissions as some of the species produced a lot less methane per kg than many of the species at present used.

Dr Steffen referred to a contribution to Track Two by Dr Walker of CSIRO Division of Wildlife and Ecology in Canberra. Dr Walker had asked three questions about extensive agriculture and its relationship to greenhouse gas emissions. How significant were they now in terms of influence on atmospheric composition, and consequently climate? The answer was not very much. How much were they likely to change in future, and how significant would any changes be in terms of functional role in the global climate system? It was difficult to identify any scenarios in which they would increase their significance compared to fossil fuel consumption, which was rising rather rapidly. Thirdly, what options were there for minimising or otherwise influencing any changes?

Dr Steffen reported that it was still believed there was a role for extensive agriculture in reducing emissions, and the Track had identified ways in which that could be done. A slide presented by Dr Walker had shown a sound way of approaching the matter. First, it involved an analysis of the environmental and land use determinants of ecosystem dynamics, and developing them into a predictive model. One needed to understand the mechanism of the system, and use that knowledge to develop some sort of predictive capability. One had to know what would happen to the system.

Secondly, one had to assess the relative pros and cons of each state with respect to both managers and the IPCC. Extensive systems could be thought of as existing in several states rather than as a gradation. One may flip from one state to another depending on management strategy, extremes in climatic events and so on. One needed to make an assessment of these states with respect to the managers - in other words, one state would be a lot better for production than another state. Also with respect to the IPCC and the Workshop's goals, one state may be much better than another in terms of greenhouse gas emissions.

One had then to decide on the state that optimised both aims so far as possible, and then use the model to develop an appropriate management strategy. Several areas were identified where these two goals were concurrent. States could be identified that were both good for the producer and for the goal of reducing greenhouse gas emissions.

It was on ideas of this sort that one would base strategies for reducing greenhouse gas emissions in terms of extensive areas.

Dr Steffen summarised the Track's conclusions by saying that in extensive areas it was believed there were limited options for action. Even if there were the resources to implement all possible strategies and one could adopt them, it would have a small impact on greenhouse gas emissions. Nevertheless, one should pursue strategies that were achievable with multiple benefits.

Dr Steffen concluded that he thought a number of strategies had been identified that could reduce greenhouse gas emissions, enhance adaptability to global change, and at the same time move to sustainability. All these were bound up together.

TRACK THREE - (INTEGRATED SYSTEMS)

Rapporteur, **Dr Miko KIRSCHBAUM,** in reporting to Plenary session on Track 3 discussions, said the much of his task had been covered in a summary which had been prepared by Dr Ken Andrasko and which was available in written form.

The Rapporteur said he felt agroforestry was a key area in the range of integrated systems, and would outline a number of statements that had been agreed during the Track 3 meeting.

It had been recognised that databases on suitable agroforestry species were in existence. They were not perfect but there were databases that were not used as widely as they could be. It was felt assistance should be given to locate and improve access to them. Further work should continue to refine and extend databases, particularly concentrating on the minimum datasets required to adequately define a species range.

Dr Trevor Booth had given Track 3 an excellent outline of the methodology that could be used to define a species natural distribution bioclimatic requirements, the profile of which could be matched with the bioclimate profiles of other world regions, thereby choosing the species most appropriately adapted to be utilised for those new species. A lot of information was available in that area which could be used more widely than had been the case up to the present. There was an obvious need to choose species which could be most suitably adapted to fulfil a particular purpose.

Dr Kirschbaum reported on discussion that had occured in the group on the appropriateness of utilising native species versus the use of introduced species. This contained an obvious dichotomy. On the one hand, native species should be encouraged in furthering the biodiversity and maintaining ecological systems in the native country. On the other hand, introduced species typically performed much better with much higher growth rates, largely because they left pests behind in country of origin and were able to perform better in their new countries. It was felt that there was a need for both native and introduced species and that neither should be excluded.

A further point related to the type of roles that could be played by integrated systems. The linking of agriculture and forest systems with energy production systems gave a variety of advantages. It increased the system's economic viability, and could increase the availability of large capital through the combination with energy production systems which had easier access to large capital than had smallholders. Also, this could lead to a gain in political and financial support. It could provide the opportunity to achieve ongoing savings in greenhouse gas emissions.

Another point that had arisen was that changes that could be made in biological systems could only have a one-off impact. One could only change the carbon balance of a system, but one was not dealing with systems with an ongoing output or input of CO_2. Therefore, the impact was relatively small compared with energy generation systems. Not so much could be achieved overall in changing the carbon budgets of ecosystems as could be achieved by changing the energy economy of a country. With the use of agriculture and forest systems for the purpose of energy generation, ongoing savings could be achieved in greenhouse gas emissions by using sugar cane or wood production as fuel substitution. It provided a unique opportunity to make ongoing savings in such emissions and this aspect deserved special attention.

A slide was shown illustrating that in areas with extreme population pressures there were particular problems in introducing environmentally more suitable alternatives as the pressure for local people to make changes was rather limited. Their need to find tomorrow's food could be more important than safeguarding the future of their land in 10 or 100 years.

It was important to overcome these problems. Three areas that were identified were:

- better education (including environmental)

- technology transfer

- introduction of alternative production systems.

All these areas were directed at trying to improve the efficiency with with the land is utilised. Better education had an obvious role, both generally and environmental education to make people aware of the impact in the short, medium and long term of their actions on the land.

In the area of technology transfer, the problem in a particular area could be overcome by technology available in a different area or a different country. Sometimes the use of an alternative production system could overcome the difficulty. Technology transfer need not necessarily mean a different production system, but different cultivars.

It had been drawn to the group's attention that the former socialist countries in Europe and the former Soviet Union posed special problems which in the past had not been adequately addressed. Countries undergoing rapid transition from socialism to market economies could have both positive and negative implications for greenhouse gas emissions. Opportunities existed to introduce international research, aid and technologies with positive environmental impacts during the period of change.

In Poland the transition from socialism a few years ago, according to figures given to Track 3, had had a positive impact on the overall greenhouse gas balance due to a variety of factors. It was not certain that this positive change up to date would continue to be positive in the years ahead as the country changed more and more. It was seen as an opportunity for the international community, in this phase of rapid change, to ensure that any new methods that were adopted had a positive environmental impact overall.

The problems of former socialist countries were different from those in developing countries and deserved special attention. These areas shared with others problems of pollution. The forest decline in Germany and through Europe was well-documented. It was felt that international cooperation was needed to rehabilitate areas degraded by pollution; to assist in technical cooperation to reduce the emissions of pollutants causing forest decline; and to assist in technical cooperation to integrate all nations' forest sectors into regional and global forest economies.

This referred very much to the former socialist countries. The situation now existed for a new start, to go to less polluting emissions and to rehabilitate degraded areas. A lot of effort needed to be dedicated to this task There was an opportunity at present but it needed to be furthered. International cooperation was a key element to bring about positive change.

It was further pointed out in a slide that no single option of forestry appeared to have the potential to offset more than several per cent of a nation's greenhouse gas emissions, but that agriculture and forest options together may potentially offset 5-25 per cent of many nations' emissions.

Dr Kirschbaum said that he took issue with a previous speaker. How small a particular sector's contribution happened to be was not a very relevant issue. The issue that should be addressed was always the cost benefit analysis. For a given cost where could one achieve the greatest benefit? If one area made a small contribution to greenhouse gas emissions but with a trivial cost and that could be limited, he felt that was more worthwhile than looking at another area with large emissions where any improvement was possible only with massive investment.

Ken Andrasko had reminded Track 3 that additional workshops and activities should follow on from the present workshop. The activities that should be pursued included carbon budget, net greenhouse gas emission, and land use allocation methodology for evaluating response options.

One also needed formal methodologies for economic assessment, a subject that had arisen several times in the workshops. This should be modelled on work done by WGI, but it was generally agreed that it needed to be developed within a consistent framework.

Integration of WGII impact findings was required, with mitigation options. There was competition for the same land. There was a need to evaluate the impact of climate change on productive agriculture and forest systems.

Dr Kirschbaum said that an important area on which he had been working for a number of years was a quantification of the CO_2 fertilisation effect. This area was still poorly understood, which was no doubt a bad reflection on this area of activity, but it was a difficult one. Whatever the answer, it had an enormous impact and there needed to be a real understanding of the situation.

The final matter that arose in the Track was the need to talk about mitigation strategies as well as minimisation of greenhouse gases. Dr Kirschbaum concluded by saying, "We are probably not in a position to stop the greenhouse effect and we need to look very seriously at what best we can do with natural systems to adapt to whatever changes come our way".

DISCUSSION

Dr Tom DENMEAD (Australia): I omitted to raise one point made by Dr Acosta. He made a plea for more research on adaptation to climate change of our present crops and cropping systems, particularly in developing countries. He suggested that this should be an important aim of such a workshop.

In general discussion it was thought that there was a need for dynamic modelling of production systems, perhaps focusing on some positive aspects of climate change and any new opportunities in agriculture which it might create.

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(END DAY THREE)

DAY FOUR

SPECIAL PLENARY - (Agricultural Adaptation and Sustainable Development)

PANEL ON SUSTAINABLE DEVELOPMENT AND AGRICULTURE

Address by Co-Chair of AFOS, Mrs R. KARIMANZIRA, Department of Meteorological Sciences, Zimbabwe:

This is the first opportunity that I have had as Co-Chair of the AFOS Sub-group to address you. I express my Government's sincere gratitude to the Australian Government for hosting this very important Workshop. That gratitude is due to the German, Australian and United States Governments for providing funds to cover travel and other expenses for speakers and to participants from developing countries, such as myself. Gratitude is also due to the IPCC Secretariat for coordinating this whole process. I also give special thanks to Dr Stuart Boag and his team for successfully organising this Workshop. I think that this is the best that we have had so far, especially as we are in Canberra with the sun shining outside.

I must admit that the quality of papers and discussions over the past few days has been very impressive and enlightening. I wish personally to congratulate all speakers and rapporteurs on their splendid presentations so far.

Turning to the business at hand, I believe that the issue of sustainable development is the all-embracing concept that this Panel that is before you wishes to discuss. Unless economic activities are considered in a holistic manner, efforts this week will be in vain as the management systems cannot be sustained. Therefore, it is necessary to take into consideration the effect of our actions on communities, be they local or further afield.

According to the Brundtland Commission report entitled "Our Common Future", sustainable development is defined as follows:

> To ensure that development meets the need of the present without compromising the ability of future generations to meet their own needs...This must also ensure that all are assured to meet their aspirations for a better life...
>
> Sustainable global development requires that those who are more affluent adopt life-styles within the planet's ecological means.

The question that immediately comes to mind is that this definition describes and makes assumptions about a perfect world in which a carefully balanced approach to resource management will imply success. However, a changing global environment with unfavourable climate may indeed spell doom to some nations. How far do we go to ensure sustainability in a changing climate especially for developing countries.

I would like to share with you an experience in Zimbabwe (Slide). This is an extract from a newspaper in my country where the concern about climate is very high, and where knowledge is limited. We have rain prayers and it is believed that this works. If we at present still have rain prayers, what is our role? These people from the backgrounds believe that following prayer we will get the right conditions in our country and probably achieve sustainability.

I do not know how effective the rain prayers in Zimbabwe have been because the percentage of rainfall as at 15 January this year has been pathetic. How can we sustain development, especially our agro-based development?

From the perspective of a developing country our sustainable development concept, which emanates from sound productivity from the agricultural sector, depends on the following factors:

- Is land available?
  - Are land use management systems applicable and affordable?
- What population growth rates will sustain such systems?
- What is the food security position?
  - What are the climatic conditions within which we operate?
  - How does national political and economic stability interact with these factors?
  - How does global political and economic stability interact with our activities?
  - What are the financial flows, trade patterns, investments and technologies, are they transferable and can we afford them?
- What is the stage of development?

These are all factors that we must look into.

In the area of food security, which for most of us is the backbone of sustainable development, it is important that this issue is not overshadowed. Agricultural performance is intensely political because of its profound influence on equity, income distribution, consumption, production and is intricately linked to economic growth, particularly in our circumstances. Hence sustainable agriculture is of prime importance, as it ensures food security.

Our task is therefore to advise our policy makers on options for sustainable economic growth based on sound agricultural performance with reduced external inputs and favourable market prices.

At this point I wish to cite the kind of dilemma faced by a typical developing country (Slide shown). Thus, addressing the issues of food security and sustainable agriculture means that we also have to address the broader national and international economic issues.

Sustainable economic growth is therefore a challenge to both developed and developing countries. In the final analysis, sustainable development is not a fixed state of harmony between changing production potential of the ecosystem and population size, but rather a process of change in which the exploitation of technological development and institutional change are made consistent with the future as well as present needs. In this regard, consumption patterns and preferences are as important as numbers and consumers in the conservation of resources.

Therefore, the discussions in this Plenary should focus on the issues I have outlined with a view to coming up with some useful sustainable adaptation and limitation measures in agriculture and forestry management systems. In the words of Minister Kelly in her opening address, "We want our economies to flourish and our environments to flourish with them."

The first speaker from the Panel is Dr Roy Green, of the CSIRO Institute of Natural Resources.

Dr Roy GREEN (CSIRO, Australia) presented a paper entitled "Sustainable Development and Forestry - An Australian Perspective".

Dr R. MAYA (Zimbabwe) presented a paper entitled "Sustainable Development and Agriculture/Forestry in Developing Countries".

Professor H. HANUS (Institut fur Pflanzenbau und Pflanzenzuchtung, Kiel, Germany) presented a paper entitled "Sustainable Development and Agriculture in Europe".

Dr Ted HENZELL (CSIRO Institute of Plant Production and Processing, Australia) presented a paper entitled "Integrated Management Strategies".

QUESTIONS TO PANEL

CHAIR: In opening discussion, I merely wish to comment that on the question of sustainable development as a total concept I think the message is that we are dealing with little pockets of people who contribute to the whole and each one of them wants to survive. Obviously countries want to increase productivity and to balance it with environmental protection.

Dr Peter COSTIGAN (United Kingdom): I must disagree with Professor Hanus's assessment of European cereal production, certainly as regards the United Kingdom. Dr Hanus said that there were large quantities of nitrate left in the soil after harvest of crop. In the United Kingdom we find that if the amounts of fertiliser are up to about the optimum yield, we don't find large amounts of nitrate in the soil after harvest. The nitrate leaching tends to come from mineralisation of soil organic matter over the autumn period, which is then leached out over the winter.

In fact, the average rates of fertiliser addition in the UK of about 70kg/h on arable land more or less equate to the removal of nitrogen in the grain. It is interesting to compare the present position with the situation when lower nitrogen rates were being used in the 1970s and earlier. The concern then was that there was a gradual reduction in the organic matter levels of soils, basically because not enough nitrogen was being added to replace that being removed from the soils within the crops.

The problem is of not being able to look at sustainability simply by looking up one characteristic, such as nitrate leaching. You have to take other factors into account, in this case soil organic matter. If we are to reduce nitrogen fertiliser rates very markedly, it is likely that soil organic matter levels would decrease and we would end up with soil degradation. It is better perhaps to search for sustainability by looking at those problems that are posed by particular agricultural practices. In this case nitrate leaching over the winter period can actually be addressed by establishing cover crops on land and ensuring that you do not end up with the nitrate that is produced being leached, held back within the system.

Obviously in some cases there may be over-application of fertiliser on individual fields, and this can be addressed by better prediction methods for determining how much fertiliser to apply in individual case. My plea is that one should not look at sustainability in a simple way, but both in terms of other sustainable fctors, such as soil organic matter levels, and also economic sustainability of the agricultural process as well.

Prof. HANUS: I believe you in the UK have very different conditions than we have in Germany. You went from the lay farming system in earlier times to a wheat cropping system, and therefore you do not need so much nitrogen to feed the crop due to the higher organic matter content you have in your soil normally. But if you talk about 170kg as a total, in Germany to harvest 8 tonness or more - in Schleswig Holstein for example - the normal application rate is about 240kg or more. It depends on the ability of a farmer to find out how much he has to apply. When producing in the field you have to apply your nitrogen at a given time, but you don't know in advance what will be the yield capacity of the crop that you are standing on. In some years you apply the same amount and get a high yield; in other years you get a low yield. That makes the position uncertain.

I pointed to the situation in one respect, but in respect of sustainability we have heard from other speakers of what would or would not be necessary. I could give rough figures of what a sustainable system should look like. To solve the problem it is also possible to measure nitrogen in the soil at the start and also the nitrogen content within the crop or in an intercropping system in seeking to reducing the problems that occur from too high amounts of nitrate.

The point is that if nitrate remains within the organic material, it must be mineralised; you do not know when that will happen and to what extent. If the plant crop cannot use it, it will be leached out. Earlier the Workshop learnt that the gaseous emission of nitrous gases will be higher the higher the input of nitrogen.

Dr SAUERBECK (Germany): The soil in nitrogen one has to worry about today was the nitrogen fertiliser of yesterday or the day before yesterday. These things were interrelated and they cannot be separated as easily as Dr Costigan suggests.

Dr Maya's presentation did not say anything about his country's soils. I wonder in what condition they are, especially in terms of their nutrient content and fertility. Once you increase the profitability of your forest system, which means increased exports of biomass, timber or anything else, you also increase the export and that means loss of nutrient. I wonder whether your soils can stand this. Could Dr Maya comment?

Dr MAYA: My basic argument was that it might not be necessary to increase production and therefore increase pressure on the soils if we increase the recovery rates, which are demonstrated to be very low. If we have a recovery rate of 40 per cent and raise it to 80 per cent, we have essentially doubled our production without increasing pressure on the soils.

As regards the ability of our soils to sustain that kind of pressure, I would not be so sure. But we would be able to increase our product levels for benefits from the forests without increasing the intensity or area of production.

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Dr John WILLIAMS (CSIRO Division of Soils, Australia) presented a paper entitled "Risk Management and Climate Change".

Risk Management and Climate Change (Draft for revision)

Dr John WILLIAMS (CSIRO Division of Soils, Australia):

This morning I am addressing the important topic of how we assess and manage risk in the context of climate change. I wish particularly to emphasise the tools that we have in place to assist us in this task. I shall try to place in perspective the variability that we encompass in our agriculture now, as against the variability and risk that we might foreshadow in the context of climate change.

I was pleased that Prof. Hanus felt in his European analysis that the climatic variation associated with proposed climate change lay well within the variability that we experience in agriculture, because that is clearly my view of the Australian situation.

(Slide shown) The climatic variability is a key issue in Australian agriculture. Our climate varies spatially - from desert to the Mediterranean-type climate to the tropics - with normal spatial variability in climatic conditions and an enormous variability in temporal conditions from flood to drought.

(Slide shown) In our context that is reflected in the coefficient of variation and the mean yield of Australian wheat taken up until 1945 and then post-1945. It is worth noting the difference in yields in Australian conditions compared with what we have heard in these discussions about European conditions.

(Slide shown) One sees here that the coefficient of variation is quite high. This is by no means the best statistic to use, but at least it sets the framework for the hypothesis of the sorts of variability that we can expect and the changes that lie within that experience in our current agricultural operations.

The methods to characterise this temporal variability have developed substantially over the past 15 years. They range from simple mean indices of rainfall/evaporation on a time step as large as a month down to time steps of days. In terms of the probability of the index means are not very helpful in this whole analysis, yet far too much of the climate change debate, I believe, has focused on means. What we are interested in is probability distribution so that we can take some sensible look at risk and how that risk will change or move as a consequence of expected changes in climate.

(Slide shown) We can move to the water balance approach and its outcome using historical data to generate risk analysis - from water balance through to crop simulation models, and then to models that put the farming system together. This is an area where we do not have many runs on the board, as Dr Henzell made clear.

(Slide shown) We have all seen the sorts of natural variation that we experience in the semi-arid parts of the world of rainfall with time. We can see how unhelpful mean rainfalls or mean changes to climate really are. This is the situation in Hyderabad and I could show you similar statistics for any part of Australia.

(Slide shown) We can take that a little bit further and do a simple water balance based essentially on water temperature index and generate two climate analogues between Australia and India, one for Katherine and another for Hyderabad and so on. That simple sort of analysis is available, but again that is a mean situation. We want to move beyond that and we can do so, but it is looking at what climate change may do to the shape of those functions that I regard as most important.

(Slide shown) If we take that further and can show it across in a spatial sense, we can do some interesting exercises on looking at the effective average rain periods for a region. We can clearly calculate the dry spell within those rain periods which are critical. How these may change in a scenario of climate change is really important to the assessment of the consequence to the agricultural enterprise. We can come back to crop failure, which is shown here for north-western Australia. The numbers look somewhat horrific, but that is the sort of scene that can be calculated. We can also look at the coefficients of variation. These are techniques that are fairly commonly used.

(Slide shown) We can take the matter a little further and look at probabilities of actual water use, potential over actual water use in a cropping situation. We can also look at a sequence of probabilities at Pine Creek in the Northern Territory. We can see there what the 30 per cent probability looks like in terms of actual to potential water use; and we can see what the 30 per cent figure would look like throughout a year. Under that we can fit what a crop of sorghum may require to produce a potential yield. Clearly it fits under the 70 per cent potential risk. We know that there it has at least a better than 70 per cent probability of being able to produce that crop, whereas in this situation it cannot. Even a 30 per cent probability is risky in that particular case.

(Slide shown) We can take the matter even further. I think that we can do a lot better. A well-used measure of climatic temporal variability based on historic data is the probability of exceedence or the cumulative probability for the given climatic index or output of the simulation model. That is an important and well-used tool.

I am saying that we have many of the tools here, but they have not been used. So when we come to look at. say, legume production in northern Australia, we can look at the cumulative frequency of a particular yield for a given location. (Slide shown) This is a reliable location at Katherine and shows the Townsville-Burdekin region where the likelihood of a given yield - any yield - is about the same as any other. This is a highly variable climate.

(Slide shown) This one is even worse. It has an 85 per cent likelihood of getting that sort of yield, provided that the nutrient and cultural constraints are not operative.

This lets us start to express a risk situation that we are working with in order to know the average used so that we may know the real differences in relation to a location in our current historical climate. It is much more helpful to express the matter in this way.

(Slide shown) What we want to know in terms of climate change, of course, is how the climate change may well influence this distribution, because that is the variable that will be most helpful.

We can move on to ask whether we have crop models that work. (Slide shown) I could show you many that are a lot worse than that illustrated here. This is a series maize model originating from the work of Bob McCowan, building on the work of Joe Ritchie and using it in Kenya. We see that it does a very satisfactory job over a very wide range of yields and in predicting yield production. It is dealing both with nitrogen and water.

(Slide shown) If we take these things and use them from the work done by Hamer and McKeon and others, we are still looking at probability and yield. This is the sort of function one might get for Emerald in central Queensland. It is interesting to take that further and look at other work that has been carried out by John Monteith. (Slide shown) We see here the cumulative probability and the sorghum yield, with the different nutrient inputs at a number of locations. It is the way in which these probability risk functions move that is most helpful in understanding the consequences of climate change.

(Slide shown) We can take the matter further and look at some other functions that look similar, in this case in Kenya. We are combining what the function does for a given location in one area of Kenya with the different planting densities. We are seeing what the fertiliser regimes do to the shape of the probability distribution. With one's cultural practice and management, has one some options for changing the risk of failure and risk of production?

One can put this information in gross margins rather than in yield. One can have information that can be used in the traditional agricultural economics framework, but so often there has not been the functional information available. Purely experimental methods have not been able to generate this. I feel that this methodology will be used more widely.

(Slide shown) This illustrates the work of Bob McCowan and his team. This is a risk analysis that looks at mean gross margin against the standard deviation of that margin. This relates to a number of different scenarios of cultural practice. One can work out the mean and the standard deviation for that cultural practice from the particular simulation and generate a response surface. Here we have a line that is indifferent to this. In other words, the person is simply interested in the maximum gross margin and the riskiness of the operation is not an issue in his judgment.

(Slide shown) From analysis of attitudes to risk, it seems that many farming communities that have been analysed in East Africa - which is surprisingly similar to some analyses in central Queensland - tend to have a feeling that if one increases the gross margins by unit 1 and only increases the risk by 2, they can live with it. We can then put in people's judgments. The systems that they choose to optimise their risk will be those with a tangent to the 2:1 line. I think this tool has a great deal of value.

(Slide shown) The same tools can be used to assess the management strategies to minimise risk through choosing and matching soils and location in the landscape, which is what Ted Henzell was talking about. One can do something about making the thing less risky by choosing soils that have larger soil stores. That is fairly obvious, but one can get a feel for the influence that soil management can have on the risk analysis compared with all the other things that are operating on the system. This starts to help one make sensible judgments on how one might move and what is likely to be most effective in dealing with risk.

(Slide shown) Graham Hamer has taken the analysis and given it a spatial context. I think that this is most important in dealing with another issue of climate change, when one moves regions and puts new rainfalls on old soils, which will affect probability distribution. One can see here probabilities of 80 per cent, 50 per cent and 20 per cent and what the yield will look like. How will the pattern of distribution change if the probability rainfall distribution, driving factors and temperature change? We have tools that can take this risk information and transpose it into spatial information.

(Slide shown) This has generally been the way that we have dealt with climate change scenarios up to the present. Essentially we have done a sensitivity analysis to changes in the property of the historic data, often unfortunately to the means and not the distribution. We obtain some probability estimates. These have been used to generate a scenario of anticipated climate change. I think that some of the approaches that Greg McKeon, Graham Hamer and John Russel have worked on tend to look at the predictive change or expected consequences of the southern oscillation index. The question asked is what the distribution function looks like when the southern oscillation index was in a particular area. We see the sort of effect that different populations of southern oscillation indices are having on the distribution of the probability for sorghum yield at Emerald.

(Slide shown) We can take that same information and use it in a spatial sense in order to look at the likely changes to the distribution for the movements one may get relative to what is happening with the southern oscillation index. We can look at the 20 per cent probability and 80 per cent probability distributions.

(Slide shown) One can come back to individual locations as shown in this illustration. These have an effect on the nature of distribution.

(Slide shown) It is important also to look at the consequences to use of fertiliser trends. One sees here the average gross margin against all-years if the southern oscillation index is above or below. We are starting to see that we do have useful tools in the cropping system with which to analyse the change of climate on the risk that we are likely to have.

If we take pasture information for Charters Towers, and area in the northern beef industry, and look at the probability of pasture growth, we can see the likelihood of the southern oscillation index influencing distribution of that function when all years are put in.

(Slide shown) We have some tools which can start to answer some of these questions. The long-term climatic change expressed as a change in risk can really be used for the frequency of short-term anomalies. This will be most important in terms of the droughts, the floods, the critical frosts - the event-type things.

(Slide shown) It has the potential to delimit the impact areas where one is shifting limits or margins. One is shifting the risk areas. Most useful tools are available in that regard. We have to look at the vulnerability of the systems at the margins. We must not just focus on the biophysical, as I have up to now. The issues are much more than that. They relate naturally to the economic and the social.

I draw on Professor Parry's approach, looking at how we might do this impact analysis and move beyond the biophysical. The simplistic impact approach is to say, "Here we have a climatic variation, we expose a certain activity and that is the impact." But that simplistic approach is shown to be quite naive and not helpful.

If we take the climatic variation and realise that it interacts with other factors, environmental and others - issues of sustainability and maintenance of the resource base - we find that we have this interaction. It is helpful to recognise that we also have scale. When we look at impact approaches, obviously we must treat it interactively. But we have to treat it at the biophysical level and local, regional, national and global. They are all related and we need to place it in that context. We do the same for the economic and the social.

(Slide shown) This leads to a fairly complex picture of Professor Parry's, but I think that it makes a lot of sense.

(Slide shown) When we look at drought or the impact of climate change on the local situation in the biophysical sense, we are dealing with yields, which immediately have an impact on farm income, stress, health, bankruptcy and all the socially critical issues. We have regional production information, migration of people, the effect on the tax base, municipality infrastructure and the rest. There is then the national position and the global position. These things must be looked at when we are thinking about climate change and about changing the risk pattern.

(Slide shown) One study that has done this to some extent is a study by another Williams in Saskatchewan. It looks at scenarios of altered climates, altered temperature, rains and cloudiness on the spring wheat yield. Again it is a fairly mean-driven exercise rather than one governed by probability, but it looks at altered yield levels. When one puts these into representative farm models, one gets the altered production, changes in regional output, altered economic activity or the non-farm sector, with the effects at the regional employment level.

(Slide shown) In doing this analysis, it is most important to recognise that all these squares represent some formal analysis or model. These are inputs to those models with the temperature and biophysical components, yield information and the changes on the regional input, output and infrastructure.

I conclude by saying that while it is encouraging to be able to say that we have methodologies that were originally designed to deal with climatic variability, which was a feature of agriculture, part of the agricultural production system, I think that we do have many tools to help us to analyse the likely effects on agriculture of climate change. I think it is most important to emphasise that climate change lies well within the current climatic variability, certainly that experienced by Australian producers, and others in the semi-arid parts of the world.

It follows that some of our existing risk analysis tools should be more widely adopted in view of the time of projected climate change. But there is one most important issue. While we have this knowledge base, we must appreciate that the people at the coalface - families, people who are the ultimate land managers - are often disfranchised from the scientific information and the tools that we use. We must not let that position continue. One of the most exciting things in Australia to me is the Landcare movement which has illustrated that the land community and rural community, once involved in the information, brings about changes. We must look at ways of bringing together the clever tools with the human interface so that we may work in the whole system, analyse it and work with the people who ultimately take the risk.

Dr' Ted MOUNT (USA) presented a paper entitled "Climate Change, Sustainable Economic Systems and Welfare".

DISCUSSION

Prof. Klaus HEINLOTH (Germany): You mentioned that due to climate change US farmers will only face a 7% loss of income, which depended on the input from climate models. If I may use as an input most recent climate models, am I wrong to assume that the loss to your farmers could be much heavier?

Dr MOUNT: I think that is what Cynthia will come up with, but I haven't seen that information yet.

Dr Brian WALKER (CSIRO Division of Wildlife and Ecology): I think all of what Dr Mount has said will happen anyway, despite climate change. One sympathises with that process, but a great deal needs to be done about it. We hope that UNCED might come up with something.

We here must focus on what IPCC is dealing with and most issues related primarily to climate and atmospheric change in this working group are supposed to deal with the way in which we can respond to them. We seek a series of strategies of response.

My point is that out of the gloom and doom we have to distil something. Too often there is a tendency to associate all climate change issues with negative effects and only negative effects, whereas in fact under any future scenario of climate and atmospheric changes that we care to come up wiith the future will be a mixture of hazards and opportunities for people. The risk assessment part with which John Williams dealt is essential to the way in which we approach that matter, but from any particular nation's point of view it is important to distinguish between those which will be opportunities and those which will involve hazards and problems to which people have to adapt.

One of the most important adaptation strategies involves how to minimise greenhouse gas emissions. That aspect has occupied 90 per cent of our attention at this conference, but in fact the conference is dealing with response strategies for minimising greenhouse gas emissions and adapting to climate change. It is the second point that I want to try to bring back into the conference's deliberations in a much more distinct way, rather than treating it as a footnote.

If we are to get any positive response or anything concrete, it has to come out of how to adapt to what will happen anyway, not just how we can minimise climate change. We all agree that it will happen to some extent. It is a mixture of opportunities and hazards. The most useful adaptive response is to be able to improve our ability to predict at a local and regional level the sorts of changes that will confront us so that we can distinguish between opportunities and hazards. If we can do that, there will be a positive way in which we can try usefully to adapt towards strengthening ourselves nationally, making use of what future climate change might bring.

Dr Kathleen HOGAN (US Environmental Protection Agency): I would like to follow up on Professor Heinloth's comment. The models that have been worked on in the United States to look at the reduced productivity in agriculture have really examined the net levels of productivity. I think that it is important to understand that to this point they have not looked at the period of time when a particular farmer would be losing the ability to grow on his land. The area where he would be able to grow a particular crop would be increasing, on the other hand. The United States has not yet decided that there should be a zero value associated with those temporal dislocations. The United States has seen some difficulties in agriculture through the '30s, and I am not sure that they are ready to deal with that situation.

The other point I want to make relates to the costs for reducing emissions of different gases in the United States, considerations that were dealt with by Dr Mount. Although I think there are options for reducing emissions that can have those kinds of costs, I also think there are many options which may even be profitable. One can look to some trends in US agriculture to see this. Apparently the US produces more milk with less than half the number of cows, compared with the 1940s. This development has all been economic, cost effective and progressive. That trend is not yet slowing, but is continuing. That is just one option. There are more options in respect of dairy, beef and waste management, all of which have a positive economic return. Therefore, before we deal with options that will cost $2000 per ton of reduction, I think that it is useful for us to identify those options again which have a no-regrets aspect about them and figure out how we can proceed on those lines.

Dr MOUNT: In regard to the last two statements, I do not agree with the first. I think the real issue is that policies dealing with climate change will have their effects a long way into the future. I find that doing an analysis where you take everything that you have now and change yields is not very interesting. The bottom line is that there will be a whole lot more people there when CO_2 levels double. Unless we recognise that in our analysis, we are missing maybe the most important piece.

In regard to costs, I emphasise that this is the combined direct cost and opportunity cost. I am not responsible for the numbers at all. I do not think Rich Adams was challenged - or perhaps he was - as to the cost of sequestering carbon being too high. That was the only number when he presented the paper that was challenged. I am sure that new information has come out and just as we are vulnerable to the assumptions we use about climate change when we put them into our model, these sorts of economic analyses are vulnerable to the assumptions about costs. I am sure that there are more up-to-date numbers that could be used.

Dr Willem BOUMA (Australia): May I make a comment about the costs quoted by Dr Mount. I see a more basic problem with those costs. The numbers are given with incredible precision. It will mean that people will try to see them as real numbers, whereas they are probably very fanciful.

At this conference we have talked about the possibilities of reducing methane from ruminants. One would find that most of the experts can give only sketchy ideas of how one would go about it, let alone putting a cost upon it. Here we have a number that looks so precise it is as if somebody knew it exactly and could put an exact dollar value upon it. Those sorts of numbers become very dangerous in their own right when they get quoted and requoted.

Dr MOUNT: That is my fault in the overheads. Rich Adams has ranges for these things.

CHAIR: If there are no further questions, I wish to thank the two presenters for their contributions.

(Luncheon adjournment)

SUMMARIES OF TRACK RAPPORTEURS - FINAL COMMENT

Stuart BOAG: I invite the meeting to discuss our draft outcomes. These have been prepared on my behalf by the three Chairs of the three tracks, with the assistance of their rapporteurs. They were: for Intensive, Professor Henry Nix, rapporteur, Dr Tom Denmead; for Extensive, Dr Gordon Neish, with Dr Will Steffen as rapporteur; and Integrated Systems, Dr David White, with Dr Miko Kirschbaum as rapporteur. On your behalf, I wish to thank them for preparing these draft outcomes.

TRACK 1 - INTENSIVE AGRICULTURE

MANAGEMENT STRATEGIES FOR REDUCING GHG EMISSIONS

(i) Holistic systems approaches are needed.
These should embrace the economic,
environmental and social factors

involved.

(ii) Measures to reduce GHG emissions
- should have low external input
- should be sustainable
- should preserve the quality of air, soil and water.

I do not think there will be any problems there. It continues:

(iii) Areas in which short and mid-term actions are possible/needed are
- agricultural practices
- research
- education and information
- land use planning and management
- monitoring
- policy and program reforms

(iv) Needs:
- integrated approaches
- better knowledge
- research & development (into mechanisms and magnitudes of emissions and their climatic effects)
- education and information

(v) Currently we pay farmers to produce food. We do not pay them to manage resources. We may have to do this in the future.
- How do we do it?

Are there any ideas that you would like to put forward on how this might be achieved. If not, I will continue:

- Incentives and disincentives are needed.

(vi) Problems of waste disposal must be addressed. This closes the cycle.

(vii) As we intensify production, there is a tendency to reduce biological diversity. This is a dangerous situation. In a time of climate change we need diversity more than ever. Who is charged with its maintenance?

(viii) Dynamic models of biophysical components of agricultural systems exist. There is a need to marry them with <u>socio-economic models.</u>

I have underlined the phrase "socio-economic models".

(ix) Mechanisms for getting people to work together in multi-disciplinary approaches are in need of research and development.

(x) There is a need to convey the issues of the GHG problem to the public in order to obtain action. This may be as important as developing technical solutions.

Could I note that I would like to see that recommendation on strategies moved high up on the priority list.

(xi) There is a need to identify what are the barriers to adopting those mitigation strategies that exist already.

(xii) The net emissions of greenhouse gas is the difference between the total emission and the sink uptake. Net emissions can be reduced both by reducing the total emission and increasing the sink strength. This needs to be recognised.

John WILLIAMS (CSIRO Division of Soils, Australia): I would like to see point (xii) moved further up and linked to education.

Greg TEGART (ASTC, Australia): It seems to me that many of these points are common to the three approaches and to take them in isolation is a bit crazy. I think they all apply equally.

Stuart BOAG: Are you moving that these general guidelines be set as applicable to all three tracks - that they are universal?

Greg TEGART: Yes, I think so. It would take out the specifics.

Stuart BOAG: I concur with your view. Perhaps you could provide some specific dash points there. Would you like to see Working Group II and Working Group III more closely integrated?

Greg TEGART: That comes out in one of the others. The problem is to try to get the three together and then see the common components.

Kathleen HOGAN (US Environment Protection Agency): To follow up the last statement, I think many of these things could be brought forward and called common guidelines, as you suggest, from the Workshop.

Stuart BOAG: That is a good suggestion; thank you.

Peter COSTIGAN (Ministry of Agriculture, Fisheries and Food, UK): I suggest that in item (ii) we delete the first bullet point as to low external input. I am not sure what it means. In many situations I think greenhouse gas emissions could be reduced by, say, increasing technology input. I think the point is that they should not consume a lot of energy resources, perhaps. Anyway, it is covered in the second point - that it should be sustainable.

Stuart BOAG: Thank you. For the record, I would ask the Chair or the Rapporteur of the track to expand on their notion of what low external inputs might be. If there is no qualification, I will continue.

Tom DENMEAD (Centre for Environmental Mechanics, Australia): No, I do not wish to expand on it. The author of the statement is sitting right next to me, and she might wish to comment.

Angele ST YVES (Agriculture Canada): I have made the statement that low external input also comprises energy. Is that what you were asking?

Stuart BOAG: Yes; thank you. We now move to the document entitled "Recommendations to Reduce Emissions of Greenhouse Gases: Intensive Grazing Systems". Again, this is from Track One, Intensive Systems. It reads:

> 1. There is a need to adopt a common framework for the assessment/evaluation of strategies to reduce the net emission of greenhouse gases
>
> - needed to consider net effect and overall balance
> - would need to consider the total system, and individual components that make up the system
> - proposed unit was NET GHG/UNIT of product. EPA proposal.

Peter COSTIGAN: With reference to the point of greenhouse gas emissions per unit of product, I think that somewhere in the documents we should stress the point that has been made several times to the meeting, that we are talking about a world where there will be a large population increase. We need to stress the fact that although we may be able to get greenhouse gas emissions per unit of product down, it will be much more difficult to get greenhouse gas emissions for agriculture down. It needs to be stressed somewhere. If we are to make the first document refer to the whole of the papers, it could be mentioned there; otherwise we are signalling the wrong message to policy makers that it is possible within agriculture to reduce greenhouse gas emissions. I think that may be rather difficult.

Stuart BOAG: I seek to qualify that. Where one expresses greenhouse gas emissions on a per unit product basis, I would surmise that that would not change with the magnitude of overall production in as much as a fraction is concerned, if you see what I mean. It does not matter whether there are five eggs or 10 eggs, greenhouse gas emissions per egg would be the same. Perhaps what you are going towards is the notion of looking at greenhouse gas emissions per unit consumer. That might pick up the issue of population.

Greg McKEON (Department of Primary Industries, Queensland): I am worried that in terms of grazing systems the concept of net emissions per unit product will not take into account any increase in product area that may occur. In the end if we are to balance emissions in the atmosphere, we want to control net emissions per unit of area.

Stuart BOAG: This is particularly pertinent in the case of extensive grazing systems. I can see your point, and it will be noted.
To continue:

> 2. Requirement for further research into the measurement of emissions from various intensive systems and investigations into the controlling processes rather than assuming the same emission in all systems and all environments - opportunity to develop mechanistic approach that will allow improved global estimates of emissions.
>
> 3. Requirement for a standard environmental and physical data set to be collected with the emission measurements. Emphasis would need to be on the controlling parameters.
>
> 4. Requirement for the development and adoption of new agricultural production systems that simultaneously increase productivity, improve nitrogen use efficiency and are matched to other production factors (e.g. water availability). The aim is to optimise nitrogen recovery and minimise the net loss of nitrogen.

Dieter SAUERBECK (Federal Research Centre of Agriculture, Germany): I will raise this matter again when we talk about greenhouse gas emissions in intensive cropping systems, but I can also raise it on point 4 that you have just read out. I put forward the message that we have to get away from these linearised nitrogen fluxes in our modern extensive agriculture. We just use the fertiliser nitrogen and it can just as well be legume nitrogen in order to produce a crop. Of course, we try to reduce the excess of unused nitrogen in the environment, but normally we do not worry about the nitrogen once it is in the crop and has been consumed by the consumers. The regular practice is that all this nitrogen goes to wastes, to surface waters and to the ocean and gets denitrified. Whichever nitrogen we introduce into the system, once it gets lost to the environment it will be denitrified somewhere, and there is no denitrification without N_2O formation.

I would like to see some statement to get away from the linearised nitrogen fluxes in present day intensive agriculture by trying to recirculate as much of the nitrogen within the system as can be achieved. Every nitrogen input, irrespective of whether it comes from fertiliser or from legumes, whether lost to the environment directly or after its passage through the crops and the consumers, is bound to return to the atmosphere somewhere and to be denitrified, thus contributing to the manmade N_2O release.

The only way to limit the anthropogenic N_2O release is to keep the nitrogen within the system and to recirculate it as much and as frequently as can be done. Only such recirculation-oriented agriculture - not only agriculture but society generally - will be able to halt or possibly even reduce the present manmade N_2O emissions. This has something to do with point 4, which you have just raised. I think that this should be made clear in more detail perhaps as a separate point - as to the nitrogen circuit and its importance in reducing our otherwise unavoidably large inputs.

Stuart BOAG: I will do the best I can. I do not want to turn this into a large discussion. If there are detailed interventions which have been written, I would like you to summarise them orally and then present the detailed and written intervention, if other people have that format. But we must move on and I will limit the discussions now to two more comments.

John CULLEY (Agriculture Canada): I think you could encapsulate that statement by expressing the fluxes in net greenhouse gases per unit or per area per unit time. I think it is important to get the units right here.

Michael MANTON (Bureau of Meteorology Research Centre, Australia): I suggest that point 3 be extended and moved to the initial overriding guidelines, particularly to emphasise the importance of monitoring the physical, chemical and biological processes involved with these systems.

Stuart BOAG: That is a good point. It is a universal statement.

I move to point 5, which says:

> 5. Adoption of improved animal management strategies to reduce methane emission from ruminant livestock, including
> - improved nutrition/diet
> - use of additives
> - increase animal productivity
> - microbial balance
> - improved genetic characteristics; better growth on same food source.

Could I move that these be expressed in terms of time frame of likely implementation?

Michael GIBBS (USA): I would perhaps reword the introduction slightly. Recognising that as to virtually all the things on the list there, increased animal productivity is the principal strategy for reducing emissions, I suggest that it should read:

> "Adoption of improved animal management strategies to produce needed food resources and reduced methane emissions from ruminant livestock by increasing animal productivity through, for example...."

and then listing improved nutrition, use of additives no longer needed to increase animal productivity - since this is the overriding thing - microbial balance et cetera.

Stuart BOAG: That is a very positive comment, and I particularly like the linkage with the need to produce food. It amplifies the point. I move to point 6, which says:

> 6. Emissions from wastes can be reduced by
> - more frequent small additions

Additions of waste, I presume. It continues:

> - collection and reuse of the methane
> - use of aerobic storage systems to prevent methane formation - increased CO_2 emission during decomposition?

Dieter SAUERBECK: As far as "more frequent small additions" is concerned, I think this could be made clearer if one states that the additions should correspond to the nutrient requirements of the following crop, in order to avoid excesses and double losses.

Tom DENMEAD: I am sorry to say that you are quoting from the wrong version. It is a little different and the wording is different.

Stuart BOAG: We will have to work with the version that is here, so if you have subsequent edits, could you please reiterate them. We can incorporate them later.

Tom DENMEAD: On the point of wastes, for instance, we ended up with: "Emission from waste can be reduced by more frequent small additions after disposal; collection and reuse of the methane during storage; use of aerobic storage systems to prevent methane formation."

Stuart BOAG: Are there substantial differences in the last two points - 7 and 8? If there are, could I ask you to read them out?

Tom DENMEAD: Yes, there are quite substantial differences from what you have. In fact you are quoting from section 1 dealing with recommendations to reduce emissions. We have followed that with a section 2 on the need for further research.

Stuart BOAG: I do not think I have that document. Perhaps we can reproduce it and come back to it later in the plenary. Would that be satisfactory?

Tom DENMEAD: Yes.

Snow BARLOW (University of Western Sydney): It might sound a bit pedantic, but we are calling this document "Intensive Grazing Systems", and it seems to include intensive animal production systems, maybe feedlot and stall animals. Would it not be better to call it "Intensive Animal Production Systems"?

Stuart BOAG: Is that generally agreed? We will note that. I move on:

> 7. Options are available to reduce nitrous oxide and methane emissions from intensive animal production. However, information is lacking
>
> - need to get integrated measurements to overcome the problems of spatial and temporal variability
> - need investigations into ways to control processes involved in GHG production, thereby allowing the development of better management options to increase the sink capacity and reduce the net emissions of GHG.
>
> 8. Concerned with NET emissions - the balance between sinks and sources

- consideration should be made at an ecosystem level
- need to keep in mind the principle of conservation of mass.

Roberto ACOSTA (Cuba): I think that if necessary we should include a recommendation about the necessity of eliminating the burning of biomass as a harvesting method.

Greenhouse Gas emissions in Intensive Arable Cropping Systems (other than rice)

Stuart BOAG: We come to intensive arable cropping systems (other than rice), and it is possible that the matter of burning might come in here. It reads:

> The most important emission is N_2O. It is believed that most of the increase in atmospheric N_2O is due to the increase of nitrogenous fertilisers and legumes. It is found that during the process of nitrifications and denitrification:
>
> 1. A number of minimisation strategies for N_2O are already apparent, although not fully tested. These include:
>
> . use of the correct form, rate and time of application of nitrogenous fertilisers. (Match supply with demand; needs knowledge of soil supply of mineral N.

Could I amplify there the need to communicate that information to practitioners. Perhaps that is the reason that it is not being picked up as much:

> . As far as possible, provision of continuous plant cover so that a large nitrogen pool does not sit unexploited in the soil.
>
> . Correct tillage, irrigation and drainage practices.
>
> . Reduction in the frequency, area and amount of biomass burned in forests, grasslands and croplands. Biomass burning can also be reduced by increasing the efficiency of biomass used as fuels. (These also reduce emission of other greenhouse gases).
>
> . Additions of lime where feasible (and required).
>
> . Use of foliar applications of N

fertilisers where feasible (avoid
soil contact).
. Use of nitrification inhibitors
(avoids the formation of N_2O during
both nitrification and denitrific-
ation and coated fertilisers).
Research to date suggests that these
can be very effective, and have the
double benefits of being attractive
economically because of the savings of
N (no denitrification) and environ-
mentally (no N_2O) Perhaps not
universally true.

Dieter SAUERBECK: It was within No. 2 that I would like to have this circulation statement included. I have a question. So far as the peat cover is concerned, it sounds to me a rather exotic possibility in individual cases only, which certainly cannot be generalised.

As far as the foliar application of nitrogen fertilisers is concerned, again if we generalise this, we disregard the fact that only a very small percentage of the overall nitrogen requirement of a plant can be applied by foliar application. If you use urea, as many people do, you have ammonia nitrogen losses as well.

Finally, so far as nitrification inhibitors are concerned, Tom Denmead has already pointed out that the statement here may not perhaps be a universal truth. I would like to stress that I have learned that the calcium carbide seems to do a very good job, but as for the other nitrification inhibitors their effectiveness is most questionable, both in duration and extent. We just cannot rely on the fact that these denitrification factors will really do the job that we expect from them because they are decomposed and inactive, depending on external conditions such as temperature, moisture, microbial activity and so on.

So I would say that if this statement is to be retained in this way, you have to specify that the Plenary is convinced that it is just the calcium carbide which does so exceedingly well, but not generally for nitrification inhibitors.

Peter COSTIGAN: I would support a couple of the suggestions made by Dr Sauerbeck. I would suggest that we could delete the bullet point on the use of foliar applications of N fertilisers, as the point is already made within the first bullet point on the correct form, rate and time of application of N.

Secondly, I would reiterate some reserve about the universality of the effect of nitrification inhibitors. Perhaps the last sentence in the final bullet point could be strengthened.

Stuart BOAG: Yes, I think I can deal with that.
It continues:

2. There are indirect contributions to N_2O emission through volatilisation of NH_3 and emissions of NO_x into the atmosphere, and its redistribution over the landscape through wet and dry deposition. These are large problems in Europe and North America. Strategies to increase the overall efficiency of N are therefore necessary. This will involve the cooperation of:

- fertiliser companies (availability, pricing of competitive N fertilisers are issues)

- agricultural advisers (correct solutions for different situations; avoidance of wasteful practices even though convenient)

- farmers.

3. It is probable that we can already design/recommend cropping systems to reduce GHG emissions with existing knowledge/technology, recognising that different solutions are required for different circumstances. Implementation will require changes in farmer practices which farmers may or may not choose to implement depending on expected economic returns. Therefore, strategies for promoting implementation must be developed in consultation with farmers and must include socio-economic evaluations. For example, it was suggested that assisting farmers to perform a rough nutrient (N) balance for their farm operation could be a very valuable educational tool.

I think that point could go to the front of the section in many regards.

Ken ANDRASKO (United States Environment Protection Agency): I would like to offer a minor clarification on point 1 on the fourth bullet, concerning biomass burning. I would propose that it should read: "Reduction in the frequency, area and amount of biomass burned in forests, grasslands and cropland production systems, by altering the use of fire as a land management practice." The point I am suggesting is that we are not simply trying to abandon fire, but saying that it needs to be reduced. We are talking about alternative uses of fire as a management tool.

Stuart BOAG: That comment should not exclude wildfire control and amelioration measures; it is not simply more effective management of fire as a tool of management, but also fire as a natural phenomenon.

Ken ANDRASKO: We could talk about improving fire suppression systems. I think fire management captures both.

Dieter SAUERBECK: On point 2 about N_2O losses, you have mentioned the ammonia in this respect and then just summarised strategies to increase the overall efficiency. I would prefer to have some statement that losses have to be reduced.

You may say that it is the same, but I do not think that everybody understands this correctly. It may be better to make clear that all possible means to reduce losses should be used. I would even like to challenge the Plenary by a statement, which I shall try to formulate somehow, as to the use of nitrogen to such an extent that it becomes economically interesting to use all possible means to reduce losses and to reduce nitrogen inputs and increase nitrogen efficiency. This refers to Dr Hanus's paper that was presented this morning.

Methane emissions from Rice

Stuart BOAG: I move on to emissions from rice:

1. Global Estimates

IPCC (1990) estimated the contribution from rice paddies as about 20 to 100Tg/per year or 20% of all emissions. Both Neue and Minami have made further estimations based on a larger set of direct measurements, and on functional relationships between soil properties, temperature, nutrient supply, etc. and CH_4 emissions. Both authors arrive at estimates of between 40 and 60Tg of CH_4 emitted from undisturbed rice paddies, considerably less than previously believed. The figure needs confirmation. This will require both measurement and modelling. In particular,

- development of mechanistic models of CH_4 production and emission

- development of measurement techniques which integrate over larger areas than chambers and do not disturb the canopy microclimate such as micrometeorological techniques

- identification and quantification of controlling factors.

About 80% of the CH_4 produced in rice paddies trapped in the sediments. However, some rice-growing systems involve operations which disturb the sediments and release the CH_4 (5 such operations are common in the Philippines for instance: cultivation, sowing, fertilising, weeding and so on). It may be that emissions from real farm systems may be greater than the 40 to 60Tg/year estimates.

Encouragement of cultivation systems with minimum soil disturbance is recommended.

2. Reducing Emissions

Emission might also be reduced by:

(i) selection of varieties that have high resistance to gas transport from soil to atmosphere (differences between varieties do exist)

(ii) use of nitriification inhibitors - chemicals that restrict oxidation of N by bacteria, thus decreasing N loss and eg. Encapsulated Calcium Carbide plus N fertiliser reduce CH_4

(iii) adoption of improved water management if soils are acidic. Drainage of soil increases oxidation state of and consequently CH_4 formation (can be done if water available, and controllable water supply).

(iv) increasing rate of water percolation and frequency of draining

.. would increase water requirement
to grow crop
.. what will be other environmental
effect, eg rising groundwater?

(v) Q: what will be the effect of
drainage (to reduce CH_4 emission)
on N_2O evolution? Oxidisation of
soil will increase mineralisation,
nitrification and N_2O evolution.

(vi) composting rice straw instead of
direct incorporation into the soil.

Kathleen HOGAN: I have comments starting with the paragraph on global estimates. I think the first sentence should read: "Working Group I of IPCC has estimated the contribution from rice paddies at 20 to 100 Tg/year or approximately 20% of all emissions". Then we should go on to say that Neue and Minami have made further estimates based on larger sets of direct measurements in Asia on the functional relationships as stated, and then say: "Neue presented new minimum estimates of between 40 and 60Tg from undisturbed rice paddies", and then immediately say that further work is required on that list of items.

Then on the next point as to the 80 per cent of methane, I think we should reiterate that the 40 to 60 Tg per year was from undisturbed fields and that the "greater than" sign would be modified by saying "substantially greater than", since Neue indicated that it is possible that the emissions that result from walking through the field could be of the order of another 40 to 60 Tg of methane.

Then we go to the encouragement of cultivation systems. That is a reduction strategy and probably should be moved below for reducing emissions. Items (iii) and (iv) could be condensed because they are very similar. We could also state a result of Minami's talk, which showed that you can get reductions of almost 50 per cent in some irrigated systems where there is high control of water supply and drainage.

Tom DENMEAD: There are quite a few typos in the text. I do not want people to think that we are as mad as this wording makes us sound.

Stuart BOAG: I would emphasise that this was done in very great haste. The document continues:

> It was noted that the US EPA has recently reviewed strategies to minimise methane emissions from rice. Its recommendations can/should be incorporated with this list.

Two final points are that:

- technologies for reducing emissions cannot be developed in isolation but must be worked out in conjunction with the people who will use them

- the lead time for technology development and transfer is 10 - 15 years.

I would seek clarification of 10 - 15 years and link it with our perceptions of the time frame of likely global impact of climate change. Ten to 15 years is a quite significant length of time for technology transfer. That would suggest to me that if I were to presume that the population might double in the next 75 years, that is not many technology transfer cycles. I am not saying that I will put it in there; I am just passing comment.

TRACK 2 - EXTENSIVE AGRICULTURE

Stuart BOAG: We now move to Track 2, the draft outcomes relating to Extensive Agriculture. The document reads:

1. Context

Agriculture is necessary to supply food for the world's population. The GHG emissions arising from this inescapable activity are relatively small in comparison with those from the industrial and transport sectors.

Within agriculture, extensive agriculture covers very large areas (approx. 40% of earth's land surface) but accounts for relatively little GHG emissions.

Most extensive agricultural systems are low input systems operating in highly variable environmental conditions. The interannual variability of the natural climate in these regions is as large as any expected secular climate change due to an enhanced greenhouse effect over the next few decades. Thus the development of strategies to optimise the management of these regions based on present climatic variability will be a substantial step in the development of strategies to adapt to climate change.

> The quantitative data on GHG sources, sinks and fluxes are inadequate to justify anything more than a "no-regrets" policy at this time.

Dieter SAUERBECK: I think that it is impossible here to state generally that the contribution of agriculture to the release of greenhouse gas is relatively small. We know that it is extensive agriculture which causes most of the forest burning, and this adds 2Gt of carbon to the atmosphere every year out of a total of somewhere between 6 and 8Gt. Can we say that this is "relatively small". I think the wording as it is at present is misleading.

Will STEFFEN: I think it is just a matter of definition. We did not include biomass burning as a result of forest clearing as part of extensive agriculture. We include the releases due to the operation of the extensive agricultural systems themselves.

Dieter SAUERBECK: These two gigatons are attributed to agriculture.

Will STEFFEN: Maybe we should put them in general, I am not sure. A lot of the systems that are put in place of the forests are not what one would call extensive agricultural systems. They are slash and burn, small operations. Where do we want to put those?

Stuart BOAG: I can't edit on my feet but imagine I can come up with something to qualify that statement. We can exclude carbon dioxide from biomass burning and can perhaps embrace the other greenhouse gases and link that with the term "relatively small".

Miko KIRSCHBAUM: I question whether it is useful at all to include a statement as to the relative magnitude of the respective emissions. I think if you can break down any sector into a small enough sector, then it becomes insignificant. I think that statement doesn't add anything and should be left out.

Stuart BOAG: Are there any further comments from elsewhere in the Plenary? I would like some broader views on this point.

David MAJOR (Canada): I think it should be kept in mind that these extensive agriculture systems are low input, and a lot of the poorest parts of the world exists there. I think it is appropriate that we say these are not a big contributor to greenhouse gases.

Michael GIBBS (USA): Within the session we had a lot of discussion about what "extensive" really meant and what was included. I think that in part is some of the confusion as to whether they are small or large relative to what. I think I would agree with the earlier statement that trying to state whether something is small or large for extensive without sufficient definition of what is included would not be useful.

Stuart BOAG: That is an excellent point. Could I ask members of the Plenary to give some thought to definitions for these three tracks? I have given very brief and rather vague definitions in the program - intensive, extensive and integrated. I think it is appropriate that we should preface each of these nest of recommendations with a better definition. I throw it over to you - not now but between now and the end of the day.

Jane VON DADELSZEN (New Zealand): I suggest that we should try to avoid doing inventory work in this workshops if we can. Working Group 1 has done a lot of work on the relative contributions of different sectors to the problem. I think the definitions of sources that they have come up with are probably those that the IPCC as a whole will end up using. I think if we then try to define "extensive" and then its relative importance, we will cut right across that. I think there is a danger when we start citing values to those things that we are using a term that might be used to describe many more things. I think in our presentation we have already discussed extensive agriculture including the clearing of forest from that agriculture. We have to be careful how we define these things.

Stuart BOAG: May I suggest that another paragraph should be drafted which would take on the difficulties or issues implicit where one tries to relate agricultural systems management to current categories which are listed within IPCC.1. I have been involved in IPCC.1 emission inventory work and can see that there are difficulties where one tries to take the hard numbers for categories which are set down and put them across. We need perhaps just to note that.

Will STEFFEN: I take the point that we must be careful in our definitions. Any guidance on how the group might think we should define these things would be helpful. On the second point as to whether we should point out relative magnitudes, I agree with Dr Major that it is very important that we include quantitative and relative estimates of what we are talking about. It does policy makers no good whatever to give them a whole grab bag of possible solutions and not tell them what is potentially more important than others. It is not a very good idea just to give them a whole unranked, unquantified list. I reiterate the point that we must be quantitative and must rank things as well.

Stuart BOAG: If we are to explore that, could I ask the Plenary for views on the convention as to greenhouse gas emission global warming potential, that being very pertinent where one is trying to make any relative estimates of greenhouse gas contributions from agriculture where one has to take on board nitrogenous gases and methane? What are we guided by? If you take a 20-year time horizon, it gives a policy maker a completely different perspective than if you run with a 100 or 500-year time horizon. It is an important policy point.

Willem BOUMA (Australia): I think it would be wrong for us to try to convert everything back into CO_2 using greenhouse warming potential that may still be subject to debate. We can be very specific by simply talking in relative terms of how much of the methane can be reduced, how much of the nitrous oxide can be reduced, and how much of the carbon dioxide can be reduced or taken up. It is far simpler. Greenhouse warming potential is an added thing that someone else can add later. It is not our problem.

Stuart BOAG: That is a fine point, thank you.

Greg McKEON (Australia): Our uncertainty is that we think the emissions in extensive systems are low per unit of product, to use the same terminology as previously used in the intensive systems. However, I would point out the lack of logic in this in that the third statement in the context says that we have little quantitative data on those sources. I think that third statement should be put up further so that someone reading this would be aware of our uncertainty before they were aware of our likely estimation.

Stuart BOAG: Thank you for those comments. They will be very helpful. I continue with the document:

2. Mitigation strategies

Of the many possible strategies, we suggest that two, one predominantly managerial and the other predominantly technological, be selected for initial emphasis.

2.1 Management for Optimum Stocking Strategy

Optimum stocking strategy is based on a <u>variable</u> stocking rate that doesn't run down resource base (vegetation productivity and composition, soil carbon, soil structure, etc over time). In practice, constant stocking rates are usually used. The safe maximum stocking rate (a constant) is a low average rate that will, for the long term, achieve an economic and ecological optimum.

Based on premise that current management systems in many parts of the world are leading to degradation of resource base and declining productivity.

Adoption of lower stocking rates would lead to an increase in the net, long-term production of livestock and direct reduction of GHG emissions, simultaneously.

David WHITE (Bureau of Rural Resources, Australia): I have done a lot of estimates of optimum stocking strategies over the years for grasslands, though not for rangelands. I am not comfortable with the comment, "In practice, constant stocking rates are usually used". I would rather it read, "In practice, near constant stocking rates are often used". I am not too comfortable even with saying "a low average rate". I think it should read "A safe maximum stocking rate will achieve an economic and ecological optimum in the long term". It is essential, certainly for financial survival, that your stocking rates are high enough in the good years to generate enough income for the farmer to survive the poor years.

Gordon NEISH (Agriculture Canada): I have no problem in accepting the comment that was made in terms of the correction.

Greg McKEON: I think we could resolve this problem if we could modify the sentence to encompass David's point about the necessary variation in numbers.

Stuart BOAG: If that is acceptable to the rest of the Plenary, I am happy to accept the revised text.
I continue with the document:

> Move to sustainable management practices could lead to significant increase in soil carbon, thus creating a sink for GHG. (More research is needed to quantify this potential effect)
>
> Requires knowledge of the functioning of the entire system (soils, vegetation, herbivores, climate etc) and how system responds to perturbations. (More research needed on functioning of extensive agricultural systems as whole ecosystems. Present calculations suggest that, when a system is operated at its optimum sustainable level for productivity, the production of GHG is also near its minimum.

Mark HOWDEN (Bureau of Rural Resources, Australia): I would like to modify the last sentence to read: "...the net production of greenhouse gases is also near its minimum per unit product".

Stuart BOAG: Thank you. To continue:

> Diversification of herbivore type (i.e., more use of "native" fauna - bison, browsing antelopes, kangaroos - in mixed systems).
>
> Improved efficiency of production (through, for example, feed supplementation, forage enhancement, etc) evaluated carefully to ensure that

overall production doesn't increase to levels which lead to secondary effects that result in additional GHG emissions through degradation processes.

2.2 Manipulation of Rumen Microbiota

Use of high technology methods (e.g. genetic engineering) to alter rumen microbiota to reduce methane emissions.

Could be introduced to herds through single, initial inoculation. Thus, it would be a low input technique with no change in management strategy required.

May improve digestibility of lower quality forage.

Large-scale implementation may be feasible within 10-20 years.

Secondary effects need to be considered carefully. If a minimisation strategy allows increased stocking rates overall, and this occurs, it could lead to ecosystem degradation.

3. Some Cautionary Comments

Social, political, economical and psychological factors are important. They will have to be considered in (a) convincing producers of what is an optimum stocking strategy, and (b) getting them to adopt it.

Minimising GHG emissions from extensive agriculture is closely related to maintaining a healthy resource base (i.e. a stable and non-degrading ecosystem). Any minimisation strategy that exceeds safe maximum stocking rate and leads to degradation will be counter-productive.

Suggestions that biomass burning should be reduced must be treated with caution, since fire is an integral part of many of these ecosystems and any change in fire regime will have profound effects on the structure of the system and its value to livestock. Therefore, the best strategy is to minimise burning consistent with management requirements.

- Broadacre cropping was not specifically included in extensive agriculture. However, if it is, zero tillage strategies are recommended if the potential negative effects of weeds can be controlled. Zero tillage in these regions has two major advantages in reducing GHG emissions - reduced wind erosion and reduced decline in soil organic matter.

4. Conclusions

> Extensive agriculture has limited options for action and, even if <u>all</u> were adopted, would have a smaller impact on <u>global</u> GHG emissions.

Again, there is the qualification on carbon dioxide and other gases, including fire and so on. That needs to be inserted. The document concludes:

> Nevertheless, we have identified several important options that will reduce GHG emissions, enhance adaptability to global change, and move extensive systems towards sustainability.

Peter COSTIGAN: Paragraph 3, bullet point 1, stresses that social, political and other factors are important, but the second sentence seems to suggest that they are only important in those two particular ways. I think that we should stress that they are also important in determining what strategies are appropriate in any particular situation and how those strategies should be structured.

Stuart BOAG: That is noted.

Michael GIBBS: I agree completely with the previous comment. In regard to section 2.2 as to manipulation of rumen microbiota, this was one of several opportunities to balance the rumen environment. An improvement would be brought about if it were to read, "Balancing the rumen environment using methods such as..." and then listing the various opportunities that were discussed in this session, including manipulation of rumen microbiota.

Stuart BOAG: If that is the case, may I ask someone involved in those discussions to provide me with the accepted list of options?

Willem BOUMA: Referring to section 3, we see that zero tillage has two major advantages in reducing greenhouse gas emissions. I would point out that wind erosion per se is not a greenhouse gas emission. It really is only the decline in soil organic matter that seems to be addressed. It should be "one advantage".

John WILLIAMS (CSIRO, Australia): In regard to 3.1, I am a little unhappy with the wording. We seem to be convincing producers as to what is an optimum stocking rate. This illustrates a naive attitude towards change. I think that our Landcare movement illustrates that we have a lot to learn. One has to involve people in the information, rather than just telling them. In that way one will get change. I think that there should be some wording to reflect the fact that things are changing and that we are learning how change takes place. The current statements are incredibly naive.

Will STEFFEN: I think that we could remove that bullet point altogether. It is included in the overall matters mentioned at the beginning.

Kathleen HOGAN: In regard to paragraph 4, Conclusions, I suggest that we remove point 1. I have already suggested that we are looking at many options and that any particular option does not necessarily have a large impact on global greenhouse gas emissions. We are also working to establish a framework by which different options will be evaluated. That result would fall out through the development of that framework, and I do not think it should be prejudged.

Stuart BOAG: I think that is a very important point, given the regional/national variation in agricultural systems and the likely different national strategies to limit greenhouse gas emissions. Probably it would be pertinent to explore that further.

Ken ANDRASKO: I wish to follow up my colleague's point. I suggest that instead of dropping that wording, we could add a sentence following the first in the conclusions. I suggest that it should read, "However, benefits could be significant for some production systems, ecosystems and nations".

Stuart BOAG: What are people's feelings on that? Perhaps that suggestion may cause more trouble than it is worth.

Greg TEGART: I am a bit concerned about paragraph 2.1 regarding the diversification of herbivore type, more use of native fauna in mixed systems. That seems to me to be way out beyond any of the reasonable options that we should be considering here. I am wondering why that should be in the document.

Gordon NEISH: I wish to clarify that point. Mixed systems are already used quite extensively in Southern Africa on gaming ranches and so on. The thought is that some of the native species produce much less methane per animal than do the more commonly used ruminants. This is the reason why this might be an important strategy in reducing GHG emissions.

Stuart BOAG: I will note that point. This might be a convenient point to break off as we are about to reach Track 3.

(Tea adjournment)

TRACK 3 - INTEGRATED SYSTEMS

Stuart BOAG: We now turn to Track 3, Integrated Systems. The document reads:

> No single option in agriculture or forestry appears to have the potential to offset more than several per cent of a nation's greenhouse gas emissions, but agriculture and forest options together may potentially offset up to 25% of many nations' emissions. Integrated systems may offer further potential to manage the terrestrial biosphere to conserve and sequester carbon as well as provide a sustained flow of goods and services to local people.
>
> Agroforestry may not be able to solve the greenhouse problem by itself. However, based on work done to date, it seems likely that agro-forestry can conserve and sequester significant amounts of carbon on a global scale. In general, for a given site, and for given environmental conditions, living systems that include woody perennial vegetation can sequester and conserve more carbon than systems consisting of annual species only.

Willem BOUMA: I would like to take issue with paragraph 1. I understand that the "25%" is really a range - something like 5 to 25%. By saying "up to 25%" gives people the impression of just the upper part of the range, not the lower part.

Stuart BOAG: Can you confirm that it is a 5 to 25 per cent range?

Miko KIRSCHBAUM: It comes to 5 to 25 per cent. If people are happy with it, there is no problem in changing that.

Stuart BOAG: I am comfortable with that.

Willem BOUMA: My second comment is on paragraph 2 where I think the word "significant" is subject to debate. It is a matter of definition, but it raises false expectations to say that agroforestry "can conserve and sequester significant amounts of carbon on a global scale". Is it significant compared with 6Gt of carbon that are emitted from fossil fuel burning?

Stuart BOAG: I suggest a possible redraft that might read: "However, based on work done to date it seems likely that agroforestry can conserve and sequester some carbon on a global scale".

Willem BOUMA: One last correction as to the sentence, "Agroforestry may not be able to solve the greenhouse problem". Either it should say "cannot" or it should be deleted altogether.

Stuart BOAG: I take that point; we will edit that accordingly. The document continues:

> A limitation of natural systems in terms of the global carbon balance lies in the fact that carbon stores in a system can be modified only once. Ongoing effects on the global carbon balance are thus prevented by feed-backs in the system itself. An option to achieve an ongoing reduction in the GHG emissions lies in the use of biological systems for energy generation as partial substitution for fossil fuels. Linkages of agricultural and forest systems with energy production systems may thus provide:
>
> - economic viability of the system
> - availability of large capital
> - political and financial support
> - ongoing reductions in total GHG emissions.

I would like to make one point here for the record. In my efforts to redraft these recommendations from each of the different tracks, I will standardise them and will put the content of this particular track into a dot-dash format.

Willem BOUMA: I find this statement a bit ambiguous. Often biomass is discussed in terms of being a fossil fuel substitute. Here there is a reference to the availability of large capital - utilities - but we are not suggesting that the power stations burn the trees; we only suggest that those concerned buy off their guilty consciences by planting the trees. That is a different issue. The linkage of energy and forest systems is ambiguous to say the least.

Stuart BOAG: Nevertheless, we need to pick up and amplify the linkages which do exist in terms of land management with perennials and energy flow-through with human assistance.

David MAJOR: Can we have clarification of the sentence "Carbon stores can be modified only once"?

Miko KIRSCHBAUM: We are dealing here with the carbon that is stored in ecosystems. If there are 100 tonnes of carbon stored in the ecosystems, then through management options we can effect a change to either 50 tonnes per hectare or 150 tonnes per hectare. Over any time span there is only 50 tonnes of carbon for that particular area that we can play with. Thus, there is only limited scope; it is not an ongoing reduction that can be sustained in perpetuity. Once the system has lost all its carbon, it can no longer lose any more. Alternatively, once a system has been brought up from a degraded state to a high carbon content state, it does not matter how well the system is maintained, no further increase in its status can be obtained. Therefore, there is automatically a limit to how much can be achieved. The only way one can overcome that limitation is by using the carbon from that system as a fossil fuel substitute. Then for a thousand years it could be playing a role in the greenhouse scenario.

David MAJOR: On a human time scale carbon is dynamic so I am not sure that this statement as written really conveys the point that has just been made.

Willem BOUMA: The point is correct. The statement may not convey it properly.

Stuart BOAG: I seek the Plenary's indulgence and ask you to allow me to pick that up from the record of the discussion. I can also clarify the matter with the Rapporteur, who is also based in Canberra.

Jane VON DADELSZEN: I wish to clarify the point about burning wood as a fuel. You might say that we do not put it in power stations. I do not know whether this has been done - I suspect it may have been in Brazil. I do not think we are simply talking about getting utilities to plant trees. In the long term we are talking about getting utilities to burn wood, rather than burn fossil fuels. I think it is broader than that.

Willem BOUMA: I was only suggesting that the statement should be made a little less ambiguous.

Stuart BOAG: At that point I think we should move on. The document continues:

> However, additional work is needed to further quantify the potential effect that integrated systems may have. The further quantification of these opportunities and benefits should follow and expand upon the emissions inventory methodology being developed by IPCC Working Group I.

I would move to relocate this part of the text as a foreword to this whole report. It continues:

> This methodology should be capable of evaluat-

> ing and comparing the potential of proposed integrated systems. Countries with quantitative data should provide this to AFOS and to Working Group I Secretariat in a cooperative process between IPCC WG I and WG III that needs to be identified and implemented.
>
> Additional research into integrated systems should specifically focus on developing the data needed to make valid comparisons between various short term and long term response options to minimise the emission of greenhouse gases.
>
> In addition to their potential effect on reducing GHG emissions, integrated systems may also be better able to adapt to a changing climate. It is highly likely that changing from mono-species to multi-species and multi-layer canopies of agroforestry systems will lead to increased resilience and less inter-annual variation in net primary productivity and carbon storage in most ecosystems.

Willem BOUMA: My query relates to the first sentence. I think the word "adaptation" is construed as being where a species adapts to being better suited to a climatic regime. That is not really what is meant, and if that were the case the statement would be incorrect. I think we should use the word "cope" instead, because I think this would convey the meaning better.

Stuart BOAG: I can see heads nodding. I will take "cope"; I am happy with that. The document continues:

> However, a system's resilience to perturbations is not simply correlated with its complexity, but the nature of the complexity is also critically important. When integrating trees into a production system, consideration should therefore be given to native species as well as non-native alternatives.

John WILLIAMS: I was not part of this group, I was part of Extensive Agriculture, but I wonder how you intend to tie in woodlands which, in Australia, are very extensive. What you are talking about here applies equally well to woodlands as integrated systems, and I think that this point needs attention.

Stuart BOAG: Thank you; that is a useful point of clarification. Extensive grazing systems which incorporate woodlands should be viewed perhaps in a similar context to agroforestry systems. That is reasonable. The document continues:

> Agroforestry and other integrated systems may have further environmental and socio-economic benefits. Taking all of these into account it may be considered a "no-regrets" option. That is, a switch to agroforestry and other integrated systems may often be justified for reasons other than the reduction in net GHG emissions. A reduction in GHG emissions may then be accompanied by other net benefits to society.
>
> Databases on suitable tree species for integrated systems exist. Assistance should be given to locate and improve access to these databases. Work should continue to further refine and extend these databases, particularly concentrating on the minimum dataset required to adequately define a species' environmental requirements. Models and analysis methods need to be further developed to predict where and how well species suitable for agroforestry will grow under present and future environmental conditions.
>
> Despite their many benefits, farming communities in many countries are slow in adopting integrated systems. We recognise that the adoption of integrated systems requires a cooperative approach by farmers, scientists, extension officers and the population in general at all stages of design, implementation and refinement.
>
> There are many potential integrated systems that can fulfil a variety of different functions. To match the most appropriate of these many potential systems to the variety of environmental, cultural and socio-economic situations where they might be used is a challenging task. Research and appropriate analytical tools are needed to identify appropriate integrated systems within developing and developed countries, and the transfer of these tools among countries should be strengthened by development assistance institutions.

B.A. ASAFA (Federal Department of Forestry, Nigeria): Paragraph 4 says "Despite their many benefits, farming communities in many countries are slow in adopting integrated systems". It then mentions a cooperative approach by farmers, scientists and extension officers. I would like to see the concept of extension officers expanded to take in officers who have skills which cut across the three domains.

Stuart BOAG: That is an excellent point.

B.A. ASAFA: "Extension officer" should also include policy planners.

Miko KIRSCHBAUM: In our discussions on that point a whole range of different people were mentioned at various times. It was very difficult to know where to draw the line.

Stuart BOAG: I am confident that I can pick up that concept. The document continues:

> In areas with extreme population pressure there are particular problems in introducing environmentally more suitable alternatives. Strategies to overcome these problems include:
>
> - better education including environmental education;
> - transfer of technology; and
> - adoption of alternative production systems.
>
> A number of countries in Europe and the former USSR are undergoing rapid transition from centrally planned to market economies. This transition may have both positive and negative implications for greenhouse gas emissions. Opportunities exist to introduce international research aid and technologies with positive environmental impacts during this period of change.

Willem BOUMA: We may need some clarification as to atmospheric pollution.

Jane VON DADELSZEN: What was being talked about was atmospheric pollution that affects the health of forests and other integrated systems - for example, acid rain. It was quite specific.

Willem BOUMA: That is not peculiar to integrated systems.

B.A. ASAFA: In terms of population pressure, better education and participation are the key words.

Stuart BOAG: I take the point about participation. I would like to make one point about a matter that has been brought to my attention. When I say that I will look after something, I really mean that I will consult with the Chairs and Rapporteurs of the various tracks in the redrafting of this document. I envisage myself as having a central role on the keyboard, but I assure everyone that it will be in the course of very detailed consultations with those people.

Wojciech GALINSKI (Poland): There have been some economic changes in Eastern Europe which will have a positive impact on greenhouse gas emissions. Perhaps this consideration also should be reflected.

Stuart BOAG: The document continues:

> Recognising that many parts of the world have been degraded by a variety of pollutants, international cooperation is needed to:
>
> - rehabilitate areas degraded by pollution;
>
> - assist in technical cooperation to reduce emissions of pollutants causing further degradation, especially forest decline; and
>
> - assist in technical cooperation to integrate all nations' forest sectors into regional and global forest economies.
>
> IPCC AFOS may want to consider additional workshops/activities to develop a common measure for comparing mitigation options:
>
> A. Carbon budget and net greenhouse gas emission and land use allocation methodologies for evaluating response options in conjunction with IPCC WGI.
>
> B. Formal methodologies for economic assessment (modelled on the process used for the Working Group I emissions inventory).
>
> C. Integration of WGII impacts findings with mitigation options should address
>
> - competition for the same land
>
> - evaluation of climate change impacts on productive agricultural and forestry systems

- CO_2 fertilisation

- changes in soil carbon and methane with temperature and moisture.

Policy makers currently face promising opportunities and significant challenges to integrate agriculture and forestry today at the international level. These include:

- the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change;
- the Intergovernmental Negotiating Committee for a Global Convention on Biodiversity;
- the Global Forest Agreement;
- UNCED including the Agenda 21 Sustainable Agriculture proposal; and
- GEF World Bank potential proposals...

Do people have any opposition or otherwise to this? If not, thank you all very much for your attention to these matters.

(END DRAFTING SESSION)

* * * * * * *

CLOSING ADDRESS

Dr Klaus HEINLOTH (Germany) Co-Chairman of the Plenary Session: The task of this Workshop was to assess technologies and management systems for agriculture and forestry in relation to global climate change and to investigate the possibilities of producing sufficient food in a sustainable way, even during times of rapid climate change, for a still rising world population. During this Workshop we have heard about intensive agriculture, extensive agriculture and integrated systems, mainly agroforestry. I not only learned of a wealth of options, many of these already proved in some regions of the world, but also I gained a feeling of optimism from what the speakers taught me - optimism that we can achieve our goals, thus assisting nature to adapt fast enough to unavoidable climate change.

I was especially happy to find that during this Workshop knowledge and experience were provided from countries of all regions around the globe. We already can learn from each other and help each other to achieve a sustainable way of living in rapidly changing conditions.

Now I would like to raise a few more questions. First, how do we spread the knowledge among all nations? Secondly, how can proper education be provided in any country to understand the problems and cooperate in servicing them? Thirdly, what are the obstacles to fast progress in sufficient food production in a sustainable way? I not only have in mind lack of financial resources and economic barriers, but also the greater obstacles of a lack of understanding of a different way of thinking and of traditionally-based living in a huge variety of societies and nations in a rapidly-changing world.

Certainly, we would all like to progress towards this goal, but what can we contribute? I have to remind you that we have been given the task within IPCC of scientific assessment, of identifying options. We should provide scientifically-based, sound advice. But we - the AFOS group - should not make recommendations and we certainly should not get entangled in politics.

So, how can we proceed properly and efficiently? I guess it might be helpful for all our governments in their international negotiations and cooperations to be provided with the answers to these questions I have just set before you. I would like to ask you for your opinions. Perhaps we should try to assess these sorts of questions in a future Workshop. At such a Workshop there should be contributions not only from scientists in our field, but also from those in other fields such as social sciences and other related subjects. I think we should discuss this at the next AFOS meeting.

In closing this Workshop, I wish to thank you all for your most valuable contributions. We really have moved a step forward. My special thanks go to our Australian organisers, to Stuart Boag and his crew, who worked so hard to make it run so smoothly.

Proceedings concluded at 4.35 p.m.

(END CONFERENCE)

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