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Towards a sustainable oil palm industry in PAPUA New Guinea

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Contents

1 Acknowledgments

The activities in this project revolved around two workshops in which all participants gave valuable contributions. They were (in addition to the authors):

John Armour, Qld Dept of Nat. Resources & Water

Felix Bakani, Oil Palm Industry Corporation

James Butler, CSIRO

Charles Dewhurst, PNGOPRA

William Griffiths, CTP Holdings

Mike Hoare, New Britain Palm Oil Ltd

Graham King, Hargy Oil Palms Ltd

Ann McNeill, Uni of Adelaide

Petra Meekers, GSA

Tony Pattison, Qld Dept of Primary Indust. & Fisheries

Rachel Pipai, PNGOPRA

Marcus Sheaves, JCU

Simon Lord (GSA) was not able to participate in the workshops, but also gave valuable contributions.

2 Executive summary

Oil palm is the most important crop in PNG in terms of export income (over K 1,000 million in 2008), directly supporting over 18,000 smallholders and driving the cash economies of the four provinces in which it is grown. In order to maintain livelihoods, food security and the integrity of surrounding ecosystems it is crucial to develop management regimes that maintain soil fertility and water quality. The oil palm industry in PNG has put a high priority on environmental sustainability, demonstrated by the participation of all PNG growers and millers in the Round Table on Sustainable Palm Oil (RSPO). This project brought together industry and research staff to define the main environmental sustainability issues for oil palm cultivation in PNG and to provide recommendations for research and development that will improve environmental sustainability.

The area of planted oil palm is small (134,000 ha) compared to Indonesia and Malaysia and there are restrictions to the rate of expansion. Nevertheless, the future expansion of the industry in relation to conservation of lowland forests and surrounding ecosystems must be considered at regional and national levels. In this project we did not consider the planning issue in depth, but concentrated on the effects of oil palm cultivation on soil, water and atmosphere.

Balances of carbon, energy and water in oil palm are generally favourable, being similar to forest, but nutrient balances are different, with higher inputs and exports from oil palm. The main concern regarding carbon balance is the substantial losses of carbon to the atmosphere when forest is converted to oil palm. Throughout most of the growing cycle oil palm has large rates of net primary productivity and carbon sequestration. Fertilisers must be applied and/or legumes grown to sustain productivity and losses of nutrients to the environment occur, particularly nitrogen. Erosion losses appear to be small but leaching loss of nitrate is known to be significant. The amount of biological nitrogen fixation that occurs through the crop cycle, and the losses of nitrogen by leaching and as gas, are the least understood and potentially most environmentally sensitive nutrient balance issues.

The quality of water and health of streams is likely to be affected by losses of nutrients, particularly nitrogen, from oil palm cultivation. The magnitude of the effects is unknown and is likely to be highly variable in space and time. Losses of sediments from oil palm blocks appear to be small, but inputs from enhanced stream bank erosion and sand extraction operations may be significant. Losses of pesticides are likely to be small, given their targeted use (weeded circle for herbicides and trunk injection for insecticides, and nurseries).

Maintenance of soil health in oil palm blocks is critical for sustainability. Soil erosion is potentially the most destructive influence on soil health, but it is generally low in PNG oil palm blocks. It can be minimized by good planning, encouraging good ground cover, and good design of roads. The main threat to soil health appears to be acidification, resulting from removal of cations and leaching loss of nitrate.

In order to ensure and improve environmental sustainability of oil palm cultivation into the future, the industry and research providers should endeavour to:

1. Identify the main risks and options for managing risks to environmental sustainability in and around smallholder blocks and plantations, with particular reference to soil and water resources.
2. Develop environmental sustainability indicators to underpin RSPO principles and criteria and to aid growers improve management practices.
3. Establish and implement management practices that ensure environmental sustainability.

3 Background

This project addressed one of the ACIAR research priorities for PNG under Sub-program 3 (Improving smallholder returns from export tree crop production and marketing): "Assessment of natural resource sustainability indicators for tree crop industries". For rural communities in PNG to benefit from a sustainable and economically viable oil palm industry, the industry must focus on practices that enable smallholders to achieve maximum productivity, profitability, and livelihood standards in an ecologically and socially sustainable manner.

Oil palm is the most important crop in PNG in terms of export income (over K 1,000 million in 2008), directly supporting over 18,000 smallholders and driving the cash economies of the four provinces in which it is grown. Rapid population growth in the oil palm growing areas is being accompanied by an increase and unplanned change from shifting agriculture to permanent agriculture. In order to maintain livelihoods, food security and the integrity of surrounding ecosystems it will become crucial to develop management regimes that maintain soil fertility and water quality.

Oil palm differs from copra, cocoa and food garden production in that it is a long-term crop with high productivity. The introduction of fertiliser use has been generally successful, with most smallholder growers now aware of the need to replace nutrients, but soil fertility is declining. Potential soil degradation issues for oil palm smallholders have been identified as erosion, acidification and organic matter decline. Degradation rates can be particularly rapid in the wet tropics. The main effect of these processes is to reduce the ability of soil to retain and supply nutrients. Nutrient deficiencies are the major limitation to oil palm production, and fertilisers comprise about 60% of the cost of production. Maintenance of soil fertility is critical for sustainability and profitability. Research is necessary to determine which degradation processes are occurring where, and what management approaches are likely to be most effective.

The oil palm industry in PNG has been pro-active in the establishment of an international Roundtable on Sustainable Palm Oil (RSPO, 2007). All plantations currently producing palm oil in PNG are participants in the RSPO and are accredited in ISO14001 through external auditors. Many of the principles of the RSPO can be directly applied by smallholders, whereas others will require new information, novel approaches to extension, a very good knowledge of social behaviour in PNG rural societies and excellent planning.

The PNG oil palm industry identified a need to define environmental sustainability risks and to determine how meaningful and practical indicators of environmental sustainability could be developed and applied.

Table 1. Abbreviations used

Abbreviation	
CSIRO	Commonwealth Scientific and Industrial research Organisation
JCU	James Cook University
NARI	National Agricultural Research Institute
OPIC	Oil Palm Industry Corporation
PNGOPRA	Papua New Guinea Oil Palm Research Association
RSPO	Round Table on Sustainable Palm Oil
WNB	West New Britain

4 Objectives

1. To develop a full research proposal between PNGOPRA, JCU, CSIRO, ACIAR and other possible contributors.
2. To produce a technical report with recommendations for future research and development to ensure a sustainable oil palm industry in PNG.

Activities.

1. PNGOPRA and JCU to develop concept note with detailed outline of proposed work in collaboration with the Australian partners.
2. PNGOPRA and JCU to contact all possible contributors to assist in the development of a full research program. Each contributor to prepare a full list of expertise and outline of how their organisation can contribute to the larger future project.
3. PNGOPRA to host a meeting of all possible contributors in PNG (proposed location Kimbe, WNB) to familiarise all contributors with the industry and develop the initial project proposal. A follow up meeting will be held in Cairns with all contributors to finalise the project submission.
4. PNGOPRA , JCU and CSIRO to develop a full project submission to ACIAR.
5. PNGOPRA , JCU and CSIRO to produce a technical report with recommendations for future R&D to ensure a sustainable oil palm industry in PNG.

5 Methodology

5.1 Activity 1: Concept note

A concept note was written and circulated. See Appendix **Error! Reference source not found.**.

5.2 Activity 2: Consultation with potential contributors

A wide range of people in Australia and PNG were consulted, including those mentioned in the acknowledgements section (who participated in the workshops), and also including Associate Professor Bofu Yu (Griffith Uni, soil erosion expert), Professor Bob Pressey (James Cook University, conservation planning expert), Dr Jean-Pierre Caliman (PT SMART, oil palm sustainability expert) and Prof Yadvinder Mahli (University of Oxford, carbon cycling expert).

5.3 Activity 3: Workshops

Workshop 1, Feb 2009

A workshop was held in Walindi, PNG on 3-5 February 2009, with the objectives of:

1. Introducing Australian sustainability scientists to the PNG oil palm industry
2. Determining the main environmental sustainability issues for oil palm in PNG, with particular reference to smallholders
3. Determining possible approaches for development of environmental sustainability indicators

The program and participants are given in Appendix 11.2. The technical report (Activity 5) was based largely on the presentations and discussions in this workshop.

Workshop 2, Apr 2009

A second workshop was held in Cairns on 7-8 April 2009, with the objective of developing an ACIAR project proposal, guided by, and building on, the results of the first workshop. The program is given in Appendix 11.3. Participants were: Murom Banabas (PNGOPRA), Sue Berthelsen (JCU), Peter Carberry (CSIRO), William Griffith (CTP), Ann McNeill (University of Adelaide, absent but provided inputs), Paul Nelson (JCU), Ian Orrell (PNGOPRA), Harm van Rees (PNGOPRA), Marcus Sheaves (JCU) and Mike Webb (CSIRO).

5.4 Activity 4: Project proposal

A preliminary project proposal, entitled **SMCN-2009-013 'Sustainable management of soil and water resources for oil palm production systems in PNG'** was submitted to ACIAR on 3 Aug 2009.

5.5 Activity 5: Technical report

A technical report, entitled '**Environmental sustainability of oil palm cultivation in Papua New Guinea**' was submitted to ACIAR on 3 Aug 2009.

6 Achievements against activities and outputs/milestones

Table 2. Achievements against activities and outputs/milestones.

No.	Task	Outputs/ milestones	Completion date	Comments
Activity 1: Concept note				
1.1	Write and distribute (A & PC)	Distributed	Jan 2009	
Activity 2: Consultation				
2.1	Consult (A & PC)	Identified experts contacted	Apr 2009	
Activity 3: Workshop				
3.1	Workshop 1 (PC)	Conducted	Feb 2009	
3.2	Workshop 2 (A)	Conducted	Apr 2009	
Activity 4: Project proposal				
3.1	Write (A & PC)	Preliminary proposal submitted	Aug 2009	
Activity 5: Technical report				
4.1	Write (A & PC)	Submitted	Aug 2009	

PC = partner country, A = Australia

7 Key results and discussion

7.1 Proposal for future research and development

The objectives and summary of the proposal that was developed are presented here.

Objectives

The principal aims of the proposal are:

1. to identify the main risks and options for managing risks to ensure sustainable use of soil and water resources by smallholder oil palm growers in PNG
2. to develop indicators to assess performance and guide management, complementary to the RSPO, and
3. to implement/establish management practices that ensure sustainable use of soil and water resources.

The proposal has 6 objectives. The first set of objectives will **Assess vulnerabilities and develop indicators to facilitate adoption of management practices that: maintain or improve soil health (Objective 1); optimise nutrient balances (Objective 2); maximise C sequestration (Objective 3); and maintain or improve aquatic ecosystem health (Objective 4).** Activities under these objectives will: i) produce models of the main processes leading to environmental risks, ii) quantify the main processes in representative and suitable study sites in the main oil palm growing areas, and iii) propose and evaluate indicators of those processes.

In addition, activities under Objectives 1, 2 and 3 will be integrated in **Objective 5: Produce a crop system model that enables prediction of management effects on soil health, C sequestration, greenhouse gas emissions and nutrient balances.** The model development will also aim at prediction of productivity, and the model will provide a tool for further knowledge generation and capacity building.

Finally, the understanding and indicators produced will be put into practice in **Objective 6: Implement integrated monitoring package, and build institutional capability to implement.** Activities will revolve around trialling the indicator package with OPIC extension officers and smallholders, transferring knowledge of key measurements and assessments, and building institutional capability and staff skills to facilitate the maintenance and further development of the monitoring program.

Summary

This proposal addresses ACIAR research priorities for PNG “Assessment of natural resource sustainability indicators for tree crop industries” (Sub-program 3). Oil palm is the most important crop in PNG in terms of export income (over K 1,000 million in 2008), directly supporting approximately 18,600 registered smallholder families and an estimated 200,000 people, and driving the cash economies of the four provinces in which it is grown. In the oil palm growing provinces, future productivity of oil palm and other crops, future food security, integrity of surrounding ecosystems, and community well-being all rely on environmentally sustainable management of oil palm. This project will develop and implement environmental sustainability indicators for soil and water resources that are meaningful, practical, and underpin the Principles and Criteria of the RSPO, in which all PNG palm oil producers participate. Project collaborators include PNGOPRA, OPIC, JCU, CSIRO and the University of Adelaide.

The aims of the proposal are: a) to identify the main risks and options for managing risks to ensure sustainable use of soil and water resources by smallholder oil palm growers in PNG; b) to implement/establish management practices that ensure sustainable use of soil and water resources, and c) to develop indicators to assess performance and guide management, complementary to the RSPO.

The project is expected to have substantial scientific, capacity and community impacts over a 5-10 year period. Scientifically, many of the environmental processes in agro-ecosystems of the humid tropics are not well understood. New insights will be gained in nutrient cycling, aquatic ecology, carbon balance, and system modelling. Capacity of PNG research and extension staff will be enhanced through training in environmental processes and assessment. Between 1 and 3 PNG staff will receive postgraduate training. The project will contribute to environmental accreditation, which is essential to the long-term viability of the industry, given PNG's relatively high costs and the discerning nature of the market. Improved focus on smallholder management is also expected to result in enhanced profitability, particularly through better nutrient management. A focus on soil and water resources in and surrounding oil palm growing areas will enhance future food security (crops and fisheries), human health and ecosystem resilience.

Communication of project findings will be through the strong research (PNGOPRA)-extension (OPIC)-grower links already existing in the industry, including field days, meetings, radio programs and on-block research. Dissemination will be enhanced by a pilot monitoring program run during the course of the project.

Project methodology will comprise of: a) choice of potential indicators based on current knowledge, b) process modelling and evaluation of indicators in the field, c) trial of indicators, and d) implementation of an integrated indicator package. Field work will target the main growing areas and environments in West New Britain, Oro and Milne Bay Provinces. The soil health component will focus on quantification of acidification, organic matter content and erosion. The nutrient balance component will focus on biological N fixation and losses of nutrients, particularly leaching loss of nitrogen. The carbon balance component will focus on calibration of readily measured vegetative parameters for C balance estimates. Crop system modelling using the APSIM framework will integrate the crop/soil research and be used to predict effects of management on environmental sustainability parameters. The stream health component will focus on quantification of ecological effects. During the last half of the project an integrated indicator package will be trialled using selected extension/technical services staff, and near the end of the project the final package will be implemented via training workshops and user support networks.

7.2 Technical report on environmental sustainability issues

The summary of the report that was produced is presented here.

Summary

This report discusses maintenance of the quality of the resources and the surrounding environment in oil palm production systems of Papua New Guinea (PNG). Based on the issues discussed, it proposes a set of recommendations necessary to ensure appropriate and science-based indicators are developed to underpin the maintenance of productivity and environmental sustainability.

The PNG oil palm industry is small by international standards (134,000 ha and approximately 1% of global palm oil production) but palm oil is the largest agricultural export earner for PNG (over 1,000 million kina in 2008). Oil palm is grown in plantations owned by three companies and on 18,600 smallholder blocks. The smallholder blocks support an estimated 200,000 people. Environmental sustainability of the industry is coming increasingly under focus by growers, non-government organizations, purchasers, and local populations. All oil palm growers and palm oil producers in PNG have joined the Round Table on Sustainable Palm Oil (RSPO). Environmental sustainability issues that are being considered can be categorised into: Planning and biodiversity; Balances of C

and energy; Balances of nutrients and water; Quality of water and atmosphere; and Health of soil.

Planning and biodiversity is a critical issue for PNG. Although expansion of the industry is currently restricted by physical geography and land tenure, future expansion must be considered in relation to conservation of lowland forests at regional and national levels. The industry impacts not only on the land used for oil palm, but also on the surrounding ecosystems, due to effects on water and the atmosphere, and effects of increased population pressure.

Balances of C and water in oil palm are generally favourable and similar to forest, but nutrient balances require more attention. Throughout most of the growing cycle oil palm has large rates of net primary productivity and C sequestration, and the water balance is similar to forest. An exception is the substantial loss of carbon dioxide (CO_2) to the atmosphere when forest is converted to oil palm. Oil palm has higher inputs and exports of nutrients than forest. Fertilisers must be applied and/or legumes grown to sustain productivity and ideally these additions would exactly balance the uptake by biomass and the losses in product. However, losses of nutrients to the environment occur, particularly N. Erosion losses appear to be small but leaching loss of nitrate is known to be significant. Gaseous losses of N may also be significant in some situations, including the loss of nitrous oxide (N_2O). The amount of biological N fixation that occurs through the crop cycle, and the losses of N by leaching and as gas, are the least understood nutrient balance issues.

The quality of water and health of streams is likely to be affected by losses of nutrients, particularly N, from oil palm cultivation. The magnitudes of the effects are unknown and are likely to be highly variable in space and time. Losses of sediments from oil palm blocks appear to be small, but inputs from enhanced stream bank erosion and sand extraction operations may be significant. Losses of pesticides are likely to be small, given their targeted use (weeded circle for herbicides and trunk injection for insecticides).

Maintenance of soil health in oil palm blocks is critical for sustainability. Soil erosion is potentially the most destructive influence on soil health, but it is generally low in PNG oil palm blocks. It can be minimized by good planning, encouraging good ground cover, and good design of roads. The main threat to soil health appears to be acidification, resulting from removal of cations and leaching loss of nitrate.

There is a need for practical and meaningful indicators of environmental sustainability that are based on a clear understanding of how the system works, to underpin the RSPO certification and to guide improvements in management.

8 Impacts

8.1 Scientific impacts – now and in 5 years

The project has identified the main knowledge gaps regarding sustainability of oil palm cultivation in PNG. That has enabled researchers to direct their attention to the most important issues needing examination.

In 5 years, results of the project are expected to have stimulated R&D into the environmental sustainability of oil palm cultivation in PNG. In that eventuality, the impacts will be considerable due to the current lack of knowledge.

There has been very little study of soil acidification in tree cropping systems of the wet tropics. That is partly because crops such as oil palm have a high tolerance to soil acidity and partly because high pH buffering has masked acidification rates. Acidification still occurs at low pH but has been little studied. Studies in PNG will be applicable to variable charge soils in many other paces.

The young soils of PNG have unique and little-studied nutrient retention properties. Nitrogen loss by leaching has been identified as a substantial loss mechanism in tree crops of the wet tropics, but only rudimentary indicators of the magnitude of losses are available. Furthermore, there is extremely little information on the amount of denitrification and N_2O emissions from oil palm, despite conditions being favourable for emissions in many areas. Similarly, despite the perceived importance of leguminous cover crops for nitrogen inputs, there is little knowledge available to underpin estimates of fixation rates in plantation cover crops. Knowledge of nutrient cycling in these environments will be directly applicable to other tropical tree crops.

Despite the importance of oil palm for C cycling in tropical regions, there is no detailed knowledge of C sequestration and CO_2 emissions in different environments and under different management. Current knowledge is restricted to gross budgets upon conversion from other types of vegetation.

There is currently no scientific understanding of potential and actual impacts of oil palm cultivation on aquatic ecosystems at a systems- wide scale, taking account contexts ranging from fisheries to environmental science. Development of a monitoring system for stream health in tropical context will be applicable to other systems, within and beyond tropics.

8.2 Capacity impacts – now and in 5 years

By involving PNGOPRA and OPIC staff in the workshops, the awareness of those staff of environmental issues and appropriate research approaches has been raised.

In 5 years, if further R&D into the environmental sustainability of oil palm eventuates, as is likely, considerable capacity impacts are expected. Several potential PNG research staff have expressed interest in undertaking postgraduate studies in the field. PNGOPRA Agronomist Rachel Pipai has already applied for a John Allwright Fellowship to undertake an MSc at the University of Adelaide, to work on biological N fixation through the oil palm cycle, one of the issues recommended for further research. The enhanced research skills of those postgraduates will have a substantial impact in PNG, where there are many biology/agriculture graduates but few skilled and active National researchers.

PNGOPRA research staff, OPIC extension staff, company technical services staff and smallholders themselves will learn new skills in field and laboratory assessment of soil, water and atmospheric quality in an agricultural context. The skills learned will include an ability to interpret results, and to apply the results to improving management interventions.

In addition, PNGOPRA research staff will develop their ability to utilise 30 years of archived fertiliser trial data and a great deal of other data (e.g. OPIC smallholder block location database; recently improved PNG Resource Information System) in an active and on-going manner.

The training in environmental processes and monitoring programs will result in improved knowledge of crop production and improved management skills by smallholders and plantation managers.

8.3 Community impacts – now and in 5 years

8.3.1 Economic impacts

There have been no appreciable economic impacts from this SRA, but future economic impacts are expected to be considerable.

PNG is a small and relatively high cost palm oil producer, so maintaining competitiveness is critical for the long-term viability of smallholder oil palm growers, the oil palm industry as a whole, and associated businesses (stores, transport, construction, communication etc). Environmental certification under the RSPO has the potential to produce premiums and all PNG palm oil producers have committed themselves to pass any premiums directly to smallholder fruit suppliers. Probably more important than premiums is continued market access. PNG currently sells almost all of its oil to the discerning European market, where there is a great deal of anti-palm oil sentiment. Continued access to that market will be best guaranteed if the whole PNG industry can prove it is environmentally sustainable. PNG has a unique opportunity in this regard as it is the only palm oil-producing country in which all producers are participating in an environmental certification scheme. Even in the absence of RSPO, the benefits of compliance to an environmental standard will live on.

Demonstrated and certified environmental sustainability will also improve the likelihood of obtaining development aid funds for oil palm growing regions in PNG. Currently, donor countries are wary of the oil palm industry due to negative public perceptions in donor countries, but these perceptions could change given evidence that the industry is operating in an environmentally sensitive manner. Increased development aid, for example for roads and bridges, will improve the viability and profitability of smallholder producers as well as improving opportunities for other business enterprises.

Smallholder yields and income are currently well below achievable levels due largely to low management inputs. Most smallholder blocks are nutrient deficient and most are losing more nutrients then are being applied. Future work to improve nutrient management, including management of leguminous cover crops, will have a positive influence on smallholder yields and profits and possibly lead to reduced reliance on purchased fertilisers.

The health and productivity of freshwater and coastal ecosystems are very important for the economies of oil palm growing areas. The economic benefits range from maintenance of food supplies to maintenance and growth of high value businesses based on sport fishing and diving. There are several local sport fishing and diving eco-tourism businesses in each of the main oil palm-growing areas, all providing substantial incomes to local communities. For example, Kimbe Bay in West New Britain and Milne Bay are world renowned for their magnificent diving, and businesses in West New Britain and Oro Provinces are world renowned for their unique Papuan black bass sports fishing ('catch-and-release').

The PNG oil palm industry is examining the possibility of earning C credits in places where grasslands are converted to oil palm, which has the potential to earn substantial returns. Future work providing C balance data will be essential to fulfilling that possibility.

8.3.2 Social impacts

There have been no appreciable social impacts from this SRA, but positive social impacts are expected in the future.

Increasing population pressure is tightening garden/fallow rotations in oil palm growing regions, even to the extent where many gardens are now permanent, which poses significant challenges for food security and livelihoods of future generations through degradation of land and water resources. Future work recommended by this project will introduce and promote concepts and practices aimed at maintaining fertility of the land and integrity of aquatic ecosystems, and the benefits are expected to move immediately beyond oil palm.

Maintenance of ecosystem integrity and resilience in and surrounding oil palm growing areas is essential for the well-being of communities. Streams and groundwater are used as sources of water for drinking, cooking and cleaning and thus impact on human health. Health of aquatic habitats is also crucial for fishing resources. Similarly, conservation of forests surrounding communities is important for many community needs such as medicines, hunting, food gathering and gardening. Involvement in measuring and interpreting indicators will provide education about environmental processes as well as producing tools to help maintain those ecosystems in good shape.

While oil palm is currently a desirable smallholder crop due to high income and compatibility with local customs, it is essential for smallholder farmers that their options for future crops are not limited. Oil palm is tolerant of degraded soil conditions, but work recommended as a results of this project will aim to ensure soil is not degraded, ensuring that options for future crops are not limited.

Any effects on long-term viability of the oil palm industry will also influence its associated benefits: infrastructure, roads, education and health services.

8.3.3 Environmental impacts

There have been no appreciable environmental impacts from this SRA, but future impacts are expected to be considerable.

Long-term maintenance of soil health and prevention of soil erosion will improve the resilience of oil palm agro-ecosystems against detrimental impacts of future environmental and land management stresses. For example, current climate change scenarios suggest a more erosive environment in the future due to more variable and extreme rainfall.

Maintaining stream health increases the resilience of aquatic ecosystems, enabling them to resist adverse changes. Aquatic ecosystems are specifically targeted for improvement in the recommendations of this project. Reduction of nutrient movement into groundwater and hence streams is one of the main impacts foreseen in this regard. Additionally, results from this project may contribute to a review of riparian buffer zone regulations; making them more appropriate to agricultural situations (they are currently derived from the Forestry Code of Practice).

As a result of compliance with environmental standards, there will be a mitigation of greenhouse gas emissions (CO_2 and N_2O in particular). Through better understanding and management of nutrient cycling, there will be a reduced reliance on fertilisers, especially N fertilisers. The attendant energy savings will lessen environmental impacts in the location of fertiliser production.

8.4 Communication and dissemination activities

The project revolved around two workshops in which people from all sectors of the PNG oil palm industry were involved. They included the General Secretary of OPIC, Felix

Bakani; the Hoskins OPIC project manager, Otto Pukam; the General manager of NBPOL, Mike Hoare; the Agricultural Director of CTP Holdings, William Griffiths; the General Manager of Hargy Oil Palms, Graham King; the Director of Research of PNGOPRA, Ian Orrell; the Senior Agronomist of PNGOPRA, Harm van Rees; and the Senior Entomologist of PNGOPRA, Charles Dewhurst. Several other OPIC extension officers, OPRA research staff and company management staff were involved. The technical report will be distributed widely throughout the industry, especially OPIC, when published. It provides a comprehensive summary of the issues covered in the project.

9 Conclusions and recommendations

9.1 Conclusions

The oil palm industry in PNG has put a high priority on environmental sustainability, demonstrated by the participation of all PNG growers and millers in the RSPO and involvement of all the companies and smallholders (through OPIC) in this project.

Much of the contention about the environmental sustainability of oil palm centres around the conversion of forest to oil palm, rather than the growing of oil palm per se. Being a perennial adapted to the wet tropics, oil palm can be cultivated sustainably in the coastal lowlands of PNG, given attention to the issues discussed in the technical report that was produced during this project and summarised below. Good environmental management of oil palm cultivation is more readily achievable than for less vigorous or shorter lived crops.

Environmental sustainability issues can be categorised in many ways. In this project a categorisation scheme was suggested based on the spatial and temporal dimensions of environmental processes. The categories are: Planning and biodiversity, Balances of C and energy, Balances of nutrients and water, Quality of water and atmosphere, and Health of soil.

Planning and biodiversity is a critical issue for PNG. The area of planted oil palm is small compared to Indonesia and Malaysia and the rate of expansion is small compared to Indonesia. Although there are restrictions to the rate of expansion, including physical geography and land tenure, the future expansion of the industry in relation to conservation of lowland forests and surrounding ecosystems must be considered at regional and national levels. In this project we did not consider the planning issue in depth, but concentrated on the effects of oil palm cultivation on soil, water and atmosphere.

Balances of C and energy in oil palm are generally favourable (net C sequestration), except for substantial losses of C to the atmosphere when forest is converted to oil palm. Throughout most of the growing cycle oil palm has large rates of net primary productivity and C sequestration. The C balance during the replant phase is largely unknown.

The water balance is similar in oil palm and forest, but nutrient balances are different, with higher inputs and exports from oil palm. Fertilisers must be applied and/or legumes grown to sustain productivity and ideally these additions would exactly balance the uptake by biomass and the losses in product. However, losses of nutrients to the environment occur, particularly N. Erosion losses appear to be small but leaching loss of nitrate is known to be significant. Gaseous losses of N may also be important, including the loss of N_2O, a greenhouse gas. The amount of biological N fixation that occurs through the crop cycle, and the losses of N by leaching and as gas, are the least understood and potentially most environmentally sensitive nutrient balance issues.

The quality of water and health of streams is likely to be affected by losses of nutrients, particularly N, from oil palm cultivation. The magnitude of the effects is unknown and is likely to be highly variable in space and time, partly due to dilution by flows from upstream of oil palm plantations. Losses of sediments from oil palm blocks appear to be small, but inputs from enhanced stream bank erosion and sand extraction operations may be significant. Losses of pesticides are likely to be small, given their targeted use (weeded circle for herbicides and trunk injection for insecticides, and nurseries).

Influences on quality of the atmosphere by oil palm cultivation are effectively restricted to greenhouse gases, which have been discussed under C and nutrient cycling.

Maintenance of soil health in oil palm blocks is critical for sustainability. Soil erosion is potentially the most destructive influence on soil health, but it is generally low in PNG oil palm blocks. It can be minimized by good planning, encouraging good ground cover, and good design of roads. The main threat to soil health appears to be acidification, resulting from removal of cations and leaching loss of nitrate.

There is a need for practical and scientifically-based indicators of environmental sustainability to underpin the RSPO certification and to guide improvements in management.

9.2 Recommendations

In order to ensure and improve environmental sustainability of oil palm cultivation into the future, the PNG oil palm industry, together with scientific collaborators and funding providers, should endeavour to:

1. Identify the main risks and options for managing risks to environmental sustainability in and around smallholder blocks and plantations, with particular reference to soil and water resources.
2. Develop environmental sustainability ‘indicators’ (measurable values of a rate or quality used to define trend in or state of land/water/system properties) to underpin RSPO ‘indicators’ (plans, practices or monitoring programs to achieve a particular criteria). The indicators should be meaningful, scientifically sound, practical, quantitative, appropriate, auditable, achievable, easily communicated to and understood by different stakeholders, especially smallholder growers, extension officers and plantation managers. The indicators should be aimed at assessing environmental sustainability and at recommending best management practices. Where necessary, research should be carried out to produce the indicators.
3. Establish and implement management practices that ensure environmental sustainability. That will include knowledge transfer to smallholders, OPIC extension staff and plantation managers.
4. Embed continuous assessment and improvement of the procedures used to assess and improve environmental sustainability

10 References

10.1 References cited in report

RSPO 2007. RSPO Principles and Criteria for Sustainable Palm oil Production. Including Indicators and Guidance. October 2007. RSPO. 53 pp

10.2 List of publications produced by project

Paul N. Nelson, Michael J. Webb, Ian Orrell, Harm van Rees, Murom Banabas, Suzanne Berthelsen, Marcus Sheaves, Felix Bakani, Otto Pukam, Michael Hoare, William Griffiths, Graham King, Peter Carberry, Rachel Pipai, Ann McNeill, Petra Meekers, Simon Lord, James Butler, Tony Pattison, John Armour, Charles Dewhurst. 2009. Environmental sustainability of oil palm cultivation in Papua New Guinea. ACIAR Technical Report.

11 Appendixes

11.1 Briefing paper for: Workshop, 3-5 Feb 2009, Walindi, PNG

ACIAR Small Research Activity (SRA) SMCN/2008/028

'Towards a sustainable oil palm industry in PNG'

This short paper serves as a briefing note for participants at the workshop. The note provides you with some background information on the palm oil industry in PNG, puts some of the issues related to sustainability into context and lists some points for major areas for discussion at the workshop.

We have an excellent mix of people at the workshop ranging from direct participants in the industry (plantation company managers and people representing smallholders) to researchers who work in agriculture / environmental sustainability. We will strive to have a solid and open discussion on the value of indicators of environmental sustainability and how the two sectors in the oil palm industry (plantations and smallholders) can use the indicators to improve their management.

1. The industry in PNG

Oil palm is grown in 5 provinces. In each area where oil palm is grown there is a plantation company with associated smallholders growing oil palm (except for Ramu which is a new plantation and smallholder production has not started in earnest there)

The plantation companies are NBPOL (New Britain Palm Oil Ltd), Hargy Oil Palm and CTP Holdings

Palm oil is the largest agricultural export industry in PNG (700 M Kina/year) (double that of coffee which is the second largest)

Area planted to oil palm and production by sector, where FFB is Fresh Fruit Bunches

	Plantation	Small holder	Total
Hectares (ha)	67,000 (55%)	56,000 (45%)	123,000
Production (FFB) MT	1.4 (67%)	0.6 (33%)	2.0

- Average production for Plantations is 20 t/ha and for smallholders it is 12 t/ha (FFB)
- 18,000 smallholders (main cash income in the four provinces where smallholders grow oil palm)
- Plantations employ some 15,000 people
- Plantations also provide infrastructure (maintaining roads, schools, clinics etc)
- Most work in the oil palm is done by hand (not much is mechanized)
- Plantation companies mill the fruit in-country to produce crude palm oil (the main product sold, which is about 22-23% of FFB production) and other products such as kernel oil

2. Smallholders

Two main types of smallholder arrangements: LSS (Land Settlement Scheme) and VOP (Village Oil Palm)

LSS	VOP
Introduced early 1970s Alienated customary land (still disputed) People settled from other areas (can still create conflict) Lease scheme Poorly administered	Customary land and tenure Informal clan agreements Payment to village elders for use of land Competes with food gardens

- Generally LSS blocks are better maintained and have a higher production compared to VOP blocks.
- Main problem with smallholder production is the generally low yield relative to plantation yields. The lower yield achieved by smallholders is generally thought to be due to poor management skills and social issues.
- OPIC (Oil Palm Industry Corporation) is the extension arm of the oil palm industry. OPIC is supported through a levy paid on smallholder production (also with support from the plantation companies).
- Smallholder blocks are mostly 2-6 ha in size.
- Another arrangement in place is where a group or village, lease land to the plantation which is then managed by the company (with some variation in different areas)

3. Where is oil palm grown

- Most plantations are in coastal areas (exceptions are Mamba estate and Ramu)
- More than 50% of oil palm is produced on volcanic soils (new soils)
- Rainfall is monsoonal with between 2500 and 5000 mm rain/annum
- Most oil palm is grown on relatively flat ground
- Soils are generally freely draining (even the alluvial clay soils have high saturated conductivities unless compacted)

4. RSPO (Roundtable on Sustainable Palm Oil)

- Sustainable palm oil production is comprised of legal, economically viable, environmentally appropriate and socially beneficial management and operations.
- This is delivered through the application of a series of principles and criteria which are outlined below (see table).
- Currently two companies have achieved RSPO status: NBPOL and Hargy Oil Palm; it is likely that CTP will achieve accreditation in 2009.
- Both NBPOL and Hargy are involved in a project with OPIC in getting all smallholders in their respective areas certified. This is a massive plan, surveys have already been performed and outcomes mapped to determine areas for improvement.

- The main RSPO Principles and Criteria relevant to environmental issues are: (note the use of Indicators in the RSPO documentation is different to the way we view Indicators in the SRA)

Principle 4: Use of appropriate best practices by growers and millers	
Criterion 4.2 Practices maintain soil fertility at, or where possible improve soil fertility to, a level that ensures optimal and sustained yield.	Indicators: • Monitoring of soil organic matter content trends. • Monitoring of net fertilizer inputs (farm gate measures of exports versus fertilizer use). Guidance: Long-term fertility depends on maintaining the structure, organic matter content, nutrient status and microbiological health of the soil. Managers should ensure that best agricultural practice is followed. Nutrient efficiency must take account of the age of plantations and soil conditions. Smallholders should be able to demonstrate that they have an understanding of the techniques required to maintain soil fertility and that they are being implemented.
Criterion 4.3 Practices minimise and control erosion and degradation of soils.	Indicators: • Monitoring of percentage of ground surface protected from impact of raindrops. • Monitoring of percentage of planting on slopes above a certain limit (needs to be soil specific). • Presence of road maintenance program. Guidance: Techniques that minimise soil erosion are well-known and should be adopted, wherever appropriate. This may include practices such as: • Planning and implementing ground clearance to minimize erosion. • Ensuring adequate ground cover and avoiding over-spraying of herbicides. • Using irrigation practices that are designed and implemented to minimise erosion • Controlling erosion wherever needed, including terracing where appropriate. • Appropriately designing and maintaining roads. • Avoiding planting on steeply sloping land or highly erodible soil-types. • Maintaining and restoring riparian areas in order to minimize erosion of stream banks. • After felling the old stand, retaining residue where soil erosion risk is significant or a cover crop or rotation crop should be planted. Burning should not be used to remove residues, except in specific situations (see criterion 5.5). Smallholders should be able to demonstrate that they have an understanding of the techniques required to minimise soil erosion and that they are being implemented.
Criterion 4.4 Practices maintain the quality and availability of surface and ground water.	Indicators: • An implemented water management plan. • Monitoring of effluent BOD.

Principle 4: Use of appropriate best practices by growers and millers	
	• Monitoring of mill water use per tonne of FFB . Guidance: Growers and millers should address the effects of their use of water and the effects of their activities on local water resources. Practices may include: • Taking account of the efficiency of use and renewability of sources. • Ensuring that the use of water does not result in adverse impacts on availability for downstream users. • Protection of water courses and wetlands, including maintaining and restoring appropriate riparian buffer zones along all bodies of water. • Avoiding contamination of surface and ground water through run-off of soil, nutrients or chemicals, or as a result of inadequate disposal of waste. • Appropriate treatment of mill effluent and regular monitoring of discharge quality, which should be in compliance with national regulations.
Criterion 4.5 Pests, diseases, weeds and invasive introduced species are effectively managed using appropriate Integrated Pest Management (IPM) techniques.	Indicators: • Monitoring of pesticide toxicity units (a.i. x LD 50 / tonne of FFB). • Monitoring extent of IPM implementation / total ha. • A program to monitor pests and diseases must be in place. Due to problems in the accuracy of measurement, monitoring of pesticide toxicity is not applicable to smallholders. Guidance: Growers should apply recognised IPM techniques, incorporating cultural, biological, mechanical or physical methods to minimise use of chemicals. Native species should be used in biological control wherever possible.
Criterion 4.6 Agrochemicals are used in a way that does not endanger health or the environment. There is no prophylactic use, and where agrochemicals are used that are categorised as World Health Organisation Type 1A or 1B, or are listed by the Stockholm or Rotterdam Conventions, growers are actively seeking to identify alternatives, and this is documented.	Indicators: • Justification of all chemical use. • Records of pesticide use (including active ingredients used, area treated, amount applied per ha and number of applications). • Documentary evidence that use of chemicals categorised as • World Health Organisation Type 1A or 1B, or listed by the • Stockholm or Rotterdam Conventions, and paraquat, is reduced and/or eliminated. • Use of selective products that are specific to the target pest, weed or disease and which have minimal effect on non-target species should be used where available. However, measures to avoid the development of resistance (such as pesticide rotations) are applied. • Chemicals should only be applied by qualified persons who have received the necessary training and should always be applied in accordance with the product label. Appropriate safety equipment must be provided and used. All precautions attached to the products should be properly observed, applied, and understood by workers. Also see criterion 4.7 on health and safety.

Principle 4: Use of appropriate best practices by growers and millers	
	• Storage of all chemicals as prescribed in FAO Code of Practice • (see Annex 1). All chemical containers must be properly disposed of and not used for other purposes (see criterion 5.3). • Application of pesticides by proven methods that minimize risk and impacts. Pesticides are applied aerially only where there is a documented justification. • Evidence of CPO residue testing, as required by the supply chain. • Proper disposal of waste material, according to procedures that are fully understood by workers and managers. Also see criterion 5.3 on waste disposal. • Annual health screening for pesticide operators. Guidance: Note: RSPO will identify safe and cost effective alternatives to replace chemicals that are categorised as World Health Organisation Type 1A or 1B, or listed by the Stockholm or Rotterdam Conventions, and paraquat. Results will be collated and reported by November 2007.
Principle 5: Environmental responsibility and conservation of natural resources and biodiversity	
Criterion 5.2 The status of rare, threatened or endangered species and high conservation value habitats, if any, that exist in the plantation or that could be affected by plantation or mill management, shall be identified and their conservation taken into account in management plans and operations.	Indicators: Information should be collated that includes both the planted area itself and relevant wider landscape-level considerations (such as wildlife corridors). This information should cover: • Presence of protected areas that could be significantly affected by the grower or miller. • Conservation status (e.g. IUCN status), legal protection, population status and habitat require ments of rare, threatened, or endangered species, that could be significantly aff ected by the grower or miller. • Identification of high conservation value habitats, such as rareand threatened ecosystems, that could be significantly affected by the grower or miller. If rare, threatened or endangered species, or high conservation value habitats, are present, appropriate measures for management planning and operations will include: • Ensuring that any legal requirements relating to the protection of the species or habitat are met. • Avoiding damage to and deterioration of applicable habitats. • Controlling any illegal or inappropriate hunting, fishing or collecting activities; and developing responsible measures to resolve human-wildlife conflicts. Guidance: This information gathering should include checking available biological records, and consultation with relevant government departments, research institutes and interested NGOs if appropriate. Depending on the biodiversity values that are present, and the level of available information, some additional field survey work may be required. For individual smallholders, a basic understanding of any applicable species or habitats, together with their conservation needs, will be sufficient.
Criterion 5.3 Waste is reduced, recycled, re-used and disposed of in an environmentally and socially responsible manner.	Indicators: • Waste management and disposal plan. • Safe disposal of pesticide containers. Guidance:

Principle 4: Use of appropriate best practices by growers and millers	
	The waste management and disposal plan should include measures for: • Identifying and monitoring sources of waste and pollution. • Improving the efficiency of resource utilisation and recycling potential wastes as nutrients or converting them into value added products (e.g. through animal feeding programmes). • Appropriate disposal of hazardous chemicals and their containers. Surplus chemical containers should be disposed of or cleaned in an environmentally and socially responsible way (e.g. returned to the vendor or cleaned using a triple rinse method), such that there is no risk of contamination of water sources or to human health. The disposal instructions on manufacturer's labels should be adhered to. Smallholders should adopt appropriate measures to dispose of hazardous chemicals and their containers.
Criterion 5.4 Efficiency of energy use and use of renewable energy is maximised.	Indicators: • Monitoring of renewable energy use per tonne of CPO/FFB. • Monitoring of fossil fuel use per ton of CPO (or FFB where thegrower has no mill). Guidance: Growers and mills should assess the energy use of their operations and energy efficiency of their operations. The feasibility of collecting and using biogas should be studied if possible.
Criterion 5.6 Plans to reduce pollution and emissions, including greenhouse gases, are developed, implemented and monitored.	Indicators: • An assessment of all polluting activities must be conducted, including gaseous emissions, particulate/soot emissions and effluent (see also criterion 4.4). Significant pollutants and emissions must be identified and plans to reduce them implemented. • A monitoring system must be in place for these significant pollutants which goes beyond national compliance. • Monitoring of methane from effluent digestion and smoke particles. This may require the use of proxy measures.
Principle 7: Responsible development of new plantings	
Criterion 7.2 Soil surveys and topographic information are used for site planning in the establishment of new plantings, and the results are incorporated into plans and operations.	Indicators: This activity should be integrated with the SEIA required by 7.1. Guidance: Soil surveys should be adequate to establish the long-term suitability of land for oil palm cultivation. Soil suitability maps or soil surveys should be appropriate to the scale of operation and should include information on soil types, topography, rooting depth, moisture availability, stoniness, fertility and long-term soil sustainability. Soils unsuitable for planting or those requiring special treatment should be identified. This information should be used to plan planting programmes, etc. Measures should be planned to minimise erosion through appropriate use of heavy machinery, terracing on slopes, appropriate road construction rapid establishment of cover, protection of riverbanks, etc. Topographic information should guide the planning of drainage and irrigation systems, roads and other infrastructure. Assessing soil suitability is also important for small-scale producers, particularly where there are significant numbers operating in a particular location. Information may be collected and provided by a smallholder organisation or mill that purchases FFB from individual smallholders.

Principle 4: Use of appropriate best practices by growers and millers	
Criterion 7.3 New plantings since November 2005 (which is the expected date of adoption of these criteria by the RSPO membership), have not replaced primary forest or any area containing one or more High Conservation Values.	Indicators: This activity should be integrated with the SEIA required by 7.1. Guidance: This criterion applies to forests and other vegetation types. This applies irrespective of any changes in land ownership or farm management that have taken place after this date. High Conservation Values (HCVs) may be identified in restricted areas of a landholding, and in such cases new plantings can be planned to allow the HCVs to be maintained or enhanced. The HCV assessment process requires appropriate training and expertise, and must include consultation with local communities, particularly for identifying social HCVs. Development should actively seek to utilise previously cleared and/or degraded land. Plantation development should not put indirect pressure on forests through the use of all available agricultural land in an area. Although planned development may be consistent with landscape level planning by national and local authorities, this requirement for protection of social and biological HCVs must still be complied with. For definition of 'High Conservation Values', see definitions.
Criterion 7.4 Extensive planting on steep terrain, and/or on marginal and fragile soils, is avoided.	Indicators: This activity should be integrated with the SEIA required by 7.1. Guidance: Marginal and fragile soils, including excessive gradients and peat soils, should be identified prior to conversion to plantation. Planting on extensive areas of peat soils > 3m deep and other fragile soils should be avoided. Where limited planting on fragile and marginal soils is proposed, plans shall be developed and implemented to protect them without incurring adverse impacts (e.g., hydrological) or significantly increased risks (e.g. fire risk) in areas outside the plantation.

For some of the Criteria listed in the RSPO scientifically validated testing procedures or 'Indicators' can be developed and have been developed in other areas. This would put these RSPO criteria on a solid footing of testability and repeatability. We have to keep in mind that any Indicators developed or discussed have to be relatively simple in operation and cannot include expensive monitoring equipment and operations.

5. Sustainability Issues

The workshop program outlines the topics to be discussed. We need to consider particular issues related to sustainability in oil palm. We have prepared a list of these issues with some dot points of direct applicability and matters to discuss.

Sustainability Issue	Matters to consider and discuss
Soil movement/loss by water	Highly episodic events (related to rainfall intensity) Not generally as sheet erosion (measured in runoff plots by Banabas and from field observations) Usually initiated on roads, during heavy rain when roads start to channel water down hill, at a break of slope or a barrier, the water channel enters an oil palm block and forms a rill which can move large amounts of soil and other debris (palm fronds etc) Most soil is moved from up slope to lower slope as soil is deposited on lower areas, soil does not necessarily end up in water ways Soil acquisition in some areas is high (volcanic activity) Little or no information on soil loss in waterways (turbidity) resulting from oil palm (relative to other practices)
Soil acidification	Soil pH generally 5 to 7 (measured in water)

	N fertilizer use is high (eg. 0.3 to 0.4 t/ha of ammonium chloride) Most common N fertilizers used are SOA, AC, AN and urea N fertilizers are generally applied in a 1m wide band around the palm on the edge of the weeded circle – hence N fertilizer is applied in a concentrated area which puts more pressure on acidification We have measured a 1 unit drop in soil pH from a single application of AC There is little or no general knowledge of the extent of soil acidification or on how big a problem it really is and what the implications are likely to be for future management
CEC decline	Volcanic ash soils have 'variable charge' due to mineralogy and organic matter content. pH decline leads directly to decline in ability of soils to retain K, Mg and Ca Where soil OM declines, effect is the same
Soil organic matter decline	Most areas have a topsoil organic C of 3 to 5% Fronds are returned and stacked (high OM under the fronds) EFB (empty fruit bunches – after oil has been extracted) are returned to some blocks (depending on distance from the mill) at a rate of 30t/ha. The EFB stacks are high in OM. Little or no knowledge on whether SOM is declining and if it is by how much Little or no information on N mineralization rates and its relationship to SOM
Nutrient balance	OPRA fertilizer trials with good data on inputs and exports From OPRA trials good information on Nutrient Use Efficiency (efficiency of fertilizer nutrient uptake) on some soil types Reasonable information on nutrients exported in bunches (more difficult to calculate what is returned in EFB)
Nutrient loss through leaching	For volcanic soils good information on leaching potential of N, K, Mg, SO4 and Cl-, but not for P Little data for other soils Little data on rate of loss for nutrients other than N Some data on nutrient flow in water ways (CTP MBE) but generally not known Offsite impact on, for example, coral reefs not known
Energy balance	Some information on energy balance in the growing of oil palm Energy return on energy invested likely to be higher for oil palm than any other crop Apparently some information on the energy balance of the mill operation
Landscape sustainability	Oil palm is expanding into forested areas in coastal lowlands, although RSPO states that no primary forest will be cleared Plantations leave riparian buffers and wildlife corridors but no info on how large they should be, where they should be etc No national or regional plans mandating land use

6. Indicators of environmental sustainability

Many indicators of environmental sustainability have been developed around the world for assessing the impact of agriculture on the environment. The usefulness of many of these indicators is debatable but generally it is clear that indicators developed in association with the practitioners (farmers, managers of the land) have a higher rate of uptake and usefulness compared to those that were developed by researchers without practitioner input. For the oil palm industry to develop a series of indicators of environmental sustainability it has to be very clear why the indicators are being developed; the indicators have to be easy to use and assess; the indicators have to be directly relevant to the operation of the industry; and preferably the successful use of the indicators should result in a higher priced product.

A series of indicators have been discussed and in the table below we raise some of the issues related with each indicator. The list of possible indicators is by no means finite and others may come out of the discussion at the workshop.

Sustainability Indicator	Issues
Soil and tissue testing as indicator of soil health	Which soil parameter is a good assessment of soil health? Soil organic matter as the indicator – is it robust enough? Does SOM encompass the concept of 'soil health'? Is SOM an accurate index of nutrient supply? Other parameters of soil health? (ie microbial biomass and population dynamics, enzyme activity) Where to sample (Oil Palm fields are not homogeneous like a wheat or cane field) Can tissue testing reflect soil health? Is tissue testing accurate enough for measures other then fertilizer recommendations? (Assuming it is accurate enough for that)
Nutrient balance	Is a reasonable indicator of nutrient mining Over-supply also readily indicated Concepts of nutrient balance: (i) Balance = Nutrients in – Nutrients out (ii) Amount needed to apply = Crop needs – amount in soil Crop N uptake as a ratio of mineralized N
Water quality	Base load versus episodic events Turbidity Chemical indicators (nutrients, DO, pH) Using water fauna as an indicator Measurement problems (automatic sampling stations are not suitable (vandalism)) Measurement of discharge to calculate loads
Biologically fixed N	Most common legumes planted (when oil palm is established) are Calopogonium, Pueraria, Mucuna Cursory inspections show active nodules with healthy rhizobium N fixation not known Generally not known whether legume cover plants would last longer if fertilized with P, K N fixation probably high initially and presumably declines when oil palm canopy closes
Field hygiene for pest control and optimum management	Good criteria available on hygiene for best practice agronomic management Also reasonable understanding of the need for good hygiene for reducing infestations of sexava (grasshopper pest)

11.2 Workshop 1 program and participants

Workshop Program, 3-5 Feb 2009, Walindi, PNG

ACIAR Small Research Activity (SRA) SMCN/2008/028

'Towards a sustainable oil palm industry in PNG'

Objectives of this SRA:

Time	Location	Topic	Contributor
9.00 – 10.00	Walindi plantation (trial site 145)	Who is OPRA Discussion - growing oil palm Trial description (why, how, outcomes)	Ian O Plantation mgmt Rachel P
10.00 – 10.30		Travel to Numundo mill	
10.30 – 12.00	Numundo	Mill inspection (incl. waste products) Nursery	Plantation mgmt OPRS (Rudolf, Philip)

		Composting	
12.00 – 12.30	Bebere	Quick stop to look at 2008 replant	Plantation mgmt
12.30 – 13.30		Travel and lunch at Dami (OPRA/OPRS)	
13.30 – 14.00	Dami	RSPO presentation. What is RSPO in an international context, implications for the industry in Indonesia and Malaysia Financial or other benefits of RSPO What is involved in accreditation What are the main stumbling blocks to achieving accreditation	Petra Meekers (NBPOL)
14.00 – 14.30	Dami	Overview seed production	TK, Dale, Rudolf
14.30 – 16.00	Smallholder Blocks	Visit smallholder blocks with OPIC Who is OPIC (roles and responsibilities) Issues facing smallholders RSPO for smallholders	Steven O Kume, Petra
16.00 – 16.30		Travel back to Walindi	
16.30 – 17.00		Wrap up discussion of field visits	

To develop a full research proposal between PNG OPRA, OPIC, JCU, CSIRO, ACIAR and other possible contributors.

To produce a technical report with recommendations for future R&D to ensure a sustainable oil palm industry in PNG.

Tuesday 3 Feb. Experiencing the oil palm industry in PNG

8:00 to 9:00 Talks

Welcome, project intro, workshop terms of reference (van Rees, Nelson)

Brief introduction to oil palm industry in PNG (Orrell)

PNG context - importance, location etc

Plantations, smallholders, milling, refining

Technical support - companies, OPIC, OPRA

Brief introduction to sustainability-related initiatives in the oil palm industry in general and PNG in particular (ISO14000, RSPO etc) (Orrell)

What is RSPO in a local context, who is involved

What are the likely consequences

What are the benefits

9:00 to 17:00 Field visits

Wednesday 4 Feb. Sustainability issues and indicators

8:00-12:00 Sustainability issues: (talks max. 25 minutes each, including questions)

Industry perspectives on sustainability

Financial benefits of RSPO and indicators

What is being done on sustainability issues

Plans for work on sustainability issues

What you would like out of the project

Presenters:

OPIC (Bakani, Pukam)

NBPOL (Hoare)

CTP (Griffiths)

Hargy (King)

Sustainability issues and indicators: some things to consider (Nelson)

Scope of sustainability issues, scale of processes and control

Types of sustainability issues: time and spatial scale, types of measurements

Indicator qualities

Project stages

Soil fertility maintenance (Webb, Berthelsen, Nelson)

Erosion issues - where, how much

Acidification - actual and potential rates and their effects

CEC decline and its effects

Organic matter decline

Nutrient, energy and water balances, including off-site effects on water and atmosphere and recycling of mill byproducts (Banabas, van Rees, Webb, Nelson,)

What is known and not

Most likely vulnerabilities, successes

Landscape scale sustainability: ecosystem services trade-offs (Butler)

Key biodiversity areas

Tradeoffs between agricultural and conservation land-use

Habitat connectivity

General discussion: Categories and ranking of issues that should be addressed.

Decide: Does project concentrate on environmental sustainability and not financial and social aspects?

Decide: Does project concentrate on growing and not milling? Except for use of mill byproducts in the field? What about nurseries?

12:00-13:00 Lunch

13:00-17:00 Possible approaches for indicators (talks max. 25 minutes each incl. discuss.)

Lessons on environmental sustainability issues and indicators in Australian tropical horticulture (Pattison)

Experiences: successes and failures

Use and usefulness of indicators

Leaf and soil analysis as indicators of soil health (Berthelsen)

Current and possible monitoring

Potential relationships with soil health

Which indicators are used in other industries

Nutrient balances as indicators (van Rees, Webb)

What's currently measured

Potential usefulness

Which indicators are used in other industries

Water quality indicators (Sheaves, Webb)

Chemical, physical, biological

Potential and problems

Applicability to different scales etc

Which indicators are used in other industries

Indicators of N inputs in legume cover crops (McNeill)

How much N do cover crops fix?

Potential indicators of N input. Eg. cover?

Indicators of field hygiene with respect to agronomy, entomology and pathology (Dewhurst, van Rees)

Main sustainability problems

Indicators and usefulness

General discussion: Types of indicators that might be used, types of input data necessary (and applicability to indicators, reliability, scale of measurement), input data that's already collected (eg. OMP, accounting, ISO14001), type of work that needs to be done (eg. research linking data and indicators, research in field to assess indicators, collation into useable tool). Develop Indicator Matrix.

Thursday 5 Feb. Modelling and wrap-up

Finish discussions from yesterday

Predictive modelling possibilities

Crop and system modelling, point to multi-point (Carberry)

Why bother with models

Types of models and how they work

Existing applicability vs development needs

Data inputs necessary

Validation

Use in focusing attention on gaps in understanding

Types of scenarios that could be tested

Sediment and nutrient runoff modelling (Armour)

Why bother with models

Types of models and how they work

Existing applicability vs development needs

Data inputs necessary

Validation

Use in focusing attention on gaps in understanding

Types of scenarios that could be tested

General discussion: Role of modelling for indicators

Wrap-up

Chance for everyone to give final comments

Summarise outcomes of workshop and project definition

Afternoon:

Project team get together to review and plan (summarise, identify any extra expertise needed, etc)

Workshop notes

Definition of 'indicator'

Please note that the term 'indictor' has different definitions in the RSPO guiding document and the SRA project proposal:

RSPO definition of 'indicator':
"Plans, practices or monitoring programs that help to achieve a particular criterion"

Definition of 'indicator' in this project:
"a measurable value of a rate or quality used to define trend in or state of land/water/system properties"

Documents distributed

SRA Proposal 'Towards a sustainable oil palm industry in PNG'

Briefing notes by Harm van Rees

RSPO Principles and Criteria for Sustainable Palm Oil Production. Including Indicators and Guidance. October 2007.

Caliman JP. 2008. Concept note. Toward sustainable palm oil production: Development of a comprehensive set of agri-environmental and social indicators and a Sustainability Index through an international network. Presented to RSPO Round Table 6, Dec 2008.

Caliman et al 2005. Development of agri-environmental indicators for sustainable management of oil palm growing: General concept and the example of nitrogen. Proceedings of the PIPOC 2005 International Palm Oil Congress: Agriculture, Biotechnology and Sustainability. 25-29 September 2005. Kuala Lumpur. Malaysia.

Caliman J.P., Wohlfahrt J., Carcasses R., Girardin P., Perel N., Wahyu A., Pujianto, Dubos B., Verwilghen A. (2006). Agri-environmental indicators for sustainable palm oil production. XV International Oil Palm Conference. 19-22 September 2006. Cartagena de Indias. Colombia.

Girardin et al. 2007. INDIGO®Palm: A method based on agro-ecological indicators to assess the environmental stability of oil palm plantations. International Conference on Oil Palm and Environment, 2007 Bali, Indonesia.

Monteiro R.C. and Rodrigues G.S. 2006. A system of integrated indicators for socio-environmental assessment and eco-certification in agriculture – Ambitec-Agro. J. Technol. Manag. Innov. 1 (3) 47-59.

Pretty et al 2008. Multi-year assessment of Unilever's progress towards agricultural sustainability. II: outcomes for peas (UK), spinach (Germany, Italy), tomatoes (Australia, Brazil, Greece, USA), tea (Kenya, Tanzania, India) and oil palm (Ghana). International Journal of Agricultural Sustainability 6(1), 63-88.

Rodrigues G.S. and Viñas A.M. 2007. An environmental impact assessment system for responsible rural production in Uruguay. J. Technol. Manag. Innov. 2 (1) 42-54.

Participants

John Armour, Qld Dept of Nat. Resources & Water (NRW), Mareeba
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Dr John Armour is a Principal Scientist with 30 years experience in soil fertility/plant nutrition management and the link to offsite water quality in tropical environments. A particular interest is movement of nutrients, particularly nitrogen, below the root zone and their fate. This research experience has been applied in recent years to catchment hydrologic models (SedNet/Annex and waterCAST) in several north Queensland catchments. He has collaborative research experience in an international project in Thailand and China. Research results have been used to develop and promote Best Management Practices for the Australian banana, papaya and sugarcane industries.

Felix Bakani, Oil Palm Industry Corporation (OPIC), Port Moresby opic@datec.net.pg

Felix Bakani worked with the Department of Agriculture and Livestock (DAL) from 1973 to 1981 as the research officer with spice crops such as vanilla, cardamom, pepper (black & white) ginger, turmeric, nutmeg & essential oils such as vetivar grass, citronella and patchouli. This was to do with agronomy, processing and marketing. From 1981 to 1989 he was the National Spices Co-ordinator. This was to do with the whole aspect of management, from the planning, organising and controlling etc. From 1989 to 1996 he was the Director for Export Crops, the biggest Division in DAL at that time. It accommodated all tree crops such as rubber, cocoa, coconut, oil palm, coffee, spices and essential oils. The responsibilities covered direction and control of the Division's operations embracing management and policy issues on tree crops in PNG. In 1996 he was appointed the General Secretary of the Oil Palm Industry Corporation which is the extension arm of the oil palm industry servicing the smallholders. From 1996 to 2005 he was the General Secretary as the Chief Executive as well as the secretary to the Board of Directors. From 2005 to date he has been acting as the General Secretary, performing the full responsibilities in the absence of an OPIC Board, awaiting the government to appoint someone to the substantive post.

Murom Banabas, Oil Palm Res. Ass. (PNGOPRA), Popondetta
murom.banabas@pnp.pngopra.org.pg

Dr Banabas is an Agronomist and is in charge of PNGOPRA operations (Agronomy, Entomology and Smallholder Studies) at Popondetta in Papua New Guinea. He has been with PNGOPRA for 16 years and during those years he was involved in designing, setting up and managing oil palm field agronomy trials. He was also actively involved in smallholder field days and training of extension and plantation managers in good agronomic practices. He completed his PhD at Massey University in NZ (2007) looking at N losses (in solution and gaseous forms) and developed a model that can assist the industry minimise losses to the environment in oil palm systems in PNG. His involvement in the project will be mainly involvement in designing and implementing the project on site.

Sue Berthelsen, James Cook Uni (JCU), Townsville Suzanne.Berthelsen@jcu.edu.au

Ms Berthelsen has had 21 years of experience in soil science and plant nutrition research, the last 14 years of which has been in the tropics. She has been involved, both as a project scientist and project leader, on two ACIAR projects, one in Papua New Guinea investigating Mg and K deficiencies in oil palm plantations, and the other in China and Thailand investigating soil chemical degradation of soils under various agricultural systems. Other work has included research into various aspects of sugarcane yield decline, in particular soil fertility, plant nutrition and root growth, and also the mechanisms and remediation of soil acidity in sugarcane production systems. Her main involvement in the project will be jointly organising the workshops and designing a new project.

James Butler, CSIRO, Cairns James.Butler@csiro.au

Dr James Butler is leader of CSIRO Sustainable Ecosystems' Livelihoods and Landscapes Group, based in Cairns. He has broad experience of researching trade-offs between landuse systems in tropical nations, with a focus on sustainable livelihoods and ecosystem services. He has experience working in PNG in collaboration with AusAID and NGOs including Conservation International.

Peter Carberry, CSIRO, Brisbane Peter.Carberry@csiro.au

Dr Carberry is a Theme Leader within CSIRO's Agricultural Sustainability Initiative (ASI) which is charged with the task of integrating and focusing CSIRO's research on the key issues in Australian and international agriculture. His disciplinary expertise is in crop physiology, and in the development and application of systems simulation models – he has been a key developer of the APSIM cropping systems model. Over the past 20 years he has been involved in ACIAR projects in Asia and Africa, the emphasis of which has been on soil fertility management and farming systems research. His role in the project will be to connect this project to CSIRO's broad research capability.

Charles Dewhurst, PNGOPRA, Dami charles.dewhurst@pngopra.org.pg

Charles Dewhurst has extensive experience in applied tropical entomology, previously in Africa. He has worked with PNGOPRA for 3.5 years, and is currently Head of Entomology, and is responsible for all applied entomological IPM and applied research on oil palm pests within PNG. Entomology Section is also responsible for P&D training for smallholders and plantation companies. We currently co-operate with ACIAR on a number of projects. PNG OPRA has out-stations in all areas in PNG where oil palm is grown, with an additional entomology sub-station on the main island.

William Griffiths, CTP Holdings, Singapore William_Griffiths@ctpholdings.com

William is currently Agricultural Director for CTP holdings, an oil palm plantation company. CTP has approximately 100,000 hectares of smallholder and estate plantings in Indonesia and Papua New Guinea. He has worked in tropical agriculture, mainly in tree crops for 30 years. He started his career as an entomologist carrying out pest control in Tea in Nepal. He has lived and worked in Philippines, Solomon Islands, Papua New Guinea, Indonesia, Liberia and Nigeria, and undertaken short term consultancy in several other Asian & African countries. Over the last 10 years he has been mainly involved in Oil Palm cultivation and management. He has worked closely with the Potash & Phosphate Institute in developing the Best Management Practice approach to increasing oil palm yields coupled with site specific fertilizer programs.

Mike Hoare, New Britain Palm Oil Ltd (NBPOL), Mosa mhoare@nbpol.com.pg

Mike has recently been appointed as General Manager of NBPOL, taking over from Nov 1st, 2008. Mike has worked with NBPOL for 20 years, joining as a Divisional Assistant in 1988. Mike's career with NBPOL has been in the field of plantation management and he was involved in the company's ISO14001 certification process as well as representing NBPOL on the PNG National Interpretation of the RSPO Principles and Criteria. Mike has had wide experience of plantation oil palm development, management, coordinating the development of the Numundo Beef enterprise and during 2007-2008, the smallholder production base of the Hoskins area.

Graham King, Hargy Oil Palms Ltd, Bialla gking@hargy.com.pg

Graham has recently been appointed as General Manager of Hargy Oil Palms Ltd and will take over officially as from 15 Dec 08. Graham came to PNG in 1980 as an agronomist with the PNG Dept of Agriculture and spent 9 years studying subsistence food production systems in lowland PNG. After a short time on an AusAid rural development project in West New Britain he joined PNGOPRA as Regional Agronomist at Dami and then at Higaturu. Since 2000 Graham has been in plantation management but with a keen interest in the smallholder oil palm projects at both Higaturu and Bialla. Since joining

Hargy in Feb 2008 Graham has been responsible for identifying land suitable for oil palm plantation expansion and working with the customary landowners to arrange lease-leaseback documents. He has also been working very closely with OPIC and the Hargy Smallholders Department to improve smallholder oil palm production. A key part of the smallholder strategy is to implement the RSPO Priciples and Criteria for smallholders.

Simon Lord, NBPOL and GSA (represented by Petra Meekers) slord@nbpol.com.sg

Dr Lord has 22 years management experience in the commercial agriculture sector. Sixteen years experience in oil palm, with 12. Currently Group Director of Sustainability for Kulim (Malaysia) Berhad directing Sustainability programs in Mills and estates across Malaysia. He is Director for Sustainability for NBPOL working in PNG and Solomon Islands adopting the Roundtable on Sustainable Oil Palm (RSPO) Principle and Criteria for Sustainability. In addition Director of Research, for NBPOL's Dami Oil Palm Research Station research group, leading programs in agronomy, plant breeding, biotechnology, and Environment. He has been involved with the RSPO initiative since 2002, Member of the Criteria Working group, verification group, smallholder task force and executive board (Vice President representing all producers outside of Indonesia and Malaysia). Qualified ISO 14001 auditor and sundry qualifications in Occupational Health & Safety and agricultural chemicals.

Ann McNeill, Uni of Adelaide ann.mcneill@adelaide.edu.au

Dr McNeill (Annie) is a senior lecturer in the Soil & Land Systems Group at Adelaide University. She currently leads GRDC funded national projects on nutrient (N and P) management and soil ecology, with primary responsibility for overseeing the work and reporting outcomes to all stakeholders. Annie's scientific expertise in aspects of nutrient and water dynamics of farming systems has developed through 28 years of involvement in agricultural research. She has worked in the UK, Syria and, for the past fifteen years in various parts of Australia. Current international work involves a DEST ISL project with Lanzhou University and the Gansu Grassland Ecological Research Institute measuring biological N fixation (BNF) and effects on N cycling in farming systems of the Loess Plateau in Western China. Annie has organized and presented training workshops in China, Sri Lanka, WA and Sicily on the use of isotope techniques to measure BNF by legumes and N inputs from roots, as well as contributing to workshops in China on the writing of scientific papers in English. She is currently a member of the SA Crawford Fund committee and is actively involved in decisions allocating resources to overseas training projects.

Petra Meekers, GSA, Singapore meekerspw@yahoo.co.uk

Paul Nelson, JCU/ NRW, Cairns paul.nelson@jcu.edu.au

Dr Nelson has 20 years of experience in crop/soil/water research, the last 10 years being in the tropics, and 3 of those in PNG as Senior Agronomist with the PNG Oil Palm Research Association. Most of his research has been related to soil health, especially soil organic matter and nutrient retention properties, and effects of soil management on water quality. He has led several research projects into nutrition of oil palm in PNG and is familiar with the soils and nutritional aspects of tree crop agronomy in the coastal lowlands of the country. He has designed and delivered training programs to farmers, managers, extension officers and agribusiness consultants in Australia and PNG over the last 9 years. He currently has projects funded by ACIAR, ARC and SRDC. He will be the project leader and have joint responsibility for organising the workshops.

Ian Orrell, PNGOPRA Ian.Orrell@pngopra.org.pg

CEO, PNG Oil Pam Research Association; Facilitator, National Implementation Working Group of RSPO; On RSPO Smallholder Taskforce

Tony Pattison, Qld Dept of Primary Indust. & Fisheries (DPI&F)
Tony.Pattison@dpi.qld.gov.au

Dr Pattison is a Principal Nematologist with the Queensland Department of Primary Industries and Fisheries. He has had 15 years experience in tropical horticultural production systems and is the Focus Team leader for Soil Health within Horticulture and Forestry Science unit. His work has focused on understanding how farm management practices impact on soil ecology and the constraints that limit soil biological diversity and suppression of soil borne diseases. This has meant developing and understanding how the soil physical, chemical and biological aspects interact on crop production. He has led soil health projects with the banana and vegetable industry in Australia and has been involved with international research projects in Costa Rica and Indonesia (CP 2005 136). His contribution to this project will be from a soil biology perspective and experiences gained from tropical banana and vegetable soil health projects.

Rachel Pipai, PNGOPRA, Dami rachael.pipai@pngopra.org.pg

Ms Rachel Pipai is an agronomist with PNG OPRA, based at the Dami Research Station, Kimbe. She has been with PNGOPRA for the last 5 years, managing the PNGOPRA fertilizer trials within New Britain Palm Oil Plantations. Three out of the twelve existing PNGOPRA trials within New Britain Palm Oil come under the ACIAR Mg Project. She manages the day to day activities and smooth running of the PNGOPRA experimental trials, statistical analysis and writing up of annual trial reports, staff matters and related administrative issues. She also has a keen interest in furthering her career as a scientist especially in the field of environmental management.

Otto Pukam, OPIC, Dami

Otto is OPIC manager for the Hoskins Project Area, the largest of the smallholder oil palm growing areas in PNG.

Harm van Rees, PNGOPRA, Alotau hvr.pngopra@global.net.pg

Dr van Rees is Head of Agronomy for PNG OPRA and is actively involved in all aspects of agronomy research and training with smallholders and plantation companies. Currently PNG OPRA have out-stations in all areas where oil palm is grown in PNG. Prior to working in PNG he was consulting in southern Australia in broad acre cropping and running research programs through the Birchip Cropping Group (BCG). He has been actively involved in running APSIM for practical day to day management decisions made by farmers. His work has primarily been in soil science, agronomy and farm management.

Marcus Sheaves, JCU marcus.sheaves@jcu.edu.au

Dr Sheaves is a senior lecturer in the School of Marine and Tropical Biology at James Cook University, and is leader of the Coastal and Estuary Ecosystem Ecology Group. He has researched the ecology of tropical estuaries and coastal wetlands for 18 years. He has worked on research projects in PNG at Milne Bay, Madang and New Britain. Most of the work in PNG has been directed to understanding the impact of the oil palm industry on coastal aquatic ecosystems, and Dr Sheaves has a particular interest in working with industry to develop best practice protocols that provide the best outcomes for both the industry and the environment. Dr Sheaves also has considerable experience in Asia, where he has worked on minimising the adverse impacts of hydropower development and on the development of monitoring plans for high ecological value marine parks.

Mike Webb, CSIRO, Townsville michael.webb@csiro.au

Dr Webb has had 16 years experience in conducting research and training in developing countries, particularly in the tropics. Mostly this has been through ACIAR projects as a project scientist and more recently as Australian project leader. Two of those years were spent in PNG as Senior Agronomist for the PNG Oil Palm Research Association. He has scientific skills in nutrient and soil management of a number of tropical crops and pastures (rapeseed in China; high-value cabinet timbers in Solomon Islands, Fiji, Niue, and Samoa;

oil palm in PNG; pasture legumes and grasses in China; pasture grasses and food crops in Thailand). He has also conducted many training workshops in aspects of soil science and plant nutrition as well as general research techniques. His main involvement in the project will be jointly organising the workshops and designing a new project.

11.3 Workshop 2 Agenda

'Towards a sustainable oil palm industry in PNG' ACIAR SMCN-2008-028

7-8 April 2009, James Cook Uni, Cairns Campus, Room E2.111

Task

Develop ACIAR Project Proposal, guided by, and building on, results of Workshop 1.

Possibly also spend time on Technical Report

Participants and roles

	Main roles in workshop, with proposal objectives
Gamini Keerthesinghe	ACIAR perspective
Ian Orrell	PNGOPRA perspective, RSPO integration
Sue Berthelsen	Obj 1&3. To produce indicators of soil health and C balance (SB & PN)
Harm van Rees	Obj 1&3. To produce indicators of soil health and C balance (SB & PN)
Paul Nelson	Obj 1&3. To produce indicators of soil health and C balance (SB & PN)
Marcus Sheaves	Obj 2. To produce indicators of stream health
Murom Banabas	Obj 4. To produce indicators of nutrient balance (MW, MB, HvR & AMcN)
Mike Webb	Obj 4. To produce indicators of nutrient balance (MW, MB, HvR & AMcN)
Ann McNeill (absent)	Obj 4. (Prior input)
Peter Carberry	Obj 5. To produce crop system model (interact with Obj 1-4)

Times (Tue and Wed)

08:30 Start

10:00 Morning tea

12:30 Lunch

15:00 Afternoon tea

17:00 Finish

Session 1 (~ 30 min)

Go through format of Proposal document and workshop agenda

Session 2 (a few hours)

Individually or in groups (as specified above), people produce a draft section 5.1 (from proposal form), assuming a 3-year project? and keeping in mind:

- particular issues for smallholder applicability
- researchable topics vs simpler compilation/implementation topics
- planned product (technique, type of measurement)
- project phases (system understanding, simplification, pilot phase and implementation) and timing
- budget

- people (including possible postgrads)
- questions you need to answer to be able to complete the proposal (eg. someone else at this workshop may be able to help)
- integration with modelling

Session 3 (a few hours)

Individuals present to group and group gives input

Session 4 (a few hours)

Individuals incorporate comments from group and produce sections 4.1, 4.2, 4.3, 4.4, 5.2, 5.3, 5.5

Session 5 (a few hours)

Individuals present to group and group gives input

Session 6 (~1 hour)

Presentation and discussion of Technical Report

Attached

Workshop 1 outcomes

Proposal form