A growing interest

Drs Manyowa Meki of Texas A&M AgriLife Research and **James Kiniry** of USD-ARS share exciting details of their work on the ALMANAC project, an endeavour that aims to expand the application of crop models in sustainable biofuel research and offer researchers a much more efficient and cost-effective tool

With more than 20 years' experience in field crops research and cropping systems modelling, what drew you to this field initially and how has your interest evolved?

MM: Having grown up in Zimbabwe, Africa, I have always looked at field crops research as a key driver for increasing crop production, alleviating poverty and hunger, as well as improving livelihoods – especially in rural Africa. However, there has been a decline in investment into agricultural research in most African countries over the past few years. Responding to this challenge, I became interested in the application of process-based crop simulation models, among which is the Agricultural Land Management and Numerical Assessment Criteria (ALMANAC) model with which I am currently working. When combined with the appropriate climatic, crops, soils and management databases, these models can be effectively applied to evaluate 'what if' field crop research scenarios in a timely and cost-effective manner.

Dr Kiniry, as the developer of ALMANAC, can you give a brief introduction to the model and the key databases needed to run it?

JK: The model uses a daily time-step to simulate various biophysical processes including crop growth and competition of plant communities; weather; hydrology; erosion; soil organic carbon; nutrient cycling; pesticide fate; and management practices. Four key databases are needed to run the model: crop management, weather data, soils data, and finally, the model has an inbuilt crops parameter database developed from extensive field studies, the literature and expert judgment. For all databases, default parameter values are given and can be modified within set limits to describe new management, soils, crops and weather scenarios.

How will you apply ALMANAC to assess feedstock production of the proposed candidate biofuel crops and potentially adverse environmental impacts at various spatial and temporal scales?

MM: Prior to applying ALMANAC, there is a need to compile data for parameterising and testing the model. The proposed candidate biofuel feedstock crops – energy cane, energy sorghum, banagrass and sugar cane (control) – have distinct growth habits, but growth parameters that are still, as yet, poorly understood. We have already made good progress in gathering these parameters from ongoing studies at Temple, Texas and the Hawaiian Commercial & Sugar (HC&S) company plantation in Maui, Hawaii. I will use the gathered parameters to calibrate and validate the model, and then apply the validated model along with historical weather, soil and management practices databases customised for this project to assess feedstock production and environmental impacts across various HC&S plantation landscapes.

Is it possible to define the production systems boundaries of feedstock supplies

with respect to spatial and temporal feedstock yield variability?

MM: Regional and site-specific differences in agroclimate, soil type, topography and management practices can result in significant variations in feedstock yields and quality. Crop simulation models like ALMANAC, with their ability to handle complex production-environment interactions, will allow us to realistically estimate spatial and temporal feedstock yield variability, and when coupled with the application of environmental sustainability indicators or criteria, will enable us to better define those landscapes or regions most suitable for feedstock production.

What importance do you accord to the advancement of the biofuel industry? What would you identify as the main factors driving this promotion?

JK: This promotion of the biofuel industry is being fuelled by several factors, including the opportunity to reduce dependence on fossil fuels through renewable energy; the search for energy independence or security; the potential to reduce net greenhouse gas emissions and hence provide mitigation options to combat climate change; and the possibility to improve farmers' incomes and rural economies.

Who will be the key beneficiaries of this research?

MM: Overall, ALMANAC model simulation outcomes will aid biofuel stakeholders – including researchers, biofuel companies, biomass farms, policy makers, investors, land managers, environmentalists and the general public – to develop sustainable biofuel feedstock production practices, and make appropriate land use planning and management decisions regarding this evolving sector of the economy. Furthermore, gathered crop parameters will also be compatible for use with other simulation models.

A **dynamic** tool

A state and federal research team from Texas is assisting the US Government in its ambitious biofuel production plans by applying a process-based crop simulation model – **ALMANAC** – along with historical weather, soils, crops and management practices databases to obtain realistic estimates of available biofuel feedstocks, as well as the associated environmental impacts

WHEN IS A sustainable fuel source unsustainable? It could be the set-up to a joke, if the topic were not so serious. As part of the revised National Renewable Fuel Standard programme, the US Government has mandated 30 billion gallons of renewable fuel by 2020 – an aggressive demand that will put immense pressure on the agricultural communities set to supply feedstock for the emerging biofuels industry. In principle, such a decisive increase in sustainable fuel is a positive development: it will mitigate the effects of climate change by lowering greenhouse gas emissions, and at the same time reduce US dependence on unsustainable fossil fuel supplies.

The problem, however, is that those sustainable fuels, produced at such a high volume, could become sustainable only in name. Fossil fuels are inescapably a finite resource – when we have consumed a certain quantity, there will be none left – but producing feedstock for biofuels is a process that also depends on finite resources. Land space and water, from the growers' point of view, are limited, and the kind of intensive farming that the new mandate will demand could have devastating effects on water quality and the fertility of agricultural land. In other words, it could make the farming of sustainable fuels unsustainable in the long term.

THE ALMANAC APPROACH

In light of these difficulties, with funding from the US Office of Naval Research (ONR), a joint USDA-ARS/Texas A&M AgriLife research project – Agricultural Land Management and Numerical Assessment Criteria (ALMANAC) – led by Drs Manyowa Meki of Texas A&M AgriLife Research and James Kiniry of the USDA-Agricultural Research Service, was initiated for a resource assessment to supply feedstock to produce advanced biofuels in Hawaii (Phase 1), and the southern US (Phase 2). The project is currently utilising the HC&S sugar cane lands in Maui, Hawaii, as the site for the pilot project. The aim is to extend to all of the Hawaiian Islands, as well as other areas of the Pacific Basin.

Regional and site-specific differences in climate, soil type, topography and management practices can result in significant variations in feedstock yields and quality. Although valuable and necessary, field studies are also quite costly. Computer simulation models like ALMANAC can complement and extend the applicability of information collected in field trials, serving as effective tools to determine the feasibility of biofuel production and environmental sustainability.

SOUTHERN COMFORT

The temperate and subtropical regions of the southern US offer a perfect climate for maximising the growth of biofuel feedstock crops, and the area as a whole is home to one of the largest renewable water supplies in the US. It undoubtedly has the capacity to house such farms and, moreover, considering its high net primary productivity, it would appear to be the ideal candidate to meet the Government's ambitious target for the region to produce 50 per cent of the nation's feedstocks – if only more time and money were available. These resources

Drs James Kiniry, (USDA-Agricultural Research Service) – (left), and Chifumi Nagai, Hawaii Agricultural Research Center – (right), standing next to one of the project's candidate high biomass energy crops: banagrass, being tested on the island of Oahu, Hawaii.

would allow for complete field research to be accomplished in the area, and subsequently the optimisation of crop yield with minimum environmental impacts. But there is little time or budget for such an arduous exercise. The region has a north-south temperature gradient and an east-west precipitation gradient, which means that growing conditions could vary greatly over a relatively small distance.

However, one research team, thinks that it may have the answer. Set to begin in the year 2014, the ALMANAC project will adapt and apply the technologies generated in Phase 1 to the southern US. Modelling biofuel cropping systems, if it could be done accurately, would save huge amounts of time and money invested in field research – and give an alternative route to designing sustainable biofuel feedstock production systems that also protect and enhance the environment.

CONSULT THE ALMANAC

The project is currently concerned with collecting data to calibrate and validate its crop modelling system. Based on pre-existing research in many fields, and accounting for a wide variety of agroclimatic environments, the crop simulation model created by Kiniry will not only allow for the optimisation of crop yield, but also for assessments of negative environmental impacts. It will be responsive to soil, weather and crop management data, and will ultimately allow for accurate, cost-effective and long-term crop planning. The team hopes that the models and practices developed as part of this endeavour will be applicable to many other regions of the world.

A BROAD COLLABORATION

Texas A&M AgriLife Research is a state institution, but it is collaborating with partners at both the federal and private sector level to bring real solutions to biofuel production. The ALMANAC project is supported by both USDA-ARS and HC&S sugarcane plantation in Maui, Hawaii – a privately owned company that owns the land that is being used as pilot sites. Meki is confident that this level of collaboration will achieve definite results: "For me, this is an excellent example of a smart research collaboration partnership involving the federal government, a state institution and a private sector company". Besides providing the US Navy in Hawaii with a ready source of biofuel, the whole project could also bring a number of benefits to Hawaii, allowing it to sustainably diversify its economy and achieve energy security in the near future.

FIELD OF DREAMS

As well as giving the US Government greater certainty in terms of its biofuel plan, and allowing growers to maximise the efficiency of their methods, there are further benefits associated with accurate modeling of biofuel crops. Some investors say that a big obstacle to putting money into this new industry is the lack of certainty that the land can sustainably support such crops. If these investors were to be made more confident, then the young industry could be looking at a large financial boon that would ultimately help them to overcome the other problems associated with reducing US dependency on fossil fuels.

The greatest benefits of this project will be felt by biofuel feedstock growers. Project outcomes will enable these agricultural communities to forge a new form of income, while avoiding the all-too-pressing risk of damaging their ecosystem services or committing to higher production levels than they can sustain. Kiniry is hopeful that success in the Hawaiian pilot sites will open doors for all Pacific Basin islands and the southern US to achieve strong biofuel production economies.

THE ETHICS OF BIOFUEL

Ultimately, the biofuels industry faces many challenges: competing with traditional food and fibre crops for space and water; overcoming the pervasive use of unsustainable alternatives; and finding a sustainable way of producing the high volume of feedstock it requires. But as Meki points out, ethics will also play a crucial role in this new industry: "There will definitely be a need for guidelines and ethics that will enable stakeholders to make informed choices". The ALMANAC project, if successful, will be the first step in establishing those guidelines.

Student interns, Anita Martinez and Joseph Moreno from New Mexico State University, taking light interception measurements on high biomass energy sorghum at the USDA-ARS field station, Temple, Texas.

INTELLIGENCE

RESOURCE ASSESSMENT FRAMEWORK FOR DEPENDABLE FEEDSTOCK SUPPLY TO PRODUCE ADVANCED BIOFUELS IN HAWAII

OBJECTIVES

To apply the ALMANAC model to determine the feasibility of biofuel production and environmental sustainability in Hawaii, as the perceived lack of dependable feedstock supplies is one of the key factors currently holding back the bioenergy industry.

PARTNERS/KEY COLLABORATORS

Mae H Nakahata, Hawaiian Commercial & Sugar Company, USA • **Jeff Arnold**, USDA Agricultural Research Service, USA • **Tim Strickland**, USDA Agricultural Research Service, USA • **Susan Crow** and **Richard Ogoshi**, University of Hawaii at Manoa, USA

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DR MANYOWA NORMAN MEKI has over 20 years' experience in field crops research and cropping systems modelling. Current research emphasis is on developing model parameterisation datasets for novel high biomass energy crops and conducting model simulations to assess bioenergy feedstock yields, their temporal and spatial variability, and associated impacts on ecosystem services.

DR JAMES KINIRY is a Research Agronomist with over 33 years' experience in basic and applied research related to simulation modelling. He is responsible for having developed the ALMANAC plant model which has been applied extensively to simulate plant growth and development. Kiniry quantified the key crop model input parameters for maize, sorghum, rice, wheat, potato, etc., and several warm-season grasses.

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