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Biosecurity in the new Bioeconomy

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DR ANDY SHEPPARD

Biosecurity in the new bioeconomy:

Sustainable IPM of new crops and minimising the invasive threats they pose to the environment

Dr Andy Sheppard, CSIRO Theme Leader for Invasive Species and Plant Biosecurity

Crop-based biofuel production has grown exponentially, driven by government policy interventions to achieve national targets and venture capital investments. This urgency may compromise the biosecurity of current and future agricultural production systems.

This issue also arises with the entrepreneurial development of new bioindustry-focused GM crops for high value industrial and pharmaceutical compounds.

Climate change and prospects of a future emissions-constrained economy are driving this development of novel non-food crops and varieties in new areas, coupled with a mix of sovereign state energy security, domestic agricultural and innovation policy and responses to recent and potential future crude oil pricing.

New species and varieties are being commercially fostered around the world to develop and reinvigorate the global agro-forestry industries. First, second and third generation biofuel solutions are in various stages of production. Their true dollar and carbon-based economic viability is unclear due to government subsidies along the value chain, and some crop-production systems are failing commercially and environmentally due to limited consideration of associated biosecurity problems.

While these novel crops and broader-scale planting of adapted varieties of existing crops for new purposes are on the increase, the associated biosecurity risks have been largely ignored. Novel agriculture in the 21st century must be based on triple-bottom-line principles.

There are two key biosecurity issues:

- **Novel crops in current production systems and new regions pose significant invasion threats to human health, agriculture, biodiversity and natural ecosystem services through**
  - uncontrolled allergen and toxicity-associated impacts on human wellbeing;
  - abandoned trial plantings of uneconomic varieties; and
  - feral individuals (or invasive species) from economically viable plantations invading agricultural and natural landscapes.
- **Novel crops will also have suites of pests, weeds and diseases that will**
  - impact pest management systems in neighbouring crops; and
  - require innovative, environmentally sustainable integrated pest management (IPM) technologies to ensure triple-bottom-line production viability.

Written by Dr Andy Sheppard and Dr Gio Braidotti
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threats and opportunities

CSIRO organised this conference to explore how research and policy can contribute to the development of new sustainable cropping systems for new biomass feedstocks and bioindustries that provide new opportunities while posing only easily manageable economic, social or environmental challenges. This was the first international conference to focus on the broad biosecurity consequences of 21st century non-food agriculture. Through workshops and public forums the enormous opportunities novel crops offer sustainable IPM strategies to deliver sustainable profitability for these new industries were discussed.

The conference was one of a series under the OECD 2010–14 Co-operative Research Programme on Biological Resources in Agriculture focused on international collaboration around science and policy. It has relevance for the three CRP Themes (Natural Resource Challenge, Sustainability in Practice, and The Food Chain).

The conference was also a CSIRO Office of the Chief Executive Cutting Edge Symposium aimed at enhancing the understanding of key challenges and developments at scientific frontiers and sharing the perspectives of world science leaders.

We hope the outcomes of this conference increase the level of understanding between science, industry and policy towards safer biotechnology empowered agricultural and forestry systems.

For a conference statement from the delegates please see pages 22 and 23.

Dr Andy Sheppard
Chair of the Organising Committee

DR IAIN GILLESPIE
OECD

Biosecurity central to biotechnology-driven economic growth

The biosciences are creating new opportunities for economic growth, especially in the face of global food, energy and environmental challenges. But for the 'bioeconomy' to emerge and flourish, the OECD's head of Science and Technology Policy believes that biosecurity must first lay the groundwork for sustainable 'green growth'.

Dr Iain Gillespie has headed the Biotechnology Division at the Organisation for Economic Co-operation and Development (OECD) from its inception in 2005 to its amalgamation to form the Science and Technology Policy Division in 2009. He works with 30 OECD-member and 70 non-member countries to understand the impact of scientific drivers on national and global economies.

Be it biofuels, genetically modified crops or bio-engineered pharmaceuticals, biotechnology is coming of age as a driver of new economic activity. Globally, policy makers have noted implications for medicine and health, food and energy security, environmental protection, and the promise of greener and more sustainable alternatives to industrial production systems.

For these reasons biotechnology has generated interest at the Organisation for Economic Co-operation and Development (OECD), where Dr Iain Gillespie heads the Science and Technology Policy Division.

Dr Gillespie said that biotechnology was especially suited to deal with the "big challenges" facing economies. He captured the sense of biotechnology's potential with the term 'green growth' and the concept of the 'bioeconomy'.

"The bioeconomy refers to those economic activities relating to the invention, development, production and use of biological products and processes," Dr Gillespie said. "If it continues on course, the bioeconomy could make major socioeconomic contributions to both OECD and non-OECD countries alike."

The topic was explored in the OECD's *The Bioeconomy to 2030* report, which sought to map the degree to which biosciences can penetrate the global economy.

While relatively small today, the OECD study found that in the future the bioeconomy could deliver improved health outcomes, boost the productivity of agricultural and industrial processes, and enhance environmental sustainability. Although it is discoveries in biomedicine that tend to steal headlines, the OECD study found that the big sources of growth are more likely to occur in agriculture and 'agri-production'.

To realise biotechnology's potential, however, Dr Gillespie said that public governance of innovation processes was necessary, which raised the need for sound biosecurity provisions. "We need biosecurity to protect against undesirable or unintentional impacts of biological organisms and entities. The point is that biosecurity cannot be viewed as an add-on, an inconvenience, or something you do after the R&D. It is the means to deliver the bioeconomy's innovation outcomes."

"THE POINT IS THAT BIOSECURITY CANNOT BE VIEWED AS AN ADD-ON, AN INCONVENIENCE, OR SOMETHING YOU DO AFTER THE R&D. IT IS THE MEANS TO DELIVER THE BIOECONOMY'S INNOVATION OUTCOMES."

But beyond securing against negative impacts and a public backlash against individual biotechnologies, Dr Gillespie takes the idea further. Biosecurity can evolve into the concept of 'eco-efficiency', defined as the decoupling of environmental impacts from economic growth.

"If innovation can be eco-efficient – with a focus on outcomes rather than just outputs – then advances in the life sciences can help drive innovation, structural change and market transition, green employment, the harmonisation of regulatory regimes, and the provision of a positive and stable international business environment," he said.

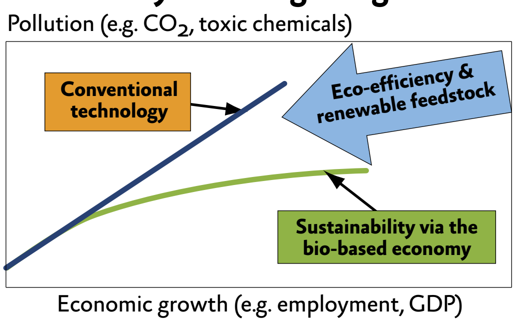
He provided the example of industrial biotechnology, in particular the race for bioethanol. He said now that capital had gone into building plants, industrial biotechnology generally was likely to fail if bioethanol failed. And with the threat of crops selected as bioenergy feedstock becoming invasive weeds or hosts to damaging diseases and pests, the issue of biosecurity was an essential component in the development of biofuels.

"Widespread use of biorefineries will require robust and credible environmental regulation and incentives," Dr Gillespie said. "That means there are multiple potential futures for industrial biotechnology. Where we end up depends on policy and private investment decisions."

For instance, the next generation of biorefineries could be fully integrated facilities that not only process high volumes of low-value biomass into fuel but also into a full range of products that add value, efficiency and sustainability to markets.

"If we are to realise biotechnology's potential we need to internalise biosecurity concerns and see them as part of the means to deliver the bioeconomy."

Bioeconomy aims for green growth



DR NEIL PARRY
UNILEVER

Industrial biotechnology meets the consumer

Unilever is in the process of replacing petrochemical feedstock with renewable materials, a process that is creating a greater role for biotechnologies that address consumer concerns about health, social values and sustainability … concerns that Unilever has come to associate with the concept of biosecurity.

With Unilever supplying nutrition, hygiene and personal care products globally, Dr Neil Parry estimates that 160 million times a day, someone somewhere is using a Unilever product. That level of market participation creates responsibility, he said. As head of Unilever's Biotechnology Science Area, Dr Parry believes that biosciences are providing opportunities to reduce the environmental impact of Unilever products and production systems. The aim, he said, is not just to replace petrochemicals but also deliver new 'functionality', including new materials based on renewable resources and smaller environmental footprints.

He provides the example of using enzymes from living organisms to make laundry detergents more effective and environmentally friendlier – a process that is vastly facilitated by the discovery of new enzymes through genome sequencing projects.

"Accessing new enzymes requires exploring genomic biodiversity, a process Unilever does through partnerships with third party technology providers," he said. "That means Unilever is a biotechnology customer, with a greater-than-ever proportion of new technology provided by third parties."

The whole approach provides opportunities for new connections between products, technology providers and the consumer. And it is not just the environment that benefits. Dr Parry cited benefits to personal health, social values and sustainability which suit the company's ethos: 'Doing well by doing good'.

"Today, people are much more aware of global concerns, such as poverty, famine, disease, global warming, water scarcity and the depletion of natural resources," he said. "The successful brands of the future will be those that not only satisfy consumers' functional needs but also address their concerns as citizens."

In response, Unilever has developed a set of guidelines to manage social and economic impacts while metrics are used to track environmental impacts based around four measures:

1. Litres of water per brand use. The total includes water used in the irrigation of raw materials, in the product's formulation and by the consumer.
2. Waste per brand use. This is the total amount of packaging plus the product leftovers minus the re-use, recycling and recovery index.
3. Greenhouses gases per brand use across the total product lifecycle.
4. Sustainable sourcing. This is the percentage of raw and packaging materials that come from sustainable or certified sources.

The metrics are being deployed in Unilever's Cleaner Planet Plan. Dr Parry reported that since 1995, the plan has delivered a 39% reduction in greenhouses gases, a 63% reduction in water use, and a 69% reduction in waste. Ultimately Unilever views these sustainability gains as a biosecurity issue.

"For Unilever, biosecurity is about people enjoying products that improve their lives without damaging the environment or depleting natural resources," Dr Parry said. "This is an important issue for us and it involves a huge amount of activity."

Roll out has also started all over the world of smaller, more compact and concentrated products associated with a 40% reduction in plastic packaging, a third less transport fuel, a 33 million litre water saving in Europe, plus a reduction of up to 20% in greenhouse gases emitted and in packaging.

The Cleaner Planet Plan also wants to motivate consumers to reduce their environmental impact. Dr Parry said that over 90% of water use based around laundry detergents comes from the consumer. By including trackers in the detergent, for example, Unilever is looking to build on its industrial biotechnology work to help change habits, behaviours and environmental impacts.

"Technology underpins the formulation of all our products and biometrics with better end-use can make a difference," Dr Parry said. "We want to motivate consumers. It's about improving the manufacture of our products, producing outstanding products and encouraging their correct use by consumers."

With that in mind, Dr Parry defines biosecurity as sustainability in a supply chain that is ethical and promotes health and safety all the way through to the consumer.

"We are seeing consumers move towards greener products, and the numbers are increasing. We want to meet that demographic demand while differentiating our products in the market."

Dr Neil Parry is the Science Leader for Biotechnology at Unilever, a post that supports the company's home, personal care and food sectors. He completed his PhD in enzyme biotechnology in 1996 before joining Unilever where he has held project-leader posts exploiting biosciences for commercial applications. He holds more than 20 patents in his name.

"THE SUCCESSFUL BRANDS OF THE FUTURE WILL BE THOSE THAT NOT ONLY SATISFY CONSUMERS' FUNCTIONAL NEEDS BUT ALSO ADDRESS THEIR CONCERNS AS CITIZENS."

DR JEAN-LUC DUBOIS
ARKEMA

A chemical company's perspective

It is not only energy production that can go 'green', renewable and sustainable. One company, Arkema, is finding it is possible for the chemical industry to enter the bioeconomy.

Dr Jean-Luc Dubois is Scientific Director at Arkema, an international chemical company with headquarters in Colombes, France. He is in charge of corporate R&D for the Catalysis Division, where he also builds long-term relationships for collaborative research with academic partners and other companies.

"AS THE SCALE OF RENEWABLE CHEMICAL PRODUCTION INCREASES, DR DUBOIS THINKS IT IS IMPERATIVE THAT GOVERNMENTS CONSIDER SUPPORTING THE GREENING OF THE CHEMICAL INDUSTRY, PERHAPS USING THE SAME KIND OF GREEN CERTIFICATE SYSTEM CURRENTLY APPLIED TO RENEWABLE ENERGY IN EUROPE."

By 2010, the international chemical company Arkema wants 10% of its sales to derive from renewable resources. While Arkema is not an agrichemical company – it deals in vinyl products, industrial chemicals, polymers and additives – it intends to increase the range of products that are derived from renewable biomass.

Arkema's Scientific Director Dr Jean-Luc Dubois said that already the company has a range of products on the market made from renewable resources. These range from bitumen additives to an ethanol-based carbon nanotube production process.

For him the term 'biosecurity' has a straightforward definition – it refers to how safe and reliable the supply chain is in green production processes.

To illustrate the point, Dr Dubois spoke about chemicals produced for intensive farming practices, primarily fertilisers and insecticides. These have caused the largest accidents in the chemical industry he said, including an explosion at a fertiliser plant in Toulouse, France, in 2001 that killed 21 people and hospitalised 2442.

While Dr Dubois was keen to avoid equating safety with 'natural', he said that Arkema's focus when it comes to renewable production processes is on biomass that is safe throughout – from the way the resource is produced through to post-harvest pollution issues.

"We have to learn from past experience," he said. "New crops or new farming practices can mean new allergens, pests or diseases."

For example, cedar trees planted in Japan after World War II are natural, he said, but now cause allergy problems for 20 million Japanese each spring. Originally, about seven million hectares of cedar and cypress were planted to provide timber for re-building and to prevent landslides, but logging has since ceased in favour of cheaper timber imports.

"For the products Arkema wants to develop, we want to look at the whole chain in terms of biosecurity," Dr Dubois said. "For example, water consumption to produce bioethanol is huge: about 10 litres of water are required per litre of ethanol."

To achieve its goals, Arkema has developed guidelines that help ensure their renewable chemicals are 'eco-efficient' – that is, decoupled as much as possible from negative environmental and social impacts. Key criteria include:

- the need for reliable, long-term sources of biomass to justify capital investment in production plants;
- the distorting impact of government subsidies, targets and incentives on biofuel production when there are no equivalent support systems for green chemicals;
- the need to avoid competition with food production when sourcing feedstock;
- allergy, disease and pest problems from new crops and farming systems;
- the impact of climate change on crop productivity; and
- impacts from post-harvest treatments – for example, when using toxic non-edible plants such as Jatropha, a biofuel feedstock also known as black vomit nut.

"Agriculture should first secure the food requirements of the population," Dr Dubois said. "There are several ways to then solve competing demands for land."

One way, he said, was to improve soil fertility using a smart combination of crops (intercropping) or crop rotations. For example, a study found that when planted in rotation with maize, castor oil plants can boost maize yields more than any other crop tested, including soybeans, cowpeas, sorghum and sunflowers. This is the kind of synergy Arkema is looking for in its renewable supply chain.

At the other end of the production chain, Arkema has a project under way to use glycerol waste from the manufacture of biodiesel and soap to develop a new process for the on-site production of acrolein, a toxic chemical that has caused industrial accidents during storage and transport.

As the scale of renewable chemical production increases, Dr Dubois thinks it is imperative that governments consider supporting the greening of the chemical industry, perhaps using the same kind of green certificate system currently applied to renewable energy in Europe. That way, environmentally conscious clients can express a preference for renewable chemicals such as biomethanol.

"It seems to me that tax incentives and subsidies could also serve 'green' renewable chemicals," Dr Dubois said. "So overall, the perspective of a new economy based on renewable resources generates a lot of hope but also a lot of questions."

DR UFFE JØRGENSEN
INSTITUTE OF AGROECOLOGY AND ENVIRONMENT

Balancing environmental risks and energy sustainability

Denmark is a world leader in the use of renewable energy and they have set their sights on completely eliminating their reliance on fossil fuel, but not at the cost of the environment.

Denmark is already generating 17% of its total energy needs from renewable sources, with about 20% of electricity needs supplied by wind power. Even the country's base load needs are going renewable, with 12% of energy coming from burning biomass, a share that Denmark is looking to increase.

There is also a national policy to eliminate altogether reliance on fossil fuels, although no timetable is yet in place. At the Institute of Agroecology and Environment, Dr Uffe Jørgensen is working to understand the balance between economic benefits and environmental risks of growing miscanthus (*Miscanthus giganteus*) as a biofuel crop.

Miscanthus is a tall perennial grass from Asia that uses the 'C4' photosynthetic process – a type more efficient at converting carbon dioxide and water into starch than 'C3' grasses, such as wheat and rice. It is out-yielding switchgrass in the US and its performance can be improved with breeding, given the many miscanthus species are available for trait selection.

Dr Jørgensen said that miscanthus is of interest in Denmark because of its tolerance to chilling and its lack of invasiveness in Europe since its introduction in the 1930s as a sterile ornamental plant. "Experiments since 1982 with this sterile variety and since 1990 with a collection of other seed-setting species have found no spreading in Europe," he said.

As a bioenergy crop, miscanthus can be put to several uses. It can be burnt directly for the production of electricity or used to distil ethanol and, if harvested early, it can serve as bioenergy feedstock for biogas production. In addition, it can provide a source of materials, for example for paper, and is used in thatching, a traditional form of roof construction that generates high value in an admittedly small market.

The main obstacle of miscanthus is its low value to farmers, as the grass sells for just A$110 per tonne. However, perennial plants help build soil health and soil carbon storage is included in the Kyoto Protocol as a way to reduce greenhouse gases. That means miscanthus has the potential to add value to farms by helping to meet environmental regulation and reduce costs.

"Perennial energy crops have better environmental profiles than annual crops," Dr Jørgensen said. "They are associated with 70% less leaching of nitrates from the soil, require 60% less pesticide use and result in 60% less greenhouse gas emissions."

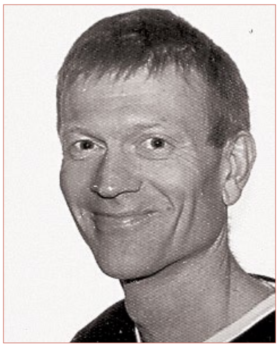
Currently just 12,000 hectares of miscanthus is being produced in all of Europe, mostly in the UK. The species spreads slowly but a system for mechanically propagating miscanthus rhizomes (the underground stem that allows the sterile plant to spread) has cut planting costs by 80%.

As an agronomist, Dr Jørgensen is keen to tap genetic resources to further improve the crop's performance. He aims to broaden its genetic base while continuing to produce sterile plants. He says progress so far is limited but several biotech companies have breeding programs, including one that has a breeding program to improve flowering time, crop architecture and lignin content to improve ethanol production.

Of the remaining biosecurity concerns – pests, disease and fire risks – miscanthus also scores well. Although new pests and diseases could be an issue if large areas are planted, miscanthus generally holds up well against biological stresses and was used to introduce pest and disease-resistance genes into sugarcane. Fire risks too are small in Denmark where the crop is green until killed by frost.

"So while currently the economic benefits of growing miscanthus are limited, sterile and non-invasive *M. giganteus* offers farmers a more sustainable production system," Dr Jørgensen said. "In the long term this could prove an incentive to include the crop in new production systems. Since Denmark is a net food exporter, there may be enough spare farming capacity to grow miscanthus without negative impacts on food security."

Miscanthus



Dr Uffe Jørgensen is a senior scientist at the Institute of Agroecology and Environment at Aarhus University. His interest is in promoting the efficient use of resources in crop production, including perennial energy crops, and the reduction of environmental impacts. Dr Jørgensen is active as an adviser at the national, European and international policy level, serving as a Danish representative to the International Energy Agency (IEA) Bioenergy organisation, which promotes cooperation between national bioenergy R&D.

"AS A BIOENERGY CROP, MISCANTHUS CAN BE PUT TO SEVERAL USES. IT CAN BE BURNT DIRECTLY FOR THE PRODUCTION OF ELECTRICITY OR USED TO DISTIL ETHANOL AND, IF HARVESTED EARLY, IT CAN SERVE AS FEEDSTOCK FOR BIOGAS PRODUCTION."

DR PIERO GENOVESI
ITALIAN INSTITUTE FOR ENVIRONMENTAL PROTECTION AND RESEARCH (ISPRA)

Renewable energy raises biosecurity awareness in Europe

The European Union's relaxed take on invasive species is coming under review as mandatory targets to replace fossil fuels with renewable energy bring greater awareness of biosecurity risks.

Dr Piero Genovesi of the Italian Institute for Environmental Protection and Research (ISPRA) has coordinated research on biological invasions and co-authored the European Strategy on Invasive Alien Species. He co-operates closely with European institutions to develop regional policy, and chairs the Invasive Species Specialist Group, a global network of scientific and policy experts organised under the auspices of the Species Survival Commission (SSC) of the International Union for Conservation of Nature (IUCN).

"THE EU HAS AGREED TO AMBITIOUS TARGETS IN WHICH 20% OF ENERGY IS TO COME FROM RENEWABLE SOURCES BY 2020. THAT MANDATE INCLUDES A TARGET OF 10% FOR RENEWABLE FUELS IN THE TRANSPORT SECTOR."

With just weak and non-binding recommendations to discourage the use of invasive plants for biofuel production, the European Union (EU) is in the process of reviewing its biosecurity provisions as the region commits to large mandatory increases in renewable energy production.

Assisting in formulating European policy is Dr Piero Genovesi, an ecologist from the Italian Institute for Environmental Protection and Research who co-authored the European Strategy on Invasive Alien Species.

He said that within the EU, the transport sector accounts for more than 30% of total energy consumption and, of this, 98% is dependent on fossil fuels that are mostly imported and vulnerable to market disturbances. Furthermore, 90% of the increase in carbon dioxide emitted since 1990 is calculated to be due to the transport sector.

"The EU has agreed to ambitious targets in which 20% of total energy production is to come from renewable sources by 2020," Dr Genovesi said. "That mandate includes a target of 10% for renewable fuels in the transport sector. We estimate that between 4% and 13% of European agricultural land would be needed to produce biofuel at that level of replacement of fossil fuels."

In setting these targets, Dr Genovesi said that decision makers proved sensitive to concerns about the impact of biofuel production on rising food prices and the destruction of rainforest. In 2009, EU legislation was revised to state that energy from biofuels may only count towards targets and be eligible for financial support if they are consistent with sustainability criteria. The directive states that:

- wetlands and continuously forested areas are not eligible for producing biofuels;
- biofuel production should comply with environmental requirements for agriculture, protection of water quality and social requirements;
- worldwide multilateral and bilateral agreements for producing biofuels are to cover key environmental and social considerations; and
- biomass cultivation should be monitored for impacts, such as consequences of land-use change, including species displacement and the introduction of invasive alien species.

"Biosecurity concerns over biofuels are definitely increasing in Europe and there is growing realisation that invasiveness is an important issue," Dr Genovesi said. "There are a lot of invader species proposed for biofuel production and the chances are really dramatic that something could go wrong, with costly consequences for agriculture, fisheries, biodiversity or ecosystems."

Currently, the EU spends about 12 billion euros a year as a direct consequence of invasive species.

Given existing EU governance structures, it is the role of the European Plant Protection Organization (EPPO) to recommend to member countries which species to regulate as quarantine pests. The EPPO generates two lists covering viruses, bacteria, fungi, parasitic plants, insects and mites. One list (EPPO A1) contains 181 pests currently absent in the EU, while a second list (EPPO A2) covers 120 pests present locally within the EPPO region. While the lists are reviewed annually, they presently contain just 44 invasive alien plants.

Dr Genovesi said that growing concerns over biosecurity saw the EPPO Council in 2007 advise the various national plant protection organisations to discourage use of invasive biofuel crops and encourage a risk-based approach to avoid dispersal. "While EPPO is collecting information from member countries about biofuel practices, it has taken no further action on this issue," he said.

However, in 2008 the European Commission formally committed to a Europe-wide early warning and information system. Additionally, there is support from the European Economic and Social Committee for a comprehensive EU legal instrument and a new agency dedicated to invasive species.

That leaves the EU with biosecurity measures that are more stringent for genetically modified organisms (GMOs), where the precautionary principle prevails under the guidance of the European Food Safety Authority (EFSA). As of 2009, those controls were extended to include non-food GMOs.

In the interim, the International Union for Conservation of Nature (IUCN) explored the issue in two workshops held at the IUCN ESARO office in Nairobi in April and October, 2009. On the basis of the outcomes of the two meetings, the IUCN is publishing guidelines that are aimed at informing biosecurity policy in all areas of the world, with a special focus on developing countries.

"Europe's long history of introductions tends to make Europeans less aware of this issue than people in other parts of the world," Dr Genovesi said. "However, there is strong public support for reducing carbon footprints, and with that comes the realisation that no measure to reduce emissions is free of costs. So momentum is building in favour of more comprehensive biosecurity policy structures."

DR ALAN V. TASKER
USDA APHIS

America confronts the biofuel crop invasion threat

America wants to shift bioethanol production away from food crops such as maize, but the species being proposed for biomass production pose an invasive weed risk that current regulatory mechanisms are ill-equipped to handle.

Growing energy demands, a desire to reduce reliance on fossil fuels and greater awareness of climate change have led US federal and state governments to pursue renewable fuels produced from plant feedstock.

The 2008 US Department of Agriculture (USDA) farm bill includes more than US$600 million in mandatory funding for renewable energy programs over five years. This includes funds for a new program called the Biomass Crop Assistance Program (BCAP) dedicated to renewable fuel production. However, BCAP explicitly excludes assistance for any plant that is invasive or noxious.

The USDA agency APHIS (Animal and Plant Health Inspection Service) is the regulatory agency charged with protecting US agriculture and wildlife. Its Noxious Weed Program Manager is Dr Alan V. Tasker.

"The 2007 Energy Independence and Security Act mandates the production of 61 billion litres of plant-cellulosic-based fuel," Dr Tasker said. "This cannot be met with current agricultural, forestry and municipal residue alone. It necessitates large-scale planting of dedicated energy crops that do not compete with food or feed."

USDA research efforts are focusing on identifying crops that will maximise yield while allowing cultivation on less productive, marginal lands with minimal agricultural inputs.

The difficulty, Dr Tasker said, is that many of the traits sought in feedstock species also make them potentially invasive. For example, researchers at Hawaii Pacific University found that biofuel crops are two to four times more likely to be invasive in tropical areas than a random sample of introduced plants.

As a result, various government and partner organisations that are under obligation to avoid promoting invasive species are asking APHIS for clarification regarding regulation or management of potentially invasive plants, including biomass and biotechnology crops.

"Many potentially invasive plants are not currently regulated by APHIS because they do not qualify as traditionally defined quarantine pests," Dr Tasker said. "As a result, APHIS is exploring possible regulatory and non-regulatory approaches with the agency charged with implementing BCAP, the Farm Services Agency."

This includes reviewing existing national and international policy structures, including recommendations by the Global Invasive Species Program (GISP), which has identified a list of potentially invasive species under consideration as biofuel feedstocks.

While US biosecurity policy for biofuels is still a work in progress, Dr Tasker has come to believe that biomass management has six core components:

- weed risk assessment (WRA) protocols;
- contingency planning in case of spread;
- site-selection processes;
- benefit-cost analysis;
- monitoring and rapid-response capacity; and
- post-performance bonds to cover costs on ongoing management.

Dr Tasker said that existing WRA systems were reviewed and a tool similar to the Australian system is under development for the US. With crop losses due to noxious weeds totalling about US$20 to $50 billion annually in the US, Dr Tasker expects that biosecurity measures to control invasive biofuel crops are likely to result in a new category of regulated article: 'Not allowed pending risk assessment.'

Draft guidelines for responding to new weeds are also being written and will contain information for early detection and rapid control responses. "These guidelines will contain the caveat that eradicating a noxious weed infestation before it becomes widespread in the environment should outweigh temporary harm to an individual site," he said.

In choosing a site for biofuel production, Dr Tasker has identified a number of key criteria that have the potential to alter sensitive habitats and make them more susceptible to invasion. These include the proposed new crop's biology, likely resource inputs (such as water or fertiliser), planting and harvesting methods, as well as transport distance of the feedstock to the biofuel facility (greater than 50 kilometres from a processing facility is unlikely to be economic).

"With industry biofuel production mandates and subsidies in place, it is now a race against time to produce guidelines before the second, weedier generation of biofuel feedstock is selected," Dr Tasker said.

Dr Alan V. Tasker is the Noxious Weed Program Manager at the US Department of Agriculture's Animal and Plant Health Inspection Service (USDA APHIS). He has served as a member of the APHIS National Weeds strategic planning team since its inception in 1992. In addition to a PhD in agronomy from the University of Missouri – Columbia, Dr Tasker has an MS in agronomy from Montana State University.

"WITH INDUSTRY BIOFUEL PRODUCTION MANDATES AND SUBSIDIES IN PLACE, IT IS NOW A RACE AGAINST TIME TO PRODUCE GUIDELINES BEFORE THE SECOND, WEEDIER GENERATION OF BIOFUEL FEEDSTOCK IS SELECTED."

MR TIM LOW

INVASIVE SPECIES COUNCIL

Risks from new biofuel crops: what should we do?

As one of the first people in the world to ring alarm bells about the weedy potential of biofuel feedstock, Mr Tim Low looks to the intertwined threats of climate change and invasive weeds to address how best to avoid biofuel production failures.

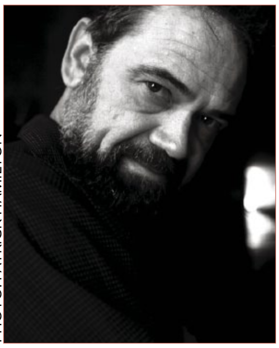


PHOTO: PATRICK HAMILTON

Mr Tim Low is co-founder of the Invasive Species Council, one of the first organisations in the world to raise concerns about the weedy potential of biofuels in a 2007 report he co-authored called *The Weedy Truth About Biofuels.* He is an internationally recognised expert on invasive species and author of *Feral Future: the Untold Story of Australia's Exotic Invaders.*

Since realising that biofuels can exacerbate global food insecurity by displacing food production, the industry has sought non-food alternatives in species that can grow on marginal land. Among the first to realise that these proposed species are potentially extremely 'weedy' was the Australian non-government organisation, the Invasive Species Council, which published an influential report, *The Weedy Truth About Biofuels*, co-authored by Tim Low.

Mr Low is well aware of the argument that climate change could be so dire that we cannot afford to be overly concerned if a few weed problems emerge as a result of biofuel crops. However, he argued that a major climate change outcome would be a dramatic worsening of problems caused by invasive species if their impacts were not mitigated, a fact recognised in the Garnaut Climate Change Review.

"If a farmer's crops or pastures are dying because of unprecedented drought, there is a high risk of invasive weeds taking over the farm," he said. "If a natural ecosystem is subjected to climatic conditions it cannot cope with, then weeds can overwhelm biodiversity. So invasive weeds and climate change are synergistic problems. To me that argues we have to take future weed issues very seriously."

From having observed past invasions that have swamped natural habitats in Australia – weeds such as the rubber vine and cat's claw creeper – Mr Low now believes it is imperative that weeds are caught at the early stages of an invasion, before they can overwhelm clean-up budgets, resources and remediation expertise.

However, spotting a potential problem requires monitoring the very process by which species are deliberately introduced as the basis of new production systems.

"A few years ago, I noticed a biofuel plant being promoted as 'green gold in a shrub'," Mr Low said. It was Jatropha.

Also called 'black vomit nut' because of its toxicity to animals and humans, Jatropha is a first-generation biofuel crop whose oilseed is used to make biodiesel. It was promoted on claims that it does not compete with food crops and can grow on marginal land. However, Mr Low found that yields obtained on good agricultural land had been extrapolated to marginal land and that rainforest has been cleared in Brazil and South-East Asia to grow it.

"What people were not saying is that if you grow Jatropha on marginal land, you only get marginal yields," Mr Low said.

Closer examination by researchers worldwide has since found that Jatropha crops have very high water needs and claims that it does not attract insect pests have proved false. In a recent survey of 615 Jatropha plantations in Africa, 90% were found to be in bad condition.

"This was the scenario I was fearing for Australia," he said. "What I didn't want was a vast number of abandoned plantations just popping seed out to the environment. That is now going on in all the areas where Jatropha was planted and there are now headlines saying 'the miracle crop that went wrong'. But Australia kept Jatropha out so we do not have to deal with problems from abandoned plantations here."

With weedy species such as giant reed being proposed as second-generation biofuel feedstock, Mr Low said that biomass production has the potential to create unprecedented pressure on existing regulatory mechanisms that urgently need to be addressed.

"The problem for regulation is that for biofuels to make any difference to climate change they have to be grown over vast areas, massive acreages," he said. "So how do you monitor compliance?"

Mr Low believes that both existing regulatory approaches – voluntary industry codes of conduct and legally binding guidelines – are likely to prove inadequate to prevent costly and damaging failures when growing low-value, high-volume weedy crops.

"We did a literature review of studies that assessed voluntary guidelines," Mr Low said. "These are especially popular in America, where there is a cultural preference for minimising regulatory burdens on business. They all said that voluntary guidelines do not work. You have to have enforced restrictions and it has be legally binding."

They would result in unprecedented levels of monitoring from qualified inspection officers, and the requirement for rapid-response clean up services. But who is going to pay for these regulatory mechanisms, Mr Low asked, industry or taxpayers?

"As a general principle, stewardship protocols require sufficient profit margins to pay for the maintenance of things like fences and buffers," he said. "At the moment biofuel is not profitable at all and that would need to change a lot for these crops to stop presenting an invisible cost to taxpayers."

"BOTH EXISTING REGULATORY APPROACHES – VOLUNTARY INDUSTRY CODES OF CONDUCT AND LEGALLY BINDING GUIDELINES – ARE LIKELY TO PROVE INADEQUATE TO PREVENT COSTLY AND DAMAGING FAILURES IN THE FACE OF LOW-VALUE, HIGH-VOLUME WEEDY BIOFUEL CROPS."

PROFESSOR TONY IVES
UNIVERSITY OF WISCONSIN

The precautionary principle

Risk assessment can prove problematic when the bioeconomy delivers innovations that bring together novel pests, technology and environments. In these cases, novelty can engender uncertainty and unpredictability, requiring caution, monitoring and new methods for analysing risk.

Unlike risk assessment in the insurance industry, where vast amounts of reliable historic data is available, within the bioeconomy the sheer novelty of biotechnologies makes predictions based on past experience impossible.

According to theoretical ecologist, Professor Tony Ives of the University of Wisconsin in the US, uncertainty is inevitable when dealing with interaction between novel pests and technologies in agro-ecosystems. In these cases, novelty translates into unpredictability, which poses particular difficulties for risk assessment protocols.

Professor Ives defines 'risk' simply as the magnitude of potential loss (L) times the probability it will occur (P).

"Risk assessment problems arise when nobody really knows the value of L or P," he said. "Furthermore, biological systems are fabulously complex and predictions need to beware of this complexity."

For Professor Ives, the limitations and dangers of assessing risks in complex agro-ecosystems highlights the need to apply the precautionary principle, without being paralysed by complexity or equating caution with inaction.

When a formal risk assessment is not possible, Professor Ives recommends a three-pronged approach:

1. Learn from individual case studies that give insights into new risks.
2. Generate theoretical models of possible future scenarios built on basic biological principles.
3. Integrate data and models to extrapolate current trends into an unknown future.

1. Learn from individual cases

The North American invasion by the soybean aphid was discovered in soybean crops in 2000 and went on to become a significant pest in the upper Midwest.

Studies revealed that interactions between a number of introduced species were a factor in the invasion. Aiding the aphids were two introduced hedgerows, called common and alderleaf buckthorn, which provide the aphid with a winter host.

In turn, the arrival of soybean aphid provided a mid-summer resource for Asian ladybeetles that were first released in the US as a biocontrol agent in 1916.

In 2007, biofuel production led to a 20% increase in land planted to maize and the effectiveness of biocontrol in soybean declined, raising pest control costs from an estimated US$390 per year to US$4,500 per acre.

Professor Ives draws three lessons from this case:

- sequential invasive species interact with each other either positively or negatively;
- large-scale changes in land use can have unexpected impacts; and
- even though crops may not share pests, they will often share natural enemies that link crops together at the landscape level.

2. Use models

Ever since a bacterial gene was engineered into crops to produce an insecticidal toxin (Bt), substantial effort has gone into preventing pests evolving resistance to this novel form of pest control. The 'high dose-refuge' management strategy for Bt crops involves planting a non-Bt variety on 20% of the acreage (the so-called 'refuge') where insects are under no selection to evolve resistance.

"Evolution is about changes in the frequency of gene variants (alleles)," Professor Ives said. "The starting frequency of resistance genes is usually unknown but critical in determining when resistance will emerge. So while we cannot make accurate predictions, models can still provide a useful tool for managing risks.

"The aim of modelling is to compare outcomes rather than to predict when resistance might arise," Professor Ives said. "We should:

- focus on assessment not prediction;
- use models to test assumptions rather than rely on expert intuition; and
- couple risk assessment with pot-decision monitoring."

3. Integrate models and data

While a field experiment can provide information about immediate responses, models can extend time scales to explore long-term consequences. This approach was taken by Professor Ives to look at climate change impacts on pests and their predators.

To obtain data, Professor Ives's team studied the impact of high temperatures on pea aphids. These experiments found that heat shock reduces aphid numbers to the same extent as predation by ladybeetles. But when both stresses were applied together, there was little additive effect. That meant that heat lessens the effect of predation and predation the effect of heat shock.

The data was then fed into models that extended out to 10 years. It then became apparent why predation was not having an additive effect. With heat shock reducing pest numbers, predators run out of food to such an extent that the impact of heat was far more apparent in predators than pests. So modelling can identify the 'canaries' that signal a system is affected by raising temperature.

Professor Tony Ives is a theoretical ecologist at the Zoology Department of the University of Wisconsin in the US. His work spans population genetics, population dynamics, community ecology and climate change. His special interest is in agricultural systems and the biological control of pests by natural predators.

"FOR PROFESSOR IVES, THE LIMITATIONS AND DANGERS OF ASSESSING RISKS IN COMPLEX AGRO-ECOSYSTEMS HIGHLIGHTS THE NEED TO APPLY THE PRECAUTIONARY PRINCIPLE. THAT MEANS PROCEEDING WITH AWARENESS ABOUT UNCERTAINTIES IN THE RISK ASSESSMENT, BUT HE WARNS NOT TO BECOME PARALYSED BY COMPLEXITY AND NOT TO EQUATE CAUTION WITH INACTION."

PROFESSOR DAVE RICHARDSON
STELLENBOSCH UNIVERSITY

Biosecurity gains from assimilating lessons from history

Alien trees have caused problems as invasive species, but Professor Dave Richardson from South Africa's Centre for Invasion Biology believes that invasions are not random, impacts can be predicted and the bioeconomy can avoid making the same mistakes in the future, including in the quest for biofuel feedstock.

Professor Dave Richardson is the Deputy Director of the Centre for Invasion Biology at Stellenbosch University in South Africa. He has performed research and published more than 180 peer-reviewed papers on the ecology and management of biological invasions.

While exotic trees and shrubs are the foundation of forestry and agroforestry activities across the world, hundreds of species have become invasive. Some now feature prominently on national lists of invasive alien plants, and some account for the most conspicuous and damaging invasions.

South Africa has had 300 years of dealing with the importation of forestry trees and now hosts the Centre for Invasion Biology where Professor Dave Richardson is a recognised world leader in understanding plant invasions.

He says benefits that woody species provide are not in dispute. They supply food, feed, timber, pulp and firewood resources and can control erosion, sandrift and dryland salinity. But problems arise when species become invasive – when they displace and disrupt ecosystems, biodiversity, water catchments or agricultural land.

"Invasive trees that are commercially important have invaded many habitats, creating conflicts of interest," Professor Richardson said. "They pose special problems with implications for the bioeconomy. However, solutions are possible in the form of regulatory and management practices that are built from an understanding of what drives invasiveness."

At the Centre for Invasion Biology, the 'nuts and bolts' of tree invasion are studied with the goal of building analytical tools that can predict how new species are likely to behave when moved around the world.

Professor Richardson said countries like South Africa, Australia and New Zealand are in an especially good position to learn from past experience with invasive foreign plants. "We have the opportunity to use our experience and apply it to other plants all over the world."

"COUNTRIES LIKE SOUTH AFRICA, AUSTRALIA AND NEW ZEALAND ARE IN AN ESPECIALLY GOOD POSITION TO LEARN FROM PAST EXPERIENCE WITH INVASIVE FOREIGN PLANTS. WE HAVE THE OPPORTUNITY TO USE OUR EXPERIENCE AND APPLY IT TO OTHER PLANTS ALL OVER THE WORLD."

To build on experience in ways that deliver predictive and proactive management principles, Professor Richardson outlined a basic R&D strategy whose key components include:

- charting which species have been introduced over time and where;
- identifying attributes that distinguish invasive from non-invasive species, including factors such as the size of the area planted;
- generating spatially explicit models and mapping the spread from both a single dense dispersal site or many smaller areas; and
- correlating plant traits with 'invasiveness' and features of the environment with 'invasibility'.

Plant attributes that generally facilitate invasions include small seeds with large wings, short juvenile periods, short intervals between large seed crops and the ability to survive moderate browsing. Large plantings over long periods are also considered facilitating factors, while sparsely vegetated grass and shrub land present the most accommodating environments. But the analysis runs deeper, including factors such as soil bacteria, disease-causing fungi, wind, flooding and climate.

"Enterprises using foreign species have options available to make them safer," he said. These include selecting less invasive species, manipulating the plant's seed production or dispersal, and manipulating the receiving environment. For example, tree plantations in New Zealand use less invasive species at the periphery to generate a barrier to dispersal.

"It is important that the response to weedy species be seen in its specific environmental context and that it interacts with land and water-management services, agricultural enterprises and national priorities," he said.

With woody species under consideration as second-generation feedstock for biofuel production, there is a sense of urgency to Professor Richardson's work. The potential of biofuel species to turn invasive is real and while they present the quintessential plant biosecurity issue facing the bioeconomy, they also present the opportunity to roll out improved national and international stewardship protocols.

There may not be a one-size-fits-all fix, Professor Richardson said, and preventing the introduction of a suspect species will always offer the most stringent form of control. But the opportunity exists to minimise the risks of a species turning invasive from the outset.

"We can learn from past mistakes," he said. "If we apply mitigating strategies very early it becomes possible to minimise damaging impacts from invasive woody species and the clean up costs. We need to proceed with caution and use wisely the information from accumulated history of exotics in the bioeconomy."

DR ARMAND SÉGUIN
LAURENTIAN FORESTRY CENTRE

GM pest control explored for biosecurity risks

Transgenic technology has provided new forms of pest control, but in Canada, where trees are likely sources of renewable biofuels, one researcher has explored the ability to safely manage field-trial sites designed for transgenic trees.

With its vast expanse of tree plantations and forests, Canada faces the option of using woody biomass as a feedstock for biofuel production. While there is public pressure to conserve Canada's remaining wild forest, concerns over climate change are creating opportunities to harvest plantation biomass as feedstock for ethanol production.

At the Laurentian Forestry Centre, molecular biologist Dr Armand Séguin is exploring the benefits and risks associated with applying transgenic breeding technology to wood ethanol production. Of particular interest is the use of gene modification (GM) technology to improve resistance to pests and diseases that have proven capable of wiping out entire plantations.

As a test case, Dr Séguin has generated GM spruce that expresses the same pesticidal toxin gene (Bt) used in GM cotton and maize crops. The goal was to provide resistance to the spruce budworm, a native pest with a track record of causing epidemics in tree plantations. In about 10 years, this insect destroyed the equivalent of more that half a billion cubic metres of wood solely in the province of Quebec.

"The project is not about advocating for GM tree plantations," Dr Séguin said. "It is more about exploring biosecurity issues and testing our ability to monitor and manage field sites during the development of biotechnology traits."

The first transgenic spruce were planted in 2000 and by 2006 Dr Séguin's team found that the trees were still stably producing Bt toxin and expressed good levels of resistance to the spruce budworm. The GM trees were also field-tested to assess the GM trait for ecological impacts and persistence in the environment in what amounted to the first GM tree trial ever undertaken in Canada.

"Being part of the national forestry organisation, it seemed sensible to test the effect of transgenic technology," Dr Séguin said. "This meant looking at impacts on tree physiology, the long-term stability of transgene expression and the transgene's persistence in the broader environment, for example, through fallen trees."

The field trial was run in accordance with the regulatory standards administered by the Canadian Food Inspection Agency (CFIA) regarding environmental assessments of 'plants with novel traits' (PNTs). That framework saw the researchers plant guard (or buffer) rows and curtail the trial before the GM trees could flower. The site was regularly monitored, with researchers keeping logbooks that were inspected by the CFIA annually.

The trial was terminated in 2007 and the site completely cleared of trees and stumps. Conscious that the project was setting a procedural precedent for GM trees, the team avoided the easy option of burning the site. Instead trees were felled and the low-residue herbicide glyphosate was used to kill the roots before tilling the site with a tractor. The site will undergo monitoring for a total of five years.

Dr Séguim said that to date, no persistence of transgenic spruce or the transgene has been detected. Transgenic trees were physiologically indistinguishable from the wild type and no effects were detected on soil microbial diversity.

"Fast-growing trees like poplar and aspen offer new opportunities within the bioeconomy in which biotechnology can provide tree attributes that improve industrial use of these crops," Dr Séguin said. "For example, the cell wall can be modified to be more compatible with ethanol production, or lignin levels can be reduced to improve paper production."

As alternatives for industrial biotechnology, Dr Séguin believes that trees present a sustainable option. There is, additionally, the advantage of value-adding through sequestering carbon and with appropriate risk-assessment protocols in place, trees are likely to prove less weedier as biofuel crops. While he is not advocating growing GM trees on a vast scale, Dr Séguin believes that biotechnology can be used safely and that, with proper management, tree plantations can support greater biodiversity.

Dr Armand Séguin is a research scientist at the Canadian Forest Service's Laurentian Forestry Centre. His research program examines the molecular responses to stress in trees, tree genetic engineering and the potential impacts of transgenic trees on the environment. Studies conducted in his laboratory have informed biotechnology regulation structures in Canada.

"THE PROJECT IS NOT ABOUT ADVOCATING FOR GM TREE PLANTATIONS. IT IS MORE ABOUT EXPLORING BIOSECURITY ISSUES AND TESTING OUR ABILITY TO MONITOR AND MANAGE FIELD SITES DURING THE DEVELOPMENT OF BIOTECHNOLOGY TRAITS."

PROFESSOR ALISON STEWART
LINCOLN UNIVERSITY

Keeping bioenergy crops healthy

Disease impacts on bioenergy crops are likely to prove such a limiting factor in crop establishment, quality and biomass yield that one national renewable energy program has included plant pathologists in its R&D team.

Professor Alison Stewart is the Director of the Bio-Protection Research Centre at Lincoln University in Christchurch, New Zealand. The centre was established by the New Zealand Government in 2003 to support the biosecurity needs of plant-based production sectors. The centre's research focus is on sustainable bio-protection technologies while Professor Stewart's own research is aimed at controlling soil-borne disease using beneficial microbes such as *Trichoderma*.

"THE DIFFICULTY POSED BY SECOND GENERATION BIOENERGY CROPS IS THAT DISEASE-CAUSING VIRUSES, BACTERIA AND FUNGI ARE LIKELY TO CONSTITUTE MAJOR PRODUCTION CONSTRAINTS, YET PATHOLOGISTS HAVE ONLY A LIMITED KNOWLEDGE ABOUT THE NEW CROPS' DISEASE PROFILES."

Professor Alison Stewart notes that agricultural scientists typically react to diseases of broadacre crops only after symptoms have emerged and are causing yield losses. As the Director of New Zealand's Bio-Protection Research Centre, she thinks such a reactive approach is not viable when it comes to the new generation of bioenergy crops.

"In the past, we have reacted to disease after the fact instead of adopting proactive measures as part of the process of developing new crop species," Professor Stewart said.

The difficulty posed by second-generation bioenergy crops is that disease-causing viruses, bacteria and fungi are likely to constitute major production constraints, yet pathologists have only a limited knowledge about the new crops' disease profiles. New Zealand has already seen bioenergy plantations and the associated companies collapse due to broad scale epidemics of pathogens.

With perennial plants accounting for many of the proposed biofuel crops, soil-borne diseases are likely to be especially problematic. However, Professor Stewart thinks viable, long-term disease management strategies are possible and is particularly impressed by the potential of natural microbial agents to protect against soil-borne diseases. She calls this strategy integrated avirulence management (IAM) and it is analogous to using insects and mites to attack pests that cause crop damage.

"With IAM, the idea is to exploit opportunities for biological control to prolong the plant's innate resistance to infectious disease," she said. "It involves not just reducing exposure to disease-causing agents, but also decreasing the selection pressure that can cause those pathogens to overcome the plant's defences."

While farming practices can influence levels of pathogens in a field – through choices in crop rotation, fungicide and fertiliser use, sowing dates and planting density – prolonging the durability of plant resistance requires R&D input. The aim is to manipulate factors that influence how pathogens evolve on one hand, and those that boost plant resistance, on the other.

Professor Stewart can cite a number of examples where such an IAM strategy has proven effective on a commercial scale. For instance, while fungicides are effective against epidemics of rust disease in willow and poplar plantations, they constitute an extra input cost that makes their use uneconomic. The IAM alternative is to exploit the use of 'genotype mixtures', that is, tree cultivars with different genetic ancestry. The approach has been tried in Ireland, where a mixture of three genotypes was found to reduce impacts from rust disease.

Additional IAM disease management options come into play from the use of:

- soil amendments, such as compost and biochar; and
- microbial bio-inoculants applied as pellets or seed coating.

Professor Stewart thinks these systems have enormous potential. Her own research efforts focus on using strains of *Trichoderma* fungus to promote healthier soil biology. The fungus has been tested with a number of crops, from tree plantations to dairy pasture. Test results include a 10% to15% gain in seedling survival and vigour in a pine-tree nursery and the total elimination of fungicide use.

In a project to transfer the technology to acacia plantations in Malaysia, *Trichoderma* strains isolated on site in Malaysia were tested in a nursery and found to deliver benefits worth RM 5 million a year (about A$1.61 million), primarily by eliminating fungicide costs and increasing the number of seedlings that meet commercial specifications by 60%.

Professor Stewart thinks a similar approach will work with bioenergy crops and she has been invited to participate in the development of New Zealand's national biodiesel program, a project run in collaboration with Chevron, Biodiesel NZ, and the Maori Land Corporations. Six non-food oilseed species have been selected for field trials and their agronomic assessment involves testing biocontrol options that can mitigate the need for uneconomic pesticides and fertilisers.

Controlling diseases with a fungal bio-inoculant.

PROFESSOR ARY HOFFMANN
UNIVERSITY OF MELBOURNE

Climate change models help predict future pest challenges

Tools to explore likely future impacts of pests on new and existing crops in southern Australia are under development as scientists anticipate that climate change and the push for biofuels will complicate efforts to sustainably manage pest populations.

At the University of Melbourne, Federation Fellow Professor Ary Hoffmann is making use of 30 years' worth of accumulated data from broadacre crops to better understand the pest challenges facing agriculture in the era of climate change.

He said the historical data shows that the impact of pests can shift quite rapidly.

The reasons for these changes are not well documented but they are likely to include a combination of altered climatic conditions, a shift to no-till farming practices, altered patterns of pesticide application and the evolution of resistance to these chemicals, as well as shifts in the types of crops planted.

"The challenge now is to use lessons from the past to model and predict key pest problems for broadacre crops, especially as new species are needed as biofuel crops," Professor Hoffmann said.

The project encompasses both pests and their predators, since new pest–predator interactions are likely to be encountered as climate change pushes cropping towards new regions and economic factors encourage new crops.

"Models such as MAXENT, CLIMEX and DYMEX are available to predict likely changes in distribution based on climate change scenarios and historical pest–predator distributions," he said. "The accuracy of prediction can be enhanced by including physiological and ecological data."

For example, there are about 20 biological and climatic variables that can be used to model changing distributions of blue oat mite. While Professor Hoffmann noted that there was enormous variability within models using different parameters, all predicted a downward trend in the mite's distribution.

However, when compared to real-world distributions Professor Hoffmann found that the pest's real-world range was generally smaller than predicted. Better results are obtainable by including mechanistic models that rely on information about the pest's biological attributes and interactions.

The result is the 'niche theory' in which a potential distribution is mapped based on the pest's physiological tolerance before this range is then whittled down by considering local environmental conditions, impacts from pest-management regimes, and biological interactions. The result is a measure of the pest's niche in the environment.

Equally important as the pests themselves are changes in distribution of the pests' natural enemies. Professor Hoffmann is keen to understand whether pests and enemies move together or whether pests can escape into a new range and whether they subsequently encounter new enemies.

Once again, modelling based on available ecological and biological data is helping Professor Hoffmann produce the information needed to bring greater resilience to crop-production systems.

When considering pest–predator interactions, Professor Hoffmann has identified a number of important factors that can influence their co-distribution – primarily landscape factors, the impact of genetically modified (GM) crops that express insecticidal toxins, and the nature of chemical insecticides in use on crops.

"GM crops are also likely to provide new options for pest control but not without potential problems," he said. "For example, the Bt insecticidal toxin in GM cotton is effective against some but not all cotton pests, so we could see shifts in pest problems, including previously innocuous species emerging as new pests."

Landscape factors too are proving influential. For example, the distribution of vegetation surrounding a crop can affect the prevalence of predators, generally increasing with more vegetation. Given these kinds of impacts, Professor Hoffmann believes there is a need for whole-area management when it comes to managing pests.

Central to an approach that recruits the broader environment to help manage pests is the need to avoid using broad-spectrum chemicals – pesticides that exterminate predators but cause pests to evolve chemical resistance. It is this scenario that can result in unmanageable pest epidemics.

"We are developing a system where we can consider the entire suite of chemicals used at a site over a year and analyse the impact on enemy populations," Professor Hoffmann said. "Studies using this tool reached the same conclusion irrespective of whether we looked at 20 or 60 sites: the lower the chemical toxicity, the more diverse the community of enemies."

Overall, Professor Hoffmann believes that novel control options will become available once there is an understanding of the interactions between pests and beneficial species within a landscape and a wider choice of 'softer' chemicals that avoid killing the beneficial species.

Professor Ary Hoffmann is a Federation Fellow at the University of Melbourne and works on invertebrate pests in the grain and grape industries. He has a particular interest in mosquito vectors and insects that act as environmental indicators, as well as predicting the likely response of invertebrates to climate change.

"THE HISTORICAL DATA HIGHLIGHTS THAT THE IMPACT OF PESTS CAN SHIFT QUITE RAPIDLY."

Australian-based invited speakers

The conference included a range of Australian-based invited speakers.

NEW GLOBAL BIOECONOMY: OPPORTUNITIES AND CHALLENGES FOR SUSTAINABLE DEVELOPMENT

Dr Mikael Hirsch, Coordinator CSIRO Biotechnology Strategy Group, described how the concept of the bioeconomy is becoming a reality through sustainable production systems focussing on the conversion of biomass to a range of food, health, fibre and industrial products, and energy. Driven by transformational, cross-cutting, global bioscience efforts, the bioeconomy is built on new integration of research disciplines – biotech, nanotech, ICT, synthetic and transformational biology, bioprospecting, NRM, process engineering – as enabling technologies for new value cycles from convergence between existing economic sectors. It is outpacing governments' capacity to respond and puts agricultural research and biosecurity in the 'hot seat'.

AN OVERVIEW OF BIOFUELS IN AUSTRALIA

Dr Mike Dunlop from CSIRO Sustainable Ecosystems explained that while the contribution from first generation biofuels is limited, second generation crops look more prospective, but there remain many uncertainties and assessment is complicated. Biofuels intersect multiple new technologies and value chains, with many experts and not much information. There is a fundamental need for a sustainable supply system, but this has challenges around energy, water, carbon, food, biosecurity, biodiversity, land use change and rural livelihoods. The source of biomass feedstocks, influenced by technology, consumer preference and trade, will remain critical – that is, what should be grown, where, how and in what combination.

MANAGING THE INVASION RISKS NEW CROPS POSE TO AGRICULTURAL AND NATURAL ECOSYSTEMS

Dr Mark Lonsdale, Chief of CSIRO Entomology, discussed how we can learn from historical introductions of tropical forage grasses and legumes into northern Australia and GMO introductions globally to help scope invasion risk in a policy context and provide recommendations for reducing biosecurity risk of biofuels. Deliberate plantings have always assisted invasions and there is a need to apply a science-based precautionary approach to risk analysis to avoid indirect as well as direct negative impacts. These should include careful benefit-cost analysis (BCA) based on international experience to ensure only highly prospective species/varieties are introduced and gradual scale-up production through careful monitoring for early implementation of management measures.

AUSTRALIAN APPROACH TO THE ANALYSIS OF THREATS ASSOCIATED WITH THE INTRODUCTION OF NEW SPECIES

Dr Bill Roberts, Principal Scientist in the Department of Agriculture, Fisheries and Forestry, presented the Australian risk-based policy and regulatory framework for introducing new genotypes and species. The Weed Risk Assessment system is used to assess new plant species. Only species that have an acceptably low level of risk are permitted. The potential benefits are not considered. The conditions for entry of plants and plant products into Australia are accessible on the ICON database at www.daff.gov.au/aqis/import

'DUTY OF CARE' WHEN INTRODUCING NEW CROPS FOR AGRICULTURE

Dr Margaret Byrne of the Department of Environment and Conservation, Western Australia, presented an environmental risk management strategy for new crops. This considers the policy context and comprises post-border weed risk assessment (WRA), genetic risk assessment, experimental site guidelines and species management guides. Genetic risk assessment considers risk from hybridisation, introgression of foreign genes and outbreeding depression, and site guidelines aim to prevent plant escape based on evaluated weed and genetic risk. The aim is to make environmental risk assessment an integral part of plant breeding.

BIO-INSECURITIES: MANAGING DEMAND FOR THE 'NEXT BIG THING' IN EXOTIC PLANT PRODUCTION

Dr Keith Ferdinands of the Northern Territory Department of Natural Resources, Environment, the Arts and Sport, has been integral in the development of post-border WRA incorporating feasibility of control and BCA into the internationally recognised and applied WRA process. WRA is starting to be applied around the world to evaluate proposed biofuel crops and varities. Dr Ferdinands presented case studies of the process for giant reed (*Arundo donax*) and gamba grass (*Andropogon gayanus*) showing how regional differences and fuel load versus fire risk drove the BCA as examples of how WRA can be continually refined and used to direct research and policy.

SUSTAINABLE PEST MANAGEMENT IN THE FUTURE: WHAT WILL IT LOOK LIKE?

Dr Gary Fitt, Deputy Chief of CSIRO Entomology, emphasised that new low-input, non-food crops, for example biofuel crops, are not immune to pests and indeed there is likely to be a lower economic capacity to manage them. Response limited to reactive dependence on broad spectrum pesticides, leads to resistance, secondary pests, disruption of natural predators, altered pest dynamics for existing crops and environmental pollution. For these new crops it is necessary to plan production systems, know pest risks and thresholds, maximise biotic mortality (manipulate crop resistance/tolerance) and actively manage beneficial species to integrate cropping into the wider landscape. This is best started at the proof-of-concept stage of a new crop BCA, but can we afford it?

SUGARCANE INDUSTRIES: HOW PREPARED ARE WE FOR PESTS?

Dr Regis Goebel, a senior scientist with CIRAD based at BSES Ltd, showed that while sugarcane production can allow easy switching from food to non-food markets dependent on price, it harbours many pests. Pest status will change with the increasing use of non-food sugarcane through more widespread planting. Managing pests is a top priority as production is often economic in some regions only because of their pest-free status. High fibre and GM Bt varieties are being developed, but keeping new pests out by knowing the threats and pathways remains the biosecurity strategy in Australia.

REFUGE OR RESERVOIR? POTENTIAL PEST IMPACTS OF A BIOFUEL CROP ON MAIZE

Dr S Raghu and his colleague **Dr JL Spencer** recognised that the area recommended for miscanthus planting in the US included the corn belt. They found the western corn rootworm can select and develop in miscanthus, creating many potential direct and indirect issues for management of this pest across both crops, especially as recommended miscanthus plantings could double the area of potential hosts for this pest. They called for better BCA for biofuel systems that take into account indirect as well as direct pest-crop interactions.

Predatory prey interactions provide a sustainable form of pest control.

Forum summaries

The Biosecurity in the New Bioeconomy conference was attended by a wide selection of delegates from government, science agencies and industry. Within the program were two public forums entitled *Weedy biofuels: should we be worried* and *New crops, new pests*. The conference concluded with two summary workshops on future directions for policy and research and development in biosecurity for the emerging bioenergy and bio-engineering non-food cropping industries.

WEEDY BIOFUELS: SHOULD WE BE WORRIED?

Public forum facilitated by Mr Low

While many proposed new biofuel species have weedy characteristics and widespread plantings will increase such risks, proposing blanket bans is neither pragmatic nor politically palatable. Governments recognise the social benefits of new industries and need for energy self-sufficiency. Although they have the power to regulate the use of invasive species, effective policy relevant for conflict cases, in which the risks and benefits are borne by different sectors, remains elusive. Bioenergy feedstock production on marginal land with biodiversity value is one such future conflict.

The current carbon price and offsets for coal and gas prevent economic biofuel cropping without subsidies. The taxpayer therefore currently provides both the private benefits (profits) and insures the risks (clean up costs) for industry. As biofuels cannot mitigate climate change, there need to be national strategies around biofuel and bioenergy with mandatory and public risk-cost-benefit analyses for the industry. Case-by-case species and context specific proposals should be placed in a broader strategic framework of risk assessment. Nonetheless biofuel crops could generate net benefits when a) the species clearly satisfy risk assessments (RAs), b) they generate lower CO_2 emissions per unit energy than alternatives and c) they offer useful agro-ecosystem services for example, N retention or increase biodiversity. The key is to identify niches where there are win-win solutions for the landscape.

Developing countries tend to follow others when recognising high risk species, but they need context specific RA of proposed new crops. Ecological RAs should go beyond simple hazard identification to be part of a mutual education process. The hazards may be much broader than the weed risks themselves, as impacts are often indirect and unpredictable (high uncertainty) involving ecological cascades and feedback loops. This makes them hard to clearly capture in regulations. Post-border weed risk assessment (WRA) needs to parallel other RAs (genetic RAs, pathway RAs) within the context of a desired endpoint (protecting biodiversity) and/or a specific spatial scale (different land-use types). Other risks include pest drift, new crops as corridors or stepping stones for pests and diseases into current cropping systems (e.g. sugarcane smut in Australia); and the consequence of GM varieties on genetic pollution and biodiversity through changing practices and landscapes.

A move away from investor-driven planting of exotics in developing countries to consider native species for biomass or bioenergy production may provide multiple benefits. Oil mallee trials on ex-cropping and degraded land in Western Australia are generating feedstock to supply energy to the grid, activated charcoal and eucalyptus oil. Other less tangible benefits arise for water balance, aboriginal employment, and increased biodiversity benefits. Similar trials are underway in New Zealand. Benefits are lost if land is cleared for plantings to meet industry economies of scale. Long-term business plans do not yet adequately incorporate risk and there remain major hurdles around market access efficient harvesting systems. Another risk is that growers will want improved hybrids that could generate new genetic risks unless mitigated through planting away from relatives. The use of native flora in the developing world may also provide sufficient benefits, even if there remain residual risks. There are many specific needs in the petroleum substitutes markets and higher revenues can be achieved if substitutes for high value components can be sustainably integrated into course biofuel production systems.

NEW CROPS, NEW PESTS

Public forum facilitated by Professor Stewart

Most new agricultural cropping systems fail to pro-actively plan for losses to pests and diseases. Many new crops (e.g. poplars for bioenergy feedstocks in New Zealand or Australian cedar plantations) or new crop rotations (soybean – sugarcane) have failed as a result, undermining whole industry viability. Government subsidies and research support is too focused on the production side and farmers rather than business managers should be making the early decisions.

GM crops forced governments and industry to consider ethics and community participation, helped by simple messages and scenario mapping. Given the unprecedented scale of the expected changes that are coming, policy makers that subsidise biofuel cropping and regulate new industrial crops can use this past experience (e.g. with Bt cotton) to include similar sustainability and IPM imperatives.

In Brazil a switch of sugar cane to biofuel production was simple because the IPM strategies were in place, although sustainability issues remain around further land clearing. Scientists and the contractors who grow the new crops are likely to have the background expertise, but to develop IPM systems *de novo* requires high investment for fledgling industries and strong levels of science and industry cooperation.

New crop profit levels dictate the capacity for IPM, so, while biofuel crops are supported by government subsides and buy-back guarantees there will be little capacity for pre-planting proactive pest management research and maintaining healthy sustainable landscapes. This highlights the folly of linking biofuel production to 'marginal land'. Here production too will be marginal and impacts on biodiversity more significant. The business case for algal biofuel is more impressive. Scenario mapped yields, outcomes and endpoint products directly attracted BP and Shell. Higher value crops for expressing key industrial compounds and polymers are coming and these too would have the margin required for sensible proactive IPM. However, a viable and sustainable bioenergy feedstocks strategy built on low value new biofuel crops seems both delusionary and a likely source of long-term environmental harm.

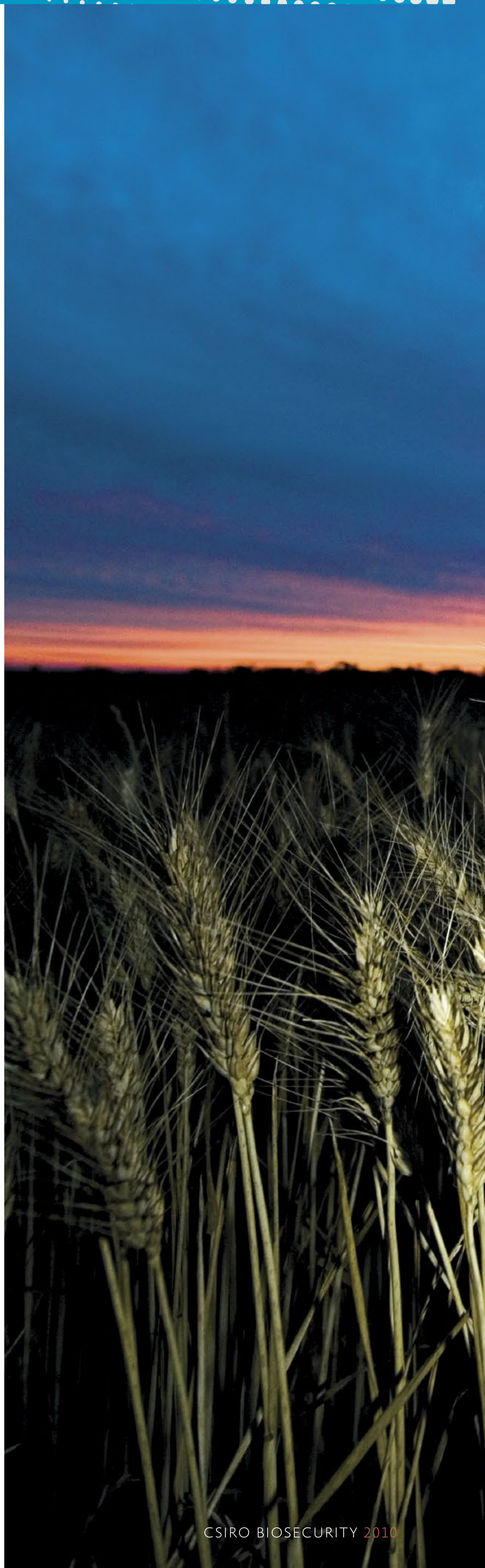
A general consensus is a need for a global future vision and plan for agriculture to support the expected 'green revolution' increasing the role of agriculture in the GDP of developed and developing countries through higher value production systems, while providing social development and protection of ecosystem service and function. Shifting agriculture to developing countries should not be because of weaker sustainability criteria. Scenario planning around future carbon sources, of which agriculture is only a part, can be assisted by multi-disciplinary research agencies.

POLICY SUMMARY WORKSHOP

Strategic national policies are needed to plan and oversee the implementation of bioenergy and bio-industry cropping systems. This should capture the context for a comprehensive risk analysis (user pays) for quarantine requirements for importation, initial field trials (as for GM) and pre- and post-border management guidelines (e.g. as South Australia has done for *Arundo donax*). Benefits also need to be considered. Proposals should be considered based on a business case that captures long-term economic viability (beyond government subsides) and the potential scale of production based on realistic assessments of the amount of available land. The potential impacts could be addressed by an Environmental Impact Statement (EIS) that has on-the-ground consideration of 1) direct risks of biological invasions in the proposed regions and the scale of production even if the species is already present in the country (e.g. large plantings of *Pomgania* into northern Australia), 2) food security, i.e. direct competition with food cropping, 3) likelihood of pest impacts (statements that new crops would be pest-free, e.g. Jatropha, have proved a fallacy), 4) likely indirect economic impacts from new crops acting as a pathway and source of pests for existing agriculture based on the proposed scale of production, 5) likely social impacts; e.g. toxins, allergens and GM on local communities and contamination of food supply chains, 6) scaled environmental impacts, pollution, fire frequency/intensity, water resources, desertification, land degradation, other ecosystem services, and 7) consequences under climate change.

International policy standards, best management practices and agreement mechanisms are needed for assisting developing economies and under-developed countries with defining high value bioenergy and bio-industries when approached by investors for plantations and for imports and exports. A first step would be standards for national policy development, regulatory processes, infrastructure and capacity building for sustainable land use for non-food crop production prior to government/industry initiating bioenergy/industry production systems. EIS and WRA could be adapted for such countries for rapid risk screening/ranking of proposed new species importation and planting including the inclusion of scaling issues and indirect effects (as above). Standards should also incorporate existing standards on effective and flexible quarantine systems, given poor capacity for prevention, and on use of GM technologies likely to be more widely applied to add value to non-food cropping. These would add to the existing International Plant Protection Convention standards linked to the Convention on Biological Diversity and run through regional plant protection organisations.

International and national-based certification schemes for sustainability of bioenergy imports/exports (similar to wood product certification) could follow from effective EIS mechanisms based on carbon footprint and regional environmental impact profiles.→



R&D SUMMARY WORKSHOP

The role of science in supporting the new Bioeconomy depends on how different future agro-forestry production systems will be. Will non-food and food cropping systems be integrated e.g. the same crops – sugarcane, maize etc? Will non-food agro-forestry become more perennial and move to more marginal land (become less intensive) and generate novel ecosystems, increase landscape fragmentation, adopt new native versus exotic species or GM approaches? Will NRM imperatives be carbon or water driven? There is a need for national/regional science-based strategic planning that takes into account the broader biosecurity concerns (risks of invasions, ensured sustainability and conservation values). Regional political imperatives around resource availability, GM and triple-bottom-line and land values will provide the context as must the product-driven business cases. The likely speed of change will also drive scientific imperatives. Science can already assist national and regional governments in their clarity of purpose and what to grow where for regional biofuel land use planning and industry in developing the safety side of ecologically sustainable business cases for particular non-food product development. Specifically, science input can come through economic and environmental decision-tools such as risk/scenario/surprise analysis, landscape and production system models, Bayesian nets and industry standards like BOSCARD[1].

R&D can assist economic, environmental and social perspectives of biosecurity in future agro-forestry production systems. Science is already increasing economic efficiency by identifying whole of production system synergies. French bio-refineries minimise waste through maximising linkage across the profit spectrum of products through explicit interdependence. Science can inform government investment (subsidies, buy-back schemes) to ensure new industries address biosecurity and maintain long-term sustainability. Ecological as well as economic viability/sustainability analysis of potentially moving production systems onto marginal lands can predict capacity to conserve biodiversity values and ecosystem function and undertake natural resource management (biological invasions, water and soil conservation). Landscape scale integrated management systems can assist with pests, weeds and diseases pre- and post-harvest across food and non-food cropping systems. Science can also inform human health risks and lead change management around the social imperatives of changing production systems, extension/ education for novel crops and associated IPM.

1 Background, Objectives, Scope, Constraints, Assumptions, Reporting, Deliverables

LANDSCAPE SCALE INTEGRATED MANAGEMENT SYSTEMS CAN ASSIST WITH PESTS, WEEDS AND DISEASES PRE- AND POST-HARVEST ACROSS FOOD AND NON-FOOD CROPPING SYSTEMS

Conference statement

DEVELOPING COUNTRIES WOULD BENEFIT FROM INTERNATIONAL ASSISTANCE WITH DECISION MAKING AROUND IMPLEMENTATION OF THESE NEW INDUSTRIES.

Target audience: OECD, IPPC, CBD and international and national plant protection organisations.

- Sustainable bioenergy feedstocks strategies are unlikely to result from low value, exotic, potentially fast-growing biofuel crops on unproductive land, because the resulting poor yields prevent the returns necessary for investment in sustainable IPM systems and insurance against environmental clean up when crops escape field boundaries.

- Bioenergy production systems based on marginal land should focus on native species to achieve sustainability, present fewer environmental risks, and may indeed offer multiple benefits including a greater capacity to support indigenous communities.

- To be economically viable, new crop-based bioenergy and bio-products feedstock systems appear to need productive land in potentially direct competition with food-cropping.

- The best scientific evidence to date indicates that great benefit would be derived from:
  - supporting the necessary environmental impact statements or risk analyses;
  - evaluating the business cases beyond subsidies and in relation to scale and availability of suitable land;
  - defining quarantine requirements for importation, initial field trials and pre- and post-border management guidelines;
  - structuring of the cost-sharing of risk management; and
  - managing potential conflicts between the agricultural, environmental and human health and other affected stakeholders.

- Existing government regulatory approaches of risk assessment for other new agricultural technologies provide a basis for assessing the likely risks from agro-forestry-based bioenergy and bioindustry production systems including:
  - direct risks of biological invasions in the proposed regions and the scale of production;
  - likelihood of pest impacts including creation of stepping stones that support invasion of exotic pests and diseases;
  - likely indirect economic impacts from new crops acting as a pathway and source of pests for existing agriculture;
  - social impacts, for example toxins, allergens on local communities and contamination of food supply chains;
  - scaled environmental impacts, pollution, fire frequency/intensity, water resources, desertification, land degradation, and other ecosystem services; and
  - consequences under climate change.

- Exotic bioenergy crops on agricultural land could generate net benefits when ecological risk assessments, supply-chain carbon dioxide emissions per unit energy, production impacts and resulting agro-ecosystem services align to create win-win solutions.

- A global future vision and plan for agriculture would be an effective approach to support the expected 'green revolution' increasing the role of agriculture in the GDP of developed and developing countries through higher-value production systems, while providing for social development and protection of ecosystem service and function.

- Developing countries would benefit from international assistance with decision making around implementation of these new industries.

- International standard-setting organisations such as the International Plant Protection Convention should be encouraged to develop standards and guidance on risk analysis for managing the opportunities that non-food agro-forestry presents.

- Developing countries need assistance in capacity building at a national level, best management practices, environmental impact, weed risk assessment, and risk analysis.

- An environmental certification scheme would assist such industries in national and international trade similar to that being developed for the wood products sector.

- Science can assist and inform:
  - national and regional governments in their clarity of purpose, investments (subsidies, buy-back schemes), human health risks and what to grow where, to ensure new bioindustries address biosecurity and maintain regional long-term land use sustainability;
  - industry in developing the safety side of ecologically sustainable business cases; and

  - government and industry in landscape-scale integrated management systems for pests, weeds and diseases, pre- and post-harvest across food and non-food cropping systems and associated extension/education needed for IPM in novel cropping systems.

- Outreach requirements
  - Locally appropriate outreach efforts and community empowerment materials are needed to convey the benefits, risks and costs of developing a new bioeconomy. These will benefit greatly from the inclusion of environmental and social consequences to enhance the informed decision making process.
  - Appointing regional facilitators would be one valuable way to integrate current science and develop relevant and balanced training materials for the public. Concise fact sheets can present what is known, what needs further study and opportunities to pursue sustainability and address long-term costs as well as the short-term gains of shifting production to a bioeconomy.

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