Examples of Positive Bioenergy and Water Relationships

GBEP Global Bioenergy Partnership

IEA Bioenergy

February 2016

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Foreword

Bioenergy is, and will continue to be, a substantial part of the global renewable energy supply in a low carbon economy. Sustainable production and use of bioenergy offers tremendous opportunities for creating positive socio-economic and environmental impacts. The water-energy nexus has been identified as one of those opportunities. Presenting innovative examples is a means of showcasing how bioenergy systems – in both the feedstock production and conversion phases – can generate positive impacts on water and energy. To realise such a showcase, the Global Bioenergy Partnership (GBEP) and the International Energy Agency (IEA) Bioenergy Technology Cooperation Program have joined forces to collect information, analyse it and present the results.

We are glad to see the results of the joint work available in this publication, and we are grateful to all the contributors and authors who have put great efforts into this work.

The examples presented in this publication illustrate an encouraging variety both in terms of bioenergy systems and geographical distribution, and they all show how solutions can be found that produce bioenergy while contributing positively to the state of water. These experiences are also meant to serve as sources of inspiration that other bioenergy producers can use to enhance the sustainability of their own activities.

However, there are significant barriers to scaling up and replicating these good examples, not the least of which are the limited awareness and capacity of relevant actors. Through this publication, and generally through our work, GBEP and IEA Bioenergy hope to contribute to the removal of such barriers and to the creation of an enabling environment for sustainable bioenergy production and the improvement of the management of water resources.

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Acknowledgements

This document is the outcome of a collaborative process between many experts, organizations and initiatives to which GBEP and IEA Bioenergy would like to express their gratitude. First and foremost, we would like to thank all of the experts for their valuable contributions. We would also like to acknowledge the Royal Swedish Academy of Agriculture and Forestry and the Chalmers Energy Area of Advance for their collaboration in the organization of the August workshop in Stockholm, Sweden.

On the GBEP Secretariat side, this work was led by Andrea Rossi and Emily Olsson, with support from Marco Colangeli, Giovanna Pesci and Valentina Subacchi, under the overall coordination of Maria Michela Morese. On the IEA Bioenergy side, the work was managed by Göran Berndes and Uwe Fritsche, with support from Kevin Fingerman (IINAS) and Jessica Chalmers (Winrock International).

We would also like to express our gratitude to IEA, and in particular to Paolo Frankl (Head, Renewable Energy Division), for their availability to chair, through IEA Bioenergy, AG6 during 2015. Finally, we would like to thank Miguel Almada (Argentina) and Bah Saho (ECREEE) who, as co-leaders of the GBEP Working Group on Capacity Building, helped guide the entire process.

1. Introduction

GBEP is an international initiative bringing together public, private and civil society stakeholders in a joint commitment to promote bioenergy for sustainable development. The IEA Bioenergy Technology Cooperation Program, functioning within an IEA framework, is a world-wide network of experts in bioenergy from research, governmental agencies and industry with the aim to accelerate the deployment of sustainable bioenergy. With the support of IEA as a GBEP partner, IEA Bioenergy Task 43, assisted by Task 40, co-chairs the GBEP Activity Group 6 (AG6) on "Bioenergy and Water", established under the GBEP Working Group on Capacity Building for Sustainable Bioenergy. The AG6 aims to identify and disseminate ways of integrating bioenergy systems into agricultural and forested landscapes as a means of improving sustainable management of water resources, including wastewater. Part of this work involves sharing knowledge and experiences on landscape management and design, best management practices as well as policies and instruments supporting bioenergy implementation that contribute positively to both the quality and availability of water.

Within this framework, GBEP AG6 concluded that a compilation of innovative examples would be a means of showcasing how bioenergy systems – in both the feedstock production and conversion phases – can generate positive impacts on water. These experiences are also meant to serve as sources of inspiration that other bioenergy producers can use to enhance the sustainability of their own activities. This initiative was launched with the 'Call for Evidence of Positive Bioenergy and Water Relationships' in April 2015 (See Appendix 1). The submissions received in response were reviewed by AG6 leadership and a representative selection (twelve responses) was presented and discussed at a workshop in Stockholm, Sweden on 25 and 26 August 2015. The workshop was jointly organized by GBEP and IEA Bioenergy, in collaboration with the Royal Swedish Academy of Agriculture and Forestry and Chalmers Energy Area of Advance. The agenda for this workshop and the list of participants can be found in Appendices 2 and 3, respectively. The examples showcased at the workshop plus eight more have been compiled into this document.

Together, they cover a wide range of geographic locations, feedstocks, bioenergy pathways and practices. As seen in Figure 1, there are examples from 11 countries across six continents, i.e. Argentina, Australia, Brazil, China, Egypt, Germany, Italy, Mexico, Paraguay, South Africa and the United States of America.

The featured examples are presented in a similar format to ease comparison and are divided into the following sub-groups:

- Integrated Planning, Best Management Practices, Bioremediation and Control of Invasive Species
- 'Waste' to Energy and Water-Smart Processes; and
- Agroforestry, Intercropping and Rotational Cropping.

There is information on the geographical area where the study/project was carried out. Each one also includes qualitative and/or quantitative data on the positive impacts on water quality and availability, biomass/bioenergy production as well as any possible co-benefits that were observed. Key enabling factors and main challenges encountered throughout the course of the study/project are then discussed. Lastly, there is a section on the potential to scale-up and replicate the example in other parts of the world.

Figure 1: Map of Examples of Positive Bioenergy and Water Relationships

The following section gives a summary of the main lessons learnt and recommendations emerging from the 20 examples included in this publication.

1.1 Key messages: Lessons learnt and recommendations for dissemination, scaling-up and capacity building

Presenters showed an encouraging variety of examples in terms of geographical distribution, bioenergy system design (feedstock supply and conversion technology) and water-related challenges addressed. They highlighted the multiple environmental, social and economic benefits of good practices in bioenergy production and management of water resources. Selected examples also provided insights into governance aspects.

It emerged during the workshop that there is a wealth of knowledge on issues surrounding the relationship between bioenergy and water. However, the science behind it still needs to be improved and significant barriers to mainstreaming good practices exist. In particular, there is a need for improved data availability and quality as well as more in-depth knowledge concerning the implementation of effective enabling instruments/policies. Awareness raising and capacity building are important to all relevant stakeholders, especially in developing countries where many practitioners in the landscape (e.g. farmers, foresters, waste managers, etc.) lack access to data or consider it irrelevant for their practices. Policymakers may also be unaware of the opportunities or deem other options to be more relevant or less complicated.

To address the above challenges and promote the replication and scaling-up of solutions that provide bioenergy while contributing positively to the state of water, a number of considerations for dissemination and capacity building were identified and elaborated during the workshop. They were the following:

- Provide an easily accessible repository of data on good practices by trusted actors. GBEP may be able to play a role here.
- Support capacity building, especially targeting farmers and NGOs in the field. In that, the social and economic dimensions must be addressed, and the broad diversity of farmers needs consideration.
- “Water” is an important and often political issue in many countries and dialogues on sustainable water management should be sought to facilitate information dissemination and advice from IEA Bioenergy, GBEP and collaborating parties, concerning implementation of bioenergy as a means to address water related challenges.
- The implementation of the Sustainable Development Goals (SDGs), in which nexus-type approaches gain importance, presents opportunities for dialogue and dissemination as well as support of concrete actions, e.g., policy development, extension services and projects.
- It should be recognized that water can be the main concern so that the value of bioenergy systems is primarily determined by their function in strategies to address water challenges.
- Policy development is commonly based on a “top-down” perspective and information dissemination concerning "bottom-up" best management practices may therefore require that key issues be “translated” into a language that makes them "manageable” for policymakers. The potential of economic instruments in fostering sustainable bioenergy-water systems needs to be highlighted in this context.
- Finally, it was noted that alignment with and integration into ongoing processes is important and several avenues to support scale-up and capacity building should be sought through collaboration with important organizations working with water and/or bioenergy.

2. Integrated Planning, Best Management Practices, Bioremediation and Control of Invasive Species

2.1 A model for bioenergy and water nexus in Egypt
Ahmed Abdelati & Abdelmenem Hegazi

2.2 Producing electricity from biomass from terrestrial invasive alien plants in South Africa
Helen Watson

2.3 AquaMak: Economic and ecological perspectives on using aquatic macrophytes for energy production in Germany
Andreas Zehnsdorf, Carsten Herbes, Walter Stinner, Markus Röhl, Lucie Moeller, Vasco Brummer, Harald Wedwitschka & Sandra Roth

2.4 Zonification for yield gap analysis and efficient use of water resources in sugarcane areas in Oaxaca, Mexico
Alma Delia Baez-Gonzalez & Ernesto Bravo-Mosqueda

2.5 Best Management Practices for maintaining water quality in riparian zones in water supply catchments during tree harvesting in Burnie, Australia
Daniel Neary & Philip Smethurst

2.1 A model for bioenergy and water nexus in Egypt

Key lessons learnt

In order to achieve a notable success, the following factors should be considered:

- presence of strategic will;
- strong and integrated presence of the national working bodies, such as EEAA, MSEA, MALR and Qena Governorate;
- NGO and local community interest;
- appreciated return values for using the bioremediation drainage water as a source of fertigation;
- economic returns of the produced wood;
- availability of markets for the produced wood; and
- need for mobilization and implementing the environmental law.

Introduction

Geographic location: Egypt – Upper Egypt – Deshna City – Qena Governorate – Naga Hamady MDF Co.

Type of example: The example is tackling three points: policy, practice/approach and specific project/activity.

Status: The example is currently being implemented. It started in 2010 and is still going on, as it offers perfect impacts on environmental aspects.

Bioenergy and water relationships

Positive impacts on water quality:
Nile water conservation is one of the Egyptian national priorities nowadays – not only because it is the main source of fresh water that Egypt has but also because it is finite for many political, social and environmental reasons. The country may be introduced to drought. As the Nile water is managed in Egypt as a closed basin, the pollutants are concentrating rapidly; therefore, special care should be taken in order to stop this decay, which negatively affects the environment.

Sugar factories, and consequently MDF and paper industries, are located intensively in Upper Egypt where sugar cane is the main cash crop. Unfortunately, these industries are consuming an enormous quantity of Nile water either during the industrial process or the translocation of bagasse (with 10 percent concentration) from sugar factories to the MDF or paper factories after sugar extraction. Yet, the most dramatic part of the story happens when this highly polluted industrial drainage is released into the Nile basin from the remaining separated drainage, which is an outcome of the poorly planned industrial revolution of the 1950s.

Sesbania aegyptiaca is being used in the bioremediation of the industrial drainage water. Not only does it provide an input for the MDF industry, including a biomass source for the ovens that existed during the industrial process, but it also provides a safe discharge (biodrainage) for the industrial drainage water away from the Nile basin, saving the fresh water and conserving the fresh water quality.

Table 1: Irrigation water quality

Water quality indicators	Irrigation water quality		
	Untreated Industrial Drainage water	EM-Bioremediation Industrial Drainage water	Nile water
BOD (mg/l)	105 a	3.7 b	2.17 c
COD (mg/l)	208 a	12 b	5.7 c
pH. (units)	9.4 a	7.3 b	7.0 c

Source: Abdelati A. A. (2013) Egy. J. Agron. (35), No. 2.

Positive impacts on water availability:

Before the industrial drainage water bioremediation project was established, the highly polluted industrial drainage waters were flushed into a secondary channel established as a drainage sink. The end of this channel is connected to the river Nile.

Due to the high values of BOD, COD, pH and TSS in the drainage water, the Nile water quality indicators were degraded, starting from the channel sink into the Nile in front of the factory and along many kilometres. This negatively affected the Nile marine life and fishermen's business in that area. Moreover, there was a strong odour that degraded air quality.

After establishing the bioremediation station, many values were added to the drainage water. The first value that was added was economic. After the bioremediation process, the second was environmental for the high content of nutrients and beneficial microorganism counts that made this drainage water an eco-friendly fertilization source reduced the dependence on the chemical fertilizers that negatively affected water quality, both in the Nile basin and groundwater. Lastly, it helped in conserving the fresh water to be used for drinking and the other domestic use instead of using it for irrigation.

Positive impacts on biomass/bioenergy production*:*

- Almost 95 percent of the electrical power consumed in the industrial process in both factories (sugar factory and MDF factory) came mainly from sugar-cane bagasse.
- The quantity of sugar-cane bagasse does not meet the annual needs for MDF manufacturing and power generation.
- It is only sufficient for eight months of the year, and the factory was forced to stop working because it was running out of bagasse.
- Using *Sesbania aegyptiaca* second branches and leaves reduced the dependence on sugar-cane bagasse, and the factory is working for the whole year.

Co-benefits:

- It helps avoid Nile water pollution.
- It helps combat desertification, using grown shrubs for sand dune fixation that existed in the backyard of the factory.
- It helps in creating new permanent jobs, both in the agriculture and industrial sector (some workers lost their jobs during the annual stop period).
- It reduced poverty by securing constant income for families of the workers.

Prospects

The main drivers for implementing this project were:

- The need for freshwater conservation;
- The strong odour waves coming from the drainage channel;
- The negative environmental consequences for the freshwater quality indicators of the Nile basin in the area of the factory;
- Providing an alternative raw material for MDF manufacturer when sugar-cane bagasse is not available, and a biomass source for the existing ovens;
- Conserving clean agriculture, with low-cost agricultural inputs as a fertigation source.
- Introduce new jobs opportunities to the community; and
- The strategic design for adaptation with environmental improvement needs.

Key enabling factors were:

- The presence of strategic will;
- The strong and integrated presence of the national policy bodies, such as the Egyptian Environmental Affairs Agency, Ministry of State for Environmental Affairs, Ministry of Agriculture and Land Reclamation and Qena Governorate;
- NGO and local community interest;
- Appreciated return values for using the bioremediation drainage water as a source of fertigation;
- Economic returns of the produced wood;
- Availability of markets for the produced wood; and
- The real desire for mobilization and implementation of the environmental law.

Main challenges encountered were:

- The need of rising public awareness through the local media who wasn't interested in this work;
- The small allocated fund for this activity;
- The illiteracy rate that negatively affected public enthusiasm;
- The absence of the political support from the people's assembly of representatives in the region;
- The real gap in trust between the governmental bodies and the local community; and
- The conflict with the fertilization business sector.

Potential for scaling-up and replicability:

This example is ready to be scaled-up or replicated in any industrial sector in Egypt, any country in Africa or any part of the world suffering from water scarcity and drought.

With some modification in the growing crop, we can choose between either a raw material crop, biomass crop or biofuel crop. The most important key to success that should be taken into consideration is the clear political will that helps promote the implementation of these kinds of projects. It is also important to take into account that without the local media's contribution and key person's involvement, local stakeholders would not have the needed level of enthusiasm that helped with the project's implementation.

References and additional information

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Affiliation / Organisation: GBEP Egypt focal point – Desert Research Center – Ministry of Agriculture and Land Reclamation

Additional Information:
The company was established with the ministerial decision No. 320 /1996. Its equity capital is EGP 150 million, and the shareholders are as follows:

- Holding Company for Food Industries: 30 percent
- Sugar Industries for supplements: 20 percent
- The National Investment Bank: 15 percent
- The Egyptian National Bank: 15 percent
- Alexandria Bank: 10 percent
- Miser Bank: 10 percent

The factory area covers 24 acres, and it employs 300 people. The production capacity is 60,000 m^3 per year. There are 300 working days per year.

More information about the good example can be found here:
http://www.geocities.com/nhfiboco/company-profite

Publications

Abdelati A. A. (2013) .Sesbania (*Sesbania Aegyptiaca* [Poir]) Agroforestry Using Industrial Drainage Water Bioremediation with Effective Microorganisms (EM), Egyptian J. Agron. (35), No. 2.

2.2 Producing electricity from biomass from terrestrial invasive alien plants in South Africa

Key lessons learnt

- South Africa (SA) is a water poor country, and water demand is likely to exceed supply by 2025.
- Ten percent of SA is covered by invasive alien plants (IAP), which decrease water quality and availability and have detrimental effects on soil, fire and biodiversity.
- A national "Working for Water" (WfW) programme has been in place since 1995 with the objective to eradicate IAPs.
- SA's electricity demand exceeds supply.
- Firewood, charcoal and briquettes can be obtained from IAPs, and in 2009, the "Working for Energy" (WfE) programme called for biomass from IAP clearance to additionally be used to produce electricity.
- Feasibility studies focused on commercial forestry species are encouraging, but there is a need to assess feasibility of using a much wider range of woody and herbaceous IAP biomass for electricity.
- Public acceptance and policies are generally favourable.
- The key challenge is willingness of electricity supplier, Eskom, to facilitate acceptable purchase agreements.
- Potentially a 'win-win' scenario of more bioenergy, more water, more jobs, safeguarding biodiversity and enhancing food security.
- There is the potential to scale-up and replicate in sub-Saharan countries.

Introduction

The positive bioenergy and water relationship example examined here is the potential of biomass from IAPs to generate electricity in SA. This example was chosen for the following reasons:

- Since late 2014, Eskom – the parastatal organization responsible for generating SA's electricity supply – has been unable to meet demand. Load-shedding is anticipated to continue until 2020 and is having severe detrimental impacts on the economy. Currently, about 69, 15 and 11 percent of the total electricity supply are generated from coal, oil and biofuels and waste, respectively (Stafford, 2014). Investment and development in new coal and nuclear power plants and renewables is being fast tracked. Eskom is currently responsible for 45 percent of SA's annual GHG emissions and has committed to reducing these. It, therefore, aims for 42 percent of the new built capacity to be from renewables by 2030 (Department of Energy (DoE), 2011).

- SA has a mean annual rainfall of 400 mm per year, which is less than half the global average of 860 mm per year. With 43 percent of rain falling on 13 percent of land, it has a great spatial variation in water availability. Groundwater accounts for 13.5 percent of total volume used and is the only source for over 300 towns and 65 percent of the population. In 2005, more than 95 percent of surface and groundwater had already been allocated. The quality of both sources has declined due to increased pollution caused by industry, urbanisation, mining, forestry, agriculture and power generation. The demand for water is likely to exceed availability of economically usable fresh water resources by 2025.

- Terrestrial IAPs are a very serious problem in SA. They cover about 10 percent of the country and about 38 percent of this invaded area is covered by commercial forestry species that have escaped from plantations and woodlots. The terrestrial IAPs have detrimental impacts on: water quality and availability; fire regimes (causing an increased frequency and intensity of fires particularly in the Fynbos biome); endemic species and biodiversity generally; and forestry, agriculture and food security generally. The national WfW programme was launched in 1995 to eradicate IAPs primarily using manual methods of clearance. It is currently the responsibility of the Department of Environment. Since 1995, IAPs have been cleared from over 1 million ha, and on an annual basis WfW has provided training and jobs to about 20,000 people from among the most marginalized sectors of society. Since 1998, additional jobs and businesses have been created by the Value Added Industries component of WfW, which encourages people to collect the biomass accumulated from clearing IAPs and process it into a wide range of products, including bioenergy products like firewood, charcoal and briquettes. In 2009, the Department of Energy (DoE) launched the national Working for Energy (WfE) programme, which called for the IAP biomass to be additionally used to generate electricity. Adegoke (2011) noted that since 1995 WfW had cost ZAR 3.2 billion, with almost half spent on 10 species, mostly wattles, mesquite, pines and gums. Both he and van Wilgen *et al* (2012) noted that despite this substantial spending, the area invaded by IAPs and the number of IAPs has increased.
- Feasibility studies into using biomass from IAPs to generate electricity in SA are encouraging. Mugido *et al* (2014) investigated the economic feasibility of replacing coal with woody IAPs to generate electricity for the Nelson Mandela (Port Elizabeth) Metropolitan Municipality in the Eastern Cape. They found that it would be financially viable to do this provided it is done in conjunction with the WfW programme, which would give it high socio-economic returns with respect to a reduction in environmental externalities and the creation of job opportunities. Stafford (2014) estimated that the annual woody biomass from areas invaded by black wattle, eucalyptus and pine trees, as well as from bush encroached areas is sufficient for a 6 percent co-firing with coal at all Eskom's power stations.

Bioenergy and water relationships

Chamier *et al* (2012) describe the following benefits of IAP clearance on water quality:

- decreased evaporation rates, increased stream flow and increased dilution capacity;
- decreased seepage of nutrients into groundwater especially from nitrogen fixing IAPs, such as *Acacia spp*; and
- decreased frequency and intensity of fires, and consequently decreased soil erosion.

Figure 1: IAPs cleared from a riparian area along river

Numerous studies looking at the effects of WfW's IAP clearance on water availability have shown that there is: increased runoff and infiltration of rainfall into soil; increased soil moisture retention and flow through the soil; increased baseflow; and increased streamflow. Le Maitre *et al* (2002) estimated that a 150 percent increase in biomass due to IAPs will reduce water availability by 30 percent. In Fynbos, IAPs can increase biomass by 300 to 1000 percent. Stafford (2014) estimated that clearing IAPs would increase streamflow from between 20 and 200 m^3 per ha. Mallory *et al* (2011) note that the very wide range in estimates of streamflow reduction attributed to IAPs in SA are caused by the numerous models, methods and rules-of-thumb that are currently in use. They caution that as a result of this the increase in water yield due to IAP clearance is often over-estimated. There are many published success stories of the WfW programme in small catchments. Once cleared of IAPs, their streams flow again after many years, and the dried up wetlands fill up with water again, supporting increased biodiversity.

Co-benefits of the WfW IAP clearance that have not yet been highlighted are: the large number of impoverished people who have acquired skills and income from it; the fact that land that was previously unproductive (and impenetrable in the case of dense thickets of *Chromoleana odorata* for example) can now be used for growing food and/or cash crops or grazing livestock; and once cleared of IAPs, indigenous plants and animals return. Many of these are traditionally used for food, making utensils and craft, building, medicine and generating an income. All three of these co-benefits significantly enhance the food security and livelihoods of vulnerable communities, particularly rural ones.

Figure 2: Workers employed by WfW programme clearing IAPs

Prospects

Main drivers:

The WfW programme was a response to a growing scientific and general public awareness of the magnitude of the area of the country already invaded, the rapid rates of spread and the wide range and severity of the detrimental environmental impacts of IAPs. Films and photographs of fires raging through IAP invaded Fynbos on Table Mountain and other mountains close to Cape Town played a major role in making the public aware of the problems posed by IAPs.

Figure 3: Fire raging through IAP invaded Fynbos

The WfE programme was a response to a policy mandate addressing the proportion of renewable energy in the energy mix. The 2003 White Paper on Renewable Energy set the renewable energy target at a cumulative 10,000 GWh of final energy consumption by 2013 (Prasad, 2010). By partnering with WfW programme, a ready source of biomass could potentially be acquired to produce bioenergy. The

WfE programme also encourages the use of biomass from cleared bush encroached areas and the use of agricultural, forestry and municipal waste for bioenergy (Batte, 2009). Energy is produced from municipal waste in Durban. Although plants established to chip and pelletize forestry trimming and harvesting waste have failed (Petrie and MacQueen, 2013; Petrie, 2014), the development of other electricity generating plants using both forestry and sawmill waste is advanced (DoE, 2015). The development of the "Biomass Action Plan for Electricity Production in South Africa" commenced in 2014 and is led by SA's Department of Public Enterprises and DoE, and the Netherland's Enterprise Agency. The initiative includes both on- and off-grid applications for electricity generation and is currently defining the requirements for creating an enabling environment for the large-scale uptake of forestry and agricultural biomass for electricity production in SA by engaging with industry specialists and interested parties. A similar initiative is needed to create an enabling environment for uptake of IAP and bush encroachment clearance biomass for electricity production. The costs of collecting and transporting this biomass to existing power plants may not be financially viable. Micro, off-grid generation may be a better option.

Enabling Factors:
The most important enabling factor was the willingness of the government to listen to the concerns of scientists regarding the detrimental impacts of IAPs and their potential use in bioenergy production. The government has sought and committed very substantial funding to both the WfW and WfE programmes. The second is the large proportion of the urban, peri-urban and rural populations who were/are unskilled and unemployed and consequently willing to be trained and employed at nominal rates on a short-term contract or ad hoc basis to clear IAPs.

Challenges encountered:
Musango *et al* (2011) note that renewable electricity generation in SA faces a number of general challenges and barriers that limit its widespread deployment. They classified these as: natural factors, economic and financial factors, institutional and regulatory barriers, infrastructure barriers, research and development, human resources barriers, infrastructure and social barriers. Their recommendations to support future development of renewable electricity generation include: establishing a single coordinating agency or authority; creating public awareness; providing financial support guarantees; and capacity building and skills development. Pegels (2010) asserts that lack of financial support is a major challenge for potential investors. In 2009, the Renewable Energy Feed-in Tariff (REFIT) was published. It provided a subsidy for electricity generation from solid biomass and guaranteed the price that covers the cost of generation and reasonable profit for electricity supply. Eskom was to be the sole buyer and distributor of REFIT electricity, but it had no obligation to buy the REFIT electricity (Prasad, 2010). In 2011, REFIT was abandoned in favour of the Renewable Energy Bid Programme (REBID). Petrie and MacQueen (2013) and Petrie (2014) claim that REBID has so far failed to establish institutional structures and alignment with other relevant legislation, such as the National Environmental Management Act, that might have allowed quicker progress and assert that the key challenge remains the willingness of Eskom to facilitate acceptable purchase agreements. DoE (2015) notes that REBID is designed to transform the electricity generation sector from one dominated by Eskom to multiple generators with the private sector playing a dominant role. Approved contracts are required to contribute to socio-economic development within their immediate locality, set within a 50 km radius of plant location.

Scaling-up and replicability:
To date, feasibility studies into using biomass from IAPs to generate electricity in SA have focused on several woody species used in commercial forestry. There are over 350 terrestrial IAP species in SA. Research into the suitability of other IAP woody species and non-woody species for use as fuelwood

and for the production of charcoal, briquettes, pellets and black pellets (torrefaction) should be prioritized. Despite intensive efforts to eradicate IAPs over two decades, their number and spatial extent has increased. We need to aim to use the biomass from most if not all of them for bioenergy, if we are to reap the full range of co-benefits of doing so.

Both the WfW and WfE programmes can be replicated in other sub-Saharan countries where extensive and intensive IAP invasion is having detrimental environmental and socio-economic consequences, and where a large (and growing) proportion of the population is unskilled and unemployed.

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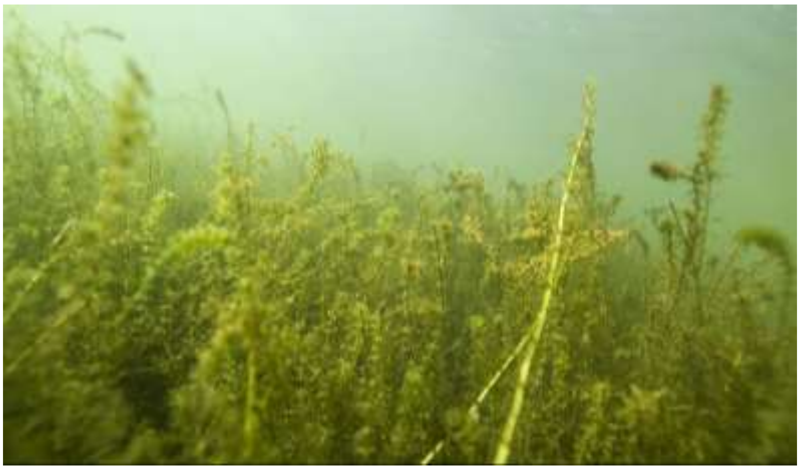
Additional Information:
http://www.energy.gov.za/files/wfe_frame.html
https://www.environment.gov.za/projectsprogrammes/wfw

2.3 AquaMak: Economic and ecological perspectives on using aquatic macrophytes for energy production in Germany

Figure 1: Aquatic macrophytes



Source: Andreas Zehnsdorf, UfZ

Key lessons learnt

The rivers and lakes of Germany face excessive growth of aquatic weeds in a high number of places. This is due to a number of reasons, including eutrophication and the spread of highly successful invasive species. This excessive growth of aquatic weeds is seen as a problem by many stakeholders, including:

- Municipal administration and agricultural businesses;
- Operators of hydropower plants;
- Tourism / leisure businesses (water sports and activities);
- Inland navigation;
- Fisheries; and
- Nature conservation (Environmental associations).

Generally, excessive growth of water plants and their removal costs about EUR 100 million each year in Germany. A strategy to lower these costs by utilizing the emerging biomass would be highly welcome. The problems encountered can be put into three categories:

- Economic
  - Costs for removing weeds are high
  - Ways to use the weeds productively have not been fully developed so far
- Social
  - Conflicts of interest are manifest
- Technical
  - Aquatic biomass needs to be ensiled with straw (30 to 45 percent of silage dry matter content) to use it in biogas plants; the optimum volume is under investigation
  - High buffer capacity and low sugar contents needs adequate ensiling.

Introduction

Geographic location: The project is based on nationwide research of Germany.

Type of example: Project “AquaMak” is a publicly-funded research project, funded by the German Federal Ministry of Food and Agriculture via *Fachagentur für nachwachsende Rohstoffe e.V*.

Status: The project began in 2014 and will continue through 2017.

Bioenergy and water relationships

Positive impacts on water quality and availability:
Removing aquatic weeds could help reduce nutrient overload, especially phosphate and nitrogen, which, in turn, would improve chemical water quality and reduce eutrophication.

The control of aquatic weeds could help ensure adequate oxygen levels for water fauna, maintain biodiversity and control neophyte dispersal (e.g. *elodea nuttalii*), thus keeping a functioning ecosystem and its services working.

Water availability is not a problem in Germany but rather flood protection. Removal of weeds from streams helps to ensure unhindered drainage.

Positive impacts on biomass/bioenergy production:
Currently, aquatic biomass is not being used in Germany. It is seen as waste and thus not incorporated in existing production chains for bioenergy. Its use could help reduce the dependency on ground-based biomass, especially energy crops, as well as help diversify the possible input materials for bioenergy production.

Co-benefits:
The use of aquatic biomass for bioenergy production could help the biogas industry achieve a better image. As aquatic weeds are seen as waste, their use for energy production would be uncomplicated in comparison to maize, which is seen as food. The negative image of using energy crops, especially maize for biogas production has become a major impediment for future growth of this sector.

Prospects

The main drivers for implementing the project are:

- Municipal administration and agriculture
  - Flood protection and groundwater level management calls for regular removal of weeds.
- Operators of hydropower plants
  - Aquatic weeds raise maintenance costs and in extreme cases lower water availability.
- Tourism and leisure businesses (water sports and activities)
  - Aquatic weed mass growth is seen as highly damaging to tourism’s interests and the touristic value of streams and lakes.
- Fishery
  - Aquatic weeds are seen as both helpful and harmful as they can act as both a fish sanctuary and can lower oxygen levels through degradation after mass growth without harvest.
- Nature conservation (environmental associations)

- There is a strong interest in ecological balance, which includes conservation of habitats, water and quality, containment of invasive species and maintenance measures.

Key enabling factors:

- In biogas power plants:
  - Positive Factors:
    - Low material costs, as aquatic biomass is mostly seen as waste;
    - Water plants contain some interesting substances (trace elements) that may stabilize the fermentation process; and
    - Positive image of biogas power, as "waste" is used for renewable energy.
  - Negative Factors:
    - Low dry matter content;
    - High logistic costs related to low energy content;
    - Raw material unfit for ensiling, but a mix with straw and additives shows promising results;
    - Logistics problems as areas of supply and demand do not necessarily match; and
    - No steady flow of input material as "production" is not managed.
- In the cosmetic industry:
  - The use of aquatic biomass as a supply for ingredients of cosmetic products seems promising.
  - Demands are high quality and purity of the input material.

Main challenges encountered:
The main challenges in harvesting and utilizing water plants in biogas processes are:

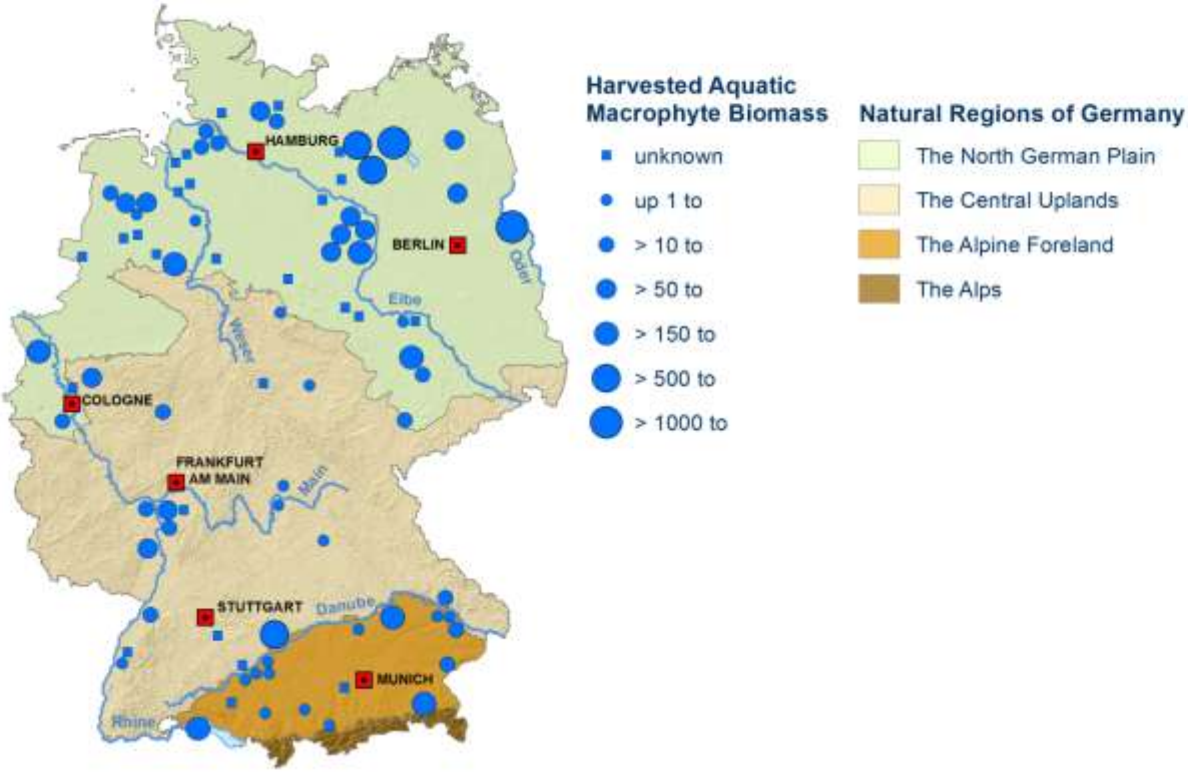
- low dry matter content;
- ensiling water plants;
- nature-conservation and potential ensuing issues of public acceptance of harvesting water plants;
- low efficient process chains (harvest, logistics, ensiling, pretreatment, fertilizer value); and
- legal status: not listed as an energy crop, no landscape cleaning material, therefore no subsidies for use as biogas substrate under German Renewable Energies Act (Erneuerbare Energien Gesetz [EEG]) can be obtained or the material is even illegal to use.

Potential for scaling-up and replicability:

- Demand-side potential in Germany is high; other countries like Italy and France are evolving in the biogas sector. These countries are very aware of the problems in Germany due to large-scale use of energy crops and are keen to avoid them by using input material with a higher public acceptance.
- Technical problems can be solved. This could be demonstrated on a laboratory scale already and will be subject to further optimization during the rest of the project.
- Supply side in Germany is limited, as so far no supply-side management is planned, which could be different in other countries.

- Aquatic biomass cultivation could improve water quality (de-eutrophication) but lead to conflict, as there are already a multitude of stakeholders involved. For example, lakes and rivers in Germany serve as high frequented regional touristic destinations, and aquatic weed cultivation would lead to a lesser touristic value. In some areas, e.g. Lake Constance, professional fishers are already concerned about eutrophication levels being too low to support fish growth.

Figure 2: Harvested aquatic macrophyte biomass



References and additional information

References:
Nation-wide AquaMak survey

Natural Regions of Germany © Federal Agency for Nature Conservation 2012

Digital Landscape Model 1:250,000 © GeoBasis-DE / BKG 2014

Digital Terrain Model Grid Width 200m © GeoBasis-DE / BKG 2015

Map designed by: Dipl.-Ing (FH) Sandra Roth (ILU)

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2.4 Zonification for yield gap analysis and efficient use of water resources in sugarcane areas in Oaxaca, Mexico

Key lessons learnt:

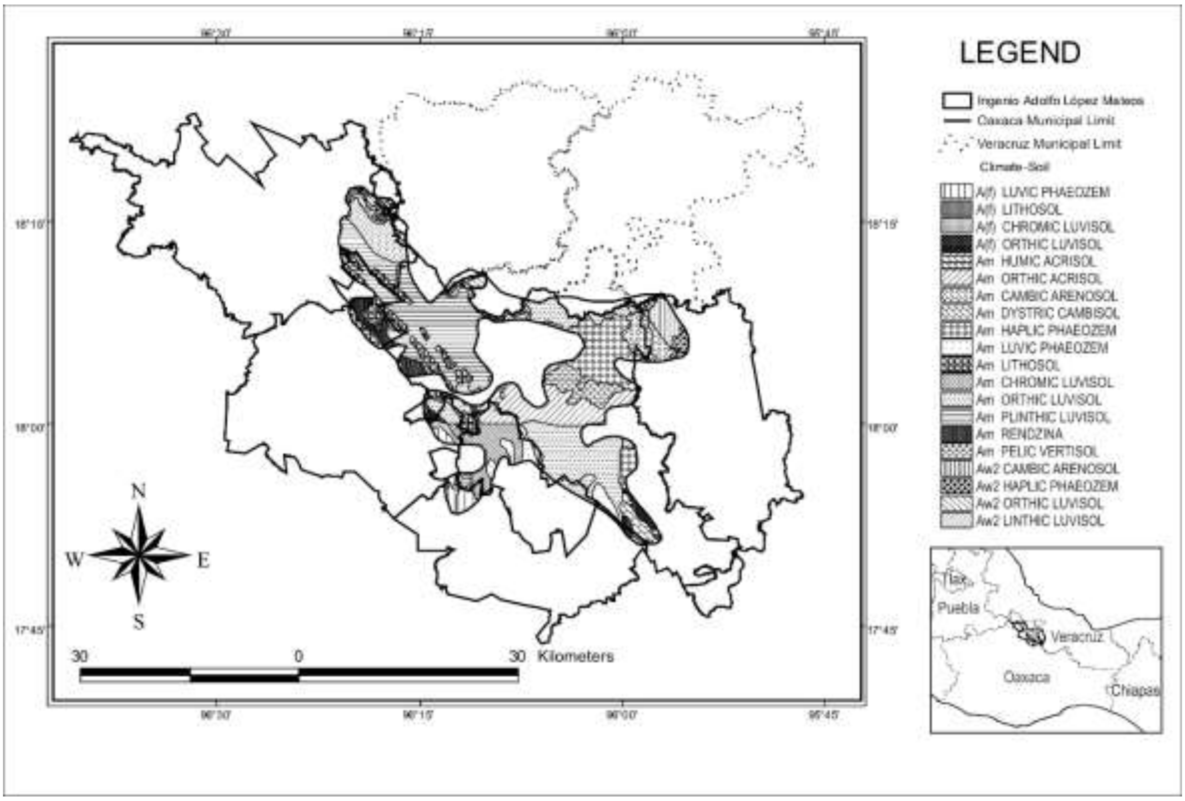
- Zonification was used to identify homogeneous sugar-cane areas and the limiting factors causing yields gaps within them.
- Climate was a limiting factor in only 11 percent of the studied mill region; accumulated precipitation was significant during the fourth to seventh month period after harvest. Providing supplemental irrigation where and when needed can improve yield while preventing wastage of water resources.
- Soil bulk density, a limiting factor in the low-yielding farms, may be improved through green management practices that increase yield without chemical fertilization, thereby lessening water pollution.
- Technology transfer based on zonification may help farmers achieve potential yields without significant increases in production costs and damage to water resources.

Figure 1 & 2: Sugar cane cultivation in Oaxaca, Mexico

Source: Ernesto Bravo-Mosqueda

Introduction

Figure 3: Climatically and edaphically homogenous areas in the sugar cane mill region of Ingenio Adolfo Lopez Mateos in Oaxaca, Mexico



Source: Bravo et al. 2014

The study was conducted in the sugar-cane mill region of Ingenio Adolfo Lopez Mateos in Oaxaca, the third-most economically marginalized state in Mexico. Sugar-cane cultivation in the mill region covers approximately 25,000 ha and is a source of livelihood for many rural families.

The research activity was part of a national project aimed at characterizing sugar-cane areas for yield gap analysis in order to help farmers achieve potential yield increases and to inform decision-making at government and industry levels. The results of the study, which began in March 2008 and ended in March 2011, have been made available to famers and policy-makers.

Bioenergy and water relationships

Zonification of the sugar-cane mill region (i.e. dividing the region into units with similar edaphic and climatic characteristics)[1] enabled the identification of twenty homogeneous areas (See Figure 3), whose soils (predominantly luvisols) and climate (85 percent Am [rainfall throughout the year but with precipitation less than 60 mm in one month]), were mostly considered favorable for sugar-cane cultivation.[2] Achieving improved yields without significant increases in production costs is thus seen as possible as long as farmers optimize agronomic management and select the best genotypes.

Soil bulk density, identified as a limiting factor in low-yielding farms in the largest homogeneous area, can be improved through green management practices that help increase yield without the use of chemical fertilization that harms water resources. The following practices may be implemented: planting on a soil surface covered with residue from the previous crop; harvesting green cane to maintain high moisture content in soil, save water and electricity and reduce water pollution; applying organic matter, such as compost material derived from the industrialization process, which most of the interviewed farmers in the mill region did not use;[3] green manuring by sowing non-competing legume species or setting bean crop between rows of newly planted cane to help improve fertility; and using biofertilizers based on mycorrhizae and *Azospirillum*.[4]

Eighty-five percent of the mill region corresponded to the Am climate type (with rainfall throughout the year but with precipitation less than 60 mm in one month), 11 percent to Aw2 (with some months having less than 60 mm and the dry period occurring in winter) and 4 percent to A (f) (with monthly rainfall of over 60 mm throughout the year). These climates have average annual temperature above 18°C and annual rainfall surpassing evaporation. Considering the requirements of the sugarcane crop, it is only in the Aw2 area where climate is a limiting factor. Although the annual rainfall is greater than 1,500 mm and exceeds the potential evapotranspiration, the annual distribution (dry winter) in this area is not favorable for sugar-cane development. Conservation of soil water is needed in this area; irrigation might also be necessary from January to May.

Accumulated precipitation (or water) during the fourth to seventh month after harvest, along with percentage of silt, explained 63 percent of yield, signaling the need for appropriate irrigation during this critical period. Administration of supplemental irrigation where and when needed can lead to better yield and more efficient use of water resources.

Zonification reduces the disadvantages that come with applying a uniform management decision to a region that is non-uniform, climatically and/or edaphically.[5] Applying the approach to yield gap analysis makes it possible to identify limiting factors that need to be properly addressed in order to improve sugar-cane biomass production.

The use of the zonification approach helps eliminate excesses or deficiencies in the use of agricultural inputs (e.g. fertilizers) and natural resources (e.g. water).[6] It is useful in the planning of technology transfer and subsidy programs for farmers.

Prospects

Sugar-cane production is the source of livelihood for many rural families in Mexico. In Oaxaca, many sugar-cane farms have low average cane yields (barely half of the national average), causing farmers to spend meager savings on fertilizers or technology that their farms may or may not need.

Government assistance is currently leaning towards greater investments in large-scale irrigation systems and the conversion of more rainfed farms to irrigated areas; however, as this case study shows, it may not be the best solution in all cases. Studies such as this can help guide decision-making and policy development to avoid wastage in investments and natural resources.

The study was made possible through the participation of the surveyed farmers, who provided data on management practices and socio-economic variables, and the cooperation of the sugar-cane mill and national sugar-cane organizations that provided additional yield data. The availability of adequate soils and climate data made it possible to characterize the region. Research funding was provided by SAGARPA (Mexican Department of Agriculture).

Further study (i.e., more years and more areas) was constrained by funding limitations. Ongoing challenges are disseminating research findings among farmers and technicians.

The zonification study has already been replicated in 12 sugar-cane mill areas in Mexico. Application of the approach to other regions and other crops will require good quality data (soils, climate, management, etc.), the cooperation of farmers, and the collaboration of soils and climate/hydrology experts and crop specialists. Scaling up using geographic information system (GIS) models such as GIS-EPIC and GIS-ALMANAC can be explored.[7, 8]

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Additional information:
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2.5 Best management practices for maintaining water quality in riparian zones in water supply catchments during tree harvesting in Burnie, Australia

Key lessons learnt

- Best Management Practices are key components of streamside zone management;
- Streamside management zones can be harvested without degradation in water quality;
- Streamside zones that are adequately managed can protect water quality while providing new sources of bioenergy feedstocks;
- Streamside management zones that are managed for bioenergy feedstocks provide a wide range of ecosystem services to farms and the broader community; and
- Success in implementing Best Management Practices involves close cooperation between landowners and technical experts.

Introduction

Geographic location: Australia, northwest Tasmania, south of Burnie

Type of example: Specific project

Status: The study was started and completed in 2008 using guidelines from the Tasmania Forest Practices Code. The Best Management Practices (BMP) described in the published paper are still being used in Tasmania.

Bioenergy and water relationships

Positive impacts on water quality:
The BMPs were able to maintain good water quality for a tributary stream of the Pet River that drains into the water supply reservoir for Burnie, Tasmania, Australia. Thus, appropriate BMPs enabled harvesting of fast growing trees along riparian (streamside) management zones whilst maintaining good water quality. The key factors were: limiting the construction of new roads; maintaining slash on the soil surface and thereby minimising soil disturbance (especially at ephemeral steam crossings); harvesting during dry periods and using wide-tracked harvesters with grapple booms that permitted harvesting of trees without entering a 10 m machinery exclusion zone along the tributary stream; and low soil erodibility. Establish riparian forest plantations improved water quality in the agricultural landscape. This study showed that appropriately managed harvesting did no compromise that goal.

Positive impacts on water availability:
The BMPs used in this study ensured that a sustained flow of high quality water would enter the Burnie, Tasmania, Australia, water supply reservoir. Water supply for municipal reservoirs needs to maintain a high quality in order to minimise water treatment costs. Sediment is a big factor in degrading water quality and affecting water availability for municipal supply sources. In this case, forest harvesting did not impact water quality.

Positive impacts on biomass/bioenergy production:
Australia is moving forward with renewable energy sources to decrease its carbon footprint. Wood feedstocks are a viable component of the potential feedstock portfolio. A large potential wood source for increasing feedstocks above current supply levels could potentially be established as riparian tree plantings. These rapidly growing plantings can provide a number of ecosystem services for farms during each rotation. Riparian tree plantings can be harvested without degrading water quality

(sediment and nutrients) using existing codes of practice as demonstrated by this study. This approach has the potential to make available for the Australia bioenergy sector some 2 to 3 million ha of fast growing eucalypts and conifers.

Co-benefits:
The use of riparian tree plantings has the potential to bring a number of ecosystem services to privately owned farms and other lands as well as increase the revenue stream for the landowners. The types of ecosystem services can include high quality water supplies for livestock and municipal uses, windbreaks for livestock, protection of riparian areas from livestock-related erosion, habitat for maintaining landscape biodiversity, protection from invasive plant species colonization, maintaining streamflows, conserving landscape nutrients, and reduction in wildfire hazard due to planting and pruning of less combustible tree species.

Prospects

Main drivers for implementing the project:
The main driver for implementing this project was to determine if forest harvesting in streamside management zones according to the Tasmanian Forest Practices Code would compromise water quality. This science can be used to guide future revisions of this code and others. A complete ban on harvesting within 10 m of streams would have precluded the attainment of environmental benefits riparian plantings on cleared farmland, with potentially increased fire and weed risks. Modern harvesting equipment facilitates low-impact practices.

Key enabling factors:
The main factors that enabled implementation of this example were environmental, economic, and social policy related. The environmental factor was the need for actual field data on the effectiveness of BMPs in protecting water quality during harvesting. Few relevant examples existed anywhere, so there was a great need for good science to back policy. The production factor was based on the desire of the farmer to gain a financial return from managing the streamside zone. The policy factor was timely and locally appropriate science input to a revision of the Tasmania Forest Practice Code. The social factor was the attitude of the private landowner to being a good environmental steward and providing excellent cooperation during the conduct of the study.

Main challenges encountered:
There were no major policy, technical, financial or other challenges. The main challenge was finding the right location to do the study and fit it into the harvesting schedule. The whole study had to be done on a very short lead time. It was completed, presented at a major international meeting, and published in an open access journal within a year.

Potential for scaling-up and replicability:
This example should be replicated elsewhere given the right combination of expertise and a range of biophysical settings covering climate, soils, topography, and vegetation. The more studies that encompass the range of environmental conditions, the greater the power and validity of the example, and the greater the confidence policy makers and managers will have in designing such practices.

References and additional information

Contact names and affiliations/organisations:

- Dr. Daniel G. Neary, USDA Forest Service, Rocky Mountain Research Station, Flagstaff, Arizona, USA; and
- Dr. Philip Smethurst, Commonwealth Scientific and Industrial Research Organization, Hobart, Tasmania, Australia.

Additional information:
The study was a public-private investment involving two government agencies and a privately owned farm. The study was conducted while the senior author was a McMaster Research Fellow in Tasmania. The research fellowship was provided by the Commonwealth Scientific and Industrial Research Organization (CSIRO) of the Australian government. The fellowship was also supported by the research and development branch of the USDA Forest Service. Private in-kind support came from Naraglen Farm, Burnie, Australia.

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Photos:

Figure 1: Minimum impact logging equipment – wide tracks and long boom with a grappling-cutting head

Figure 2: Retention of slash near an ephemeral stream to protect soil and waterway from disturbance and erosion

Figure 3: Harvesting up to stream edge without disturbing soil, using a 10 m machinery exclusion strip

3. 'Waste' to Energy and Water-Smart Processes

3.1 Livestock waste to biogas: the Italian BiogasDoneRight® model
Guido Bezzi & Carlo Pieroni

3.2 Biogas from livestock waste to reduce pollution in Lake Tai, China
Takahashi Hayashi & Daisuke Kunii

3.3 Reducing GHG emissions from the energy sector through the utilization of organic waste for energy generation in agriculture, forestry and agro-industries in Argentina
Miguel Almada & Maria R. Murmis

3.4 Management of water resources in the sugar-cane agro-industry in Brazil
André Elia Neto

3.5 Sustainability in movement: Water energy nexus in southern Brazil
Rafael González & Marcelo Alves de Souza

3.6 Vinasse concentration for water use reduction in Piribebuy, Paraguay
Guillermo Parra Romero

3.7 Use of vinasse in biogas production through anaerobic digestion in the Brazilian sugar-cane industry
André Felipe de Melo Sales Santos, Julia Torreão Pecly & Márcia M. G. Alcoforado de Moraes

3.8 Development of a scalable algae cultivation system that enhances water sustainability in algal biofuel production in the United States
George Philippidis

3.1 Livestock waste to biogas: the Italian BiogasDoneRight® model

Key lessons learnt

The management of animal manure is an important cost that farmers incur to remain compliant with nitrate directive. With a biogas plant, cattle farms can valorise animal manure to produce renewable electricity, heat or biomethane. Moreover, manure is stabilized and turned into digestate, an organic biofertilizer, which is returned to soils closing the farm production cycle. Such a model helps decrease the risk of nitrogen pollution in aquifers compared to typical cattle farms that use manure as a fertilizer without previous treatments. In terms of water-saving, thanks to the correct use of digestate and an advanced agronomic approach, it is possible to increase soil fertility and organic matter content. This generates improvements in carbon sequestration and water retention capacity of soils and increases water use efficiency in farms.

The application of Biogasdoneright® model in agriculture can:

- Reduce nitrogen leaching risk and stabilize organic nitrogen;
- Improve the efficient use of water, water soil capacity and hydrologic stability;
- Create "Carbon Negative" agriculture by increasing organic carbon sequestration in soils and mitigating GHG emissions;
- Contribute to the closure of the carbon cycle in the soil in order to create an efficient "Bioenergy with Carbon Capture and Storage (BECCS)" model.

Introduction

BiogasDoneRight® is an Italian sustainable agricultural model, which has been developed in farms with an integrated biogas plant. We use the term BiogasDoneRight® to describe a technological platform that combines Anaerobic Digestion technologies and other Industrial and Agricultural practices that are applied synergistically in order to improve traditional farming by adding value to livestock and by-products and creating a positive and circular agro-energy system. The integration of a biogas plant in a farm generates environmental, social and economic improvements, with particular attention to soil fertility, water quality and water availability. Moreover, the model maintains the established farm production without lowering food and feed output. BiogasDoneRight® is an example of multifunctional and sustainable agriculture according to the objectives of "EU road map of efficient Europe" and is now being applied in several farms in northern Italy.

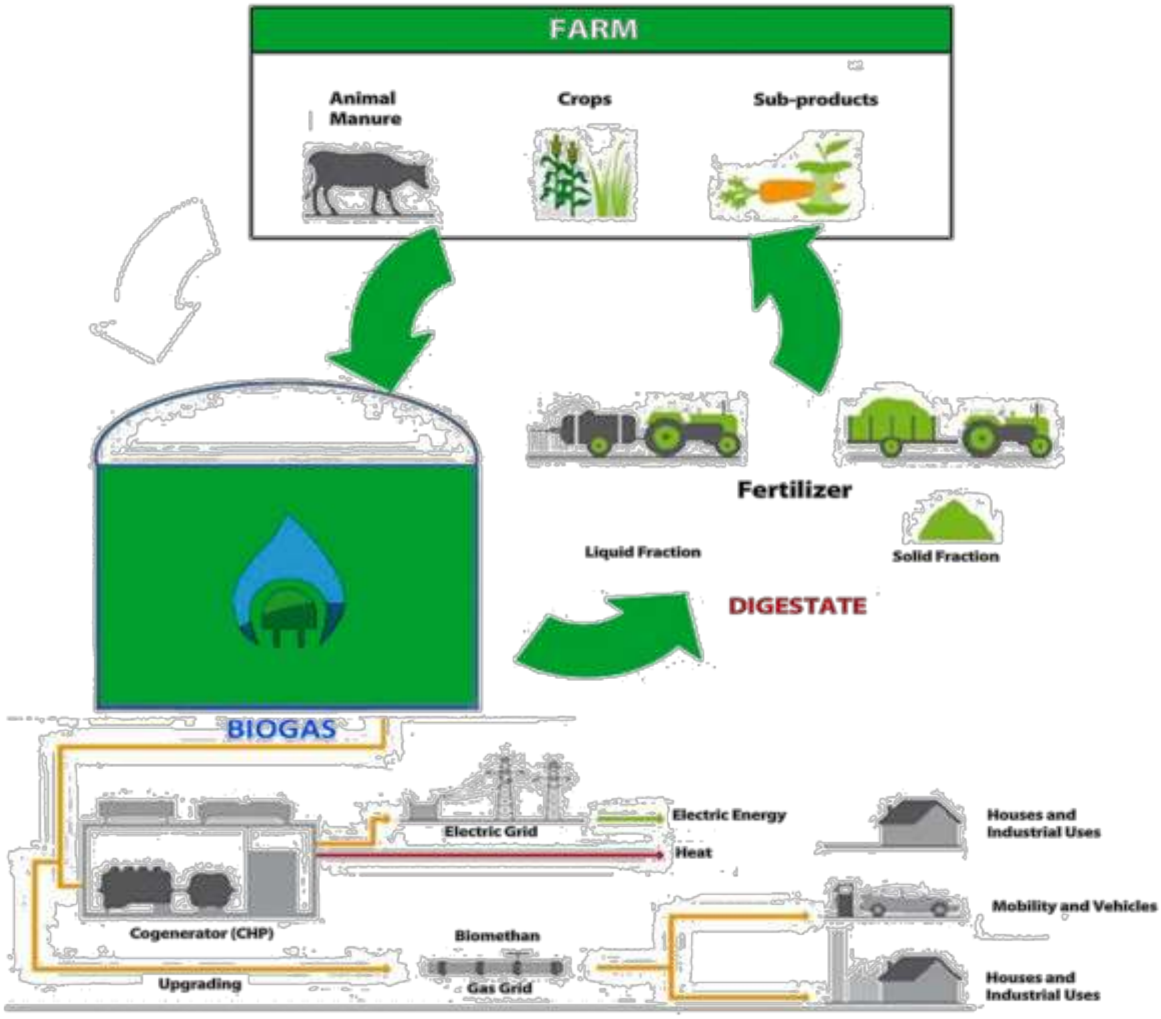
With the Biogasdoneright® model (Figure 1), the farmer can use an expanded plant diet based on the following options:

- Cover crops from a second harvest applied before or after food and feed traditional crops, producing double crops in the period of the year when the land is set aside;
- Livestock effluents, originating at the farm;
- Nitrogen fixing plants, in rotation with other cereals for the market;
- Perennials in set-aside lands or lands undergoing desertification; and
- Agricultural by-products and organic wastes.

From the biogas plant the farmer can obtain electric energy, heat, biomethane and digestate, which can be given back to the soil as fertilizer through distribution systems that avoid soil compaction.

The BiogasDoneRight® platform considers also the use of watering techniques (such as drip irrigation or pivot irrigation) that are more efficient and water saving, the distribution of nutrients via the irrigation system and the adoption of no tillage agriculture for seeding, thus keeping the moisture of soils and shorten the time between first and second harvest.

Figure 1: Scheme of circular agriculture with the introduction of a biogas plant



Source: Elab. G.Bezzi, 2015 from AA.VV., 2012

Bioenergy and water relationships

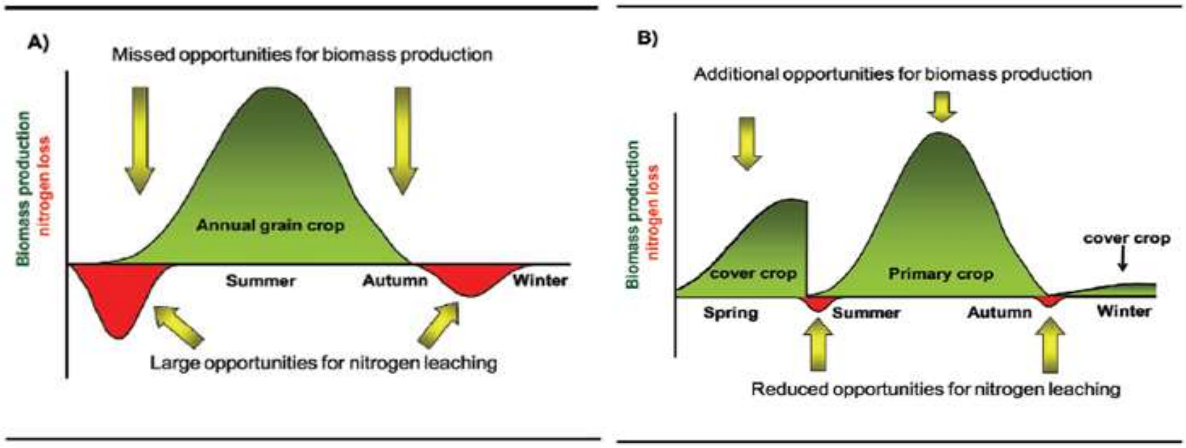
Positive impacts on water quality:

The introduction of a biogas plant in a cattle farm generates huge benefits for both the environment and farmers, allowing for the production of renewable electricity and heating from manure. Before the installation of the biogas plant, this manure would have represented a cost for farmers as they would have had to pay for its disposal.

In typical cattle farms, manure is used as a fertilizer without any previous treatment. Manure has a high level of nitrogen, which is not stabilised. Therefore, the risk that it will penetrate the soil and reach the aquifer is very high. When a biogas plant is integrated into the farm, manure nitrogen can be stabilised through the anaerobic digestion process and it becomes more available for crop uptake. This is the first step to reduce nitrogen leaching risk.

When biogas is produced in a conventional way, the farm usually has to face the reduction of its food and feed production and the replacement of its conventional crops with biomass crops cultivated with a mono-cropping system. Conversely, with the introduction of the BiogasDoneRight® model, the farm can use its by-products to feed the biogas plant and it can create a double-cropping system where cover crops can be harvested for biomass and food and feed crops can be preserved. Moreover, thanks to the return of digestate to the soil, it is possible to increase productivity about 10-15 percent and also recover degraded land (Figure 2).

Figure 2: Reduction of nitrogen leaching risk and additional biomass production from mono-cropping system (on left) to BiogasDoneRight® (on right)

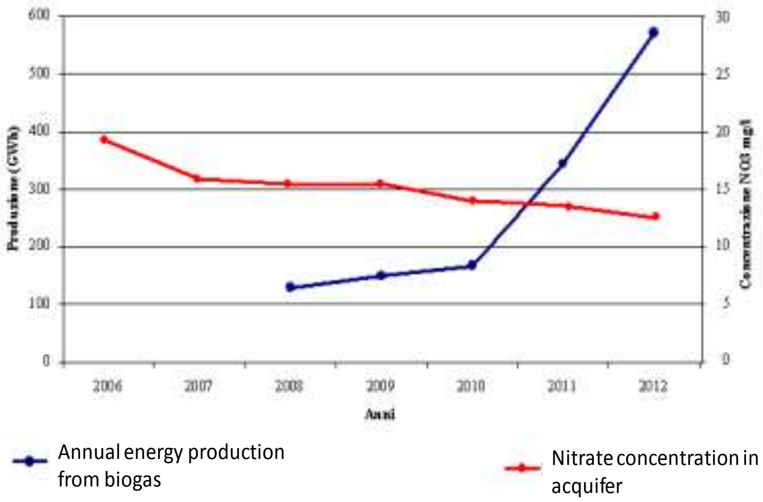


Source: A.H. Heggenstaller, 2008

Therefore, the Biogasdoneright® model provides stabilised organic nitrogen from digestate and guarantees coverage of the soil all year long. The effects of this combined approach include:

- A significant improvement of soil quality in terms of fertility and amount of organic matter that goes back to the soil through fertilization with digestate.
- An improvement in water quality through reduction of nitrogen leaching and aquifer pollution as demonstrated in a study published by Veneto region. The authors described how biogas can reduce the total amount of nitrogen in agricultural areas by an average of 13.3 percent (Belcaro P., Schenato F., 2015), reducing nitrogen loss in aquifers (Figure 3).
- A better hydrological stability since the soil is constantly covered by crops and abandoned lands can be cultivated with biomass crops.
- An increased water soil capacity correlated to the improvement in organic matter.

Figure 3: Development of biogas and management of the nitrates in Veneto



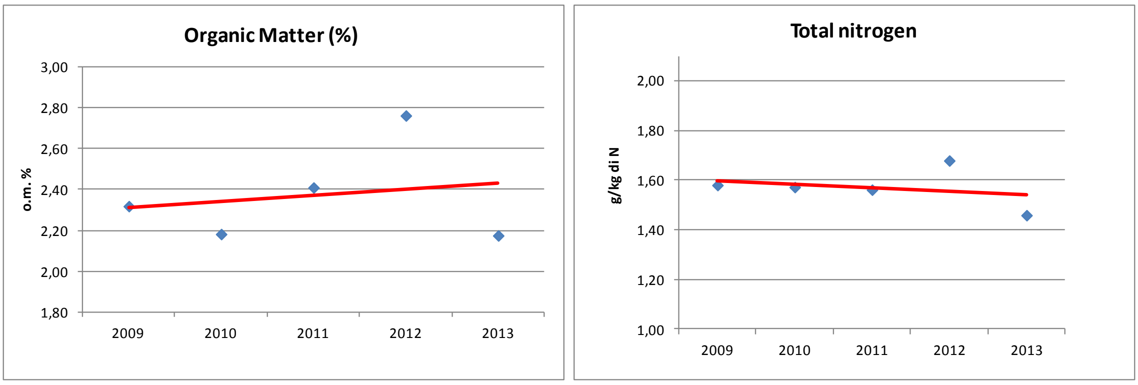
Development of biogas and management of the nitrates in Veneto

P.Belcaro, F.Schenato, 2015

<u>Positive impacts on water availability</u>:

The BiogasDoneRight® model has shown positive effects also on water availability through reduction of water evaporation, prevention of water waste and increase in water holding capacity of soil. Yearlong soil coverage and a double cropping system prevent water lost due to evaporation from the soil on set-aside soils and possible desertification in abandoned areas. Moreover, the farmer can introduce new crop rotations and cultivation systems such as strip or minimum tillage, precision farming, drip irrigation and fertirrigation in order to save water during the routine farming procedures. The continuous return of digestate to soil improves its quality through an increase in organic matter content (0.2 - 0.3 percent average increase of stable organic matter in soil over a five-year period - Bezzi G. and Sibilla F., 2015). This can lead to maintenance of soil structure and improvement of soil's water holding capacity (a soil rich in organic matter can absorb 20 times its weight in water) (Figure 4).

Figure 4: Trend of organic matter and total nitrogen content in northern Italy's soil



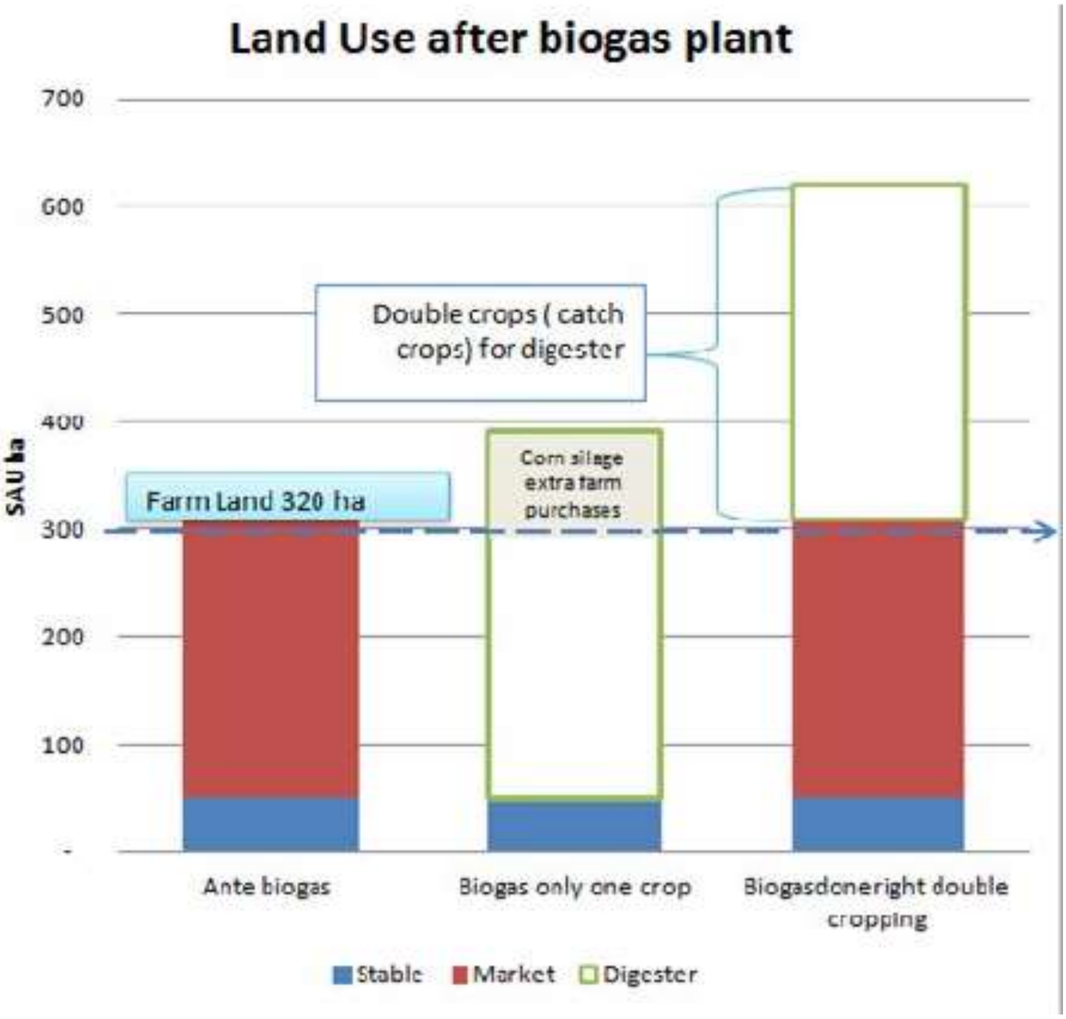
Source: Data Pioneer Hi-Breed from Coop. Speranza Farm (Turin) Elab. G. Bezzi, 2015

Some field trials have been conducted to test the effects of fertigation with the liquid fraction of digestate. They demonstrated that when digestate is applied in a 10 percent water solution for fertigation (pivot or ranger systems), it is possible to save water through the recycling of water contained in digestate and to obtain a yield increase of up to 15 percent. Some studies have also focused on use of liquid fraction of digestate in drip irrigation in order to obtain maximum efficiency of water-use and fertilization effect.

<u>Positive impacts on biomass/bioenergy production</u>:

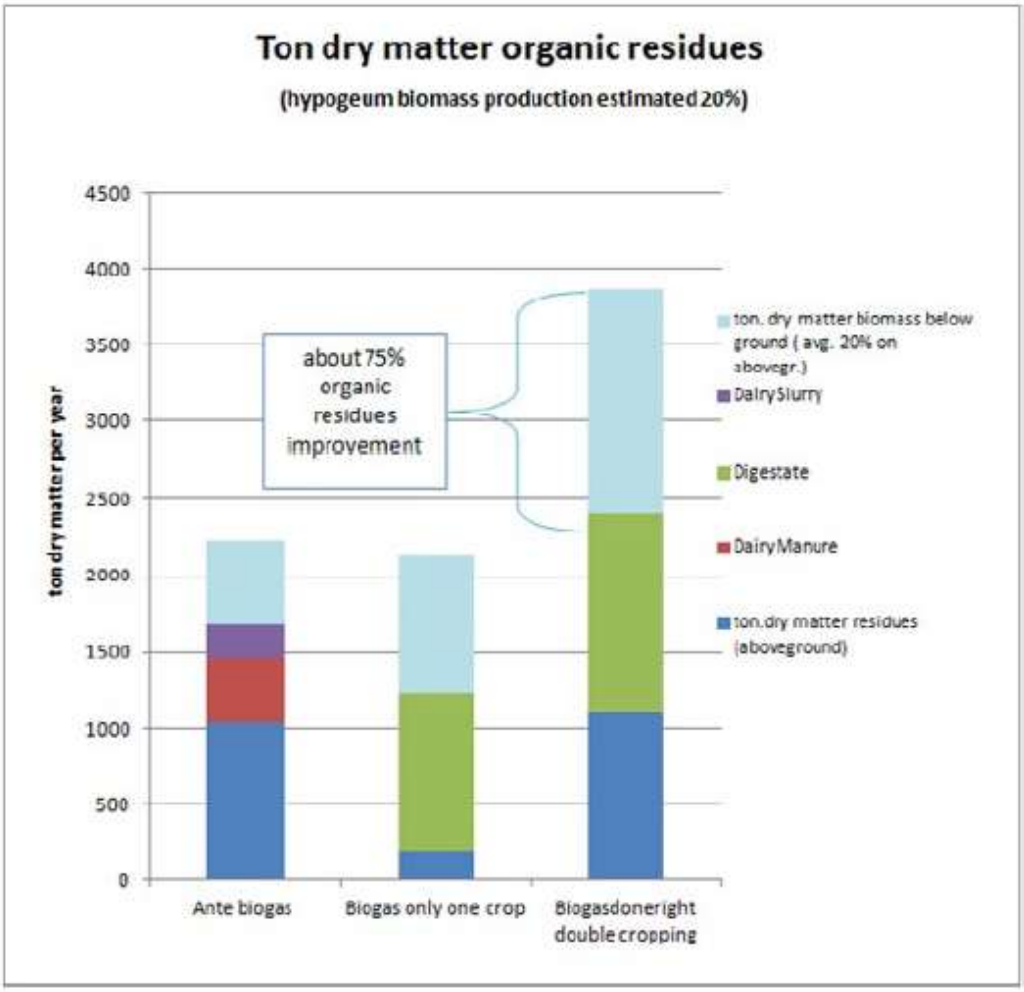
The introduction of a biogas plant ensures positive financial flows to farmers, allowing them to invest money in innovative technologies that can improve the efficiency of cultivation and produce more products with less inputs. Using the Biogasdoneright® model, *Consorzio Italiano Biogas* (CIB) has estimated a potential production of 8 billion Nmc of biomethane equivalent to be achieved by 2030 using 400,000 ha of land under an extensive use of biomass integration. This potential was calculated exclusively from set-aside land. These evaluations also include products and wastes that are typically not re-used and often represent a disposal cost for the company, and in that way, they will not create competition with food production but rather allow for the simultaneous production of food and feed. More specifically, those products and wastes are: crops of second harvest or in precession sequence in forage crops or food; livestock effluents; agricultural by-products; agroproducts; biomass derived from bio-refinery; no food on land not used for feed.

Figure 5: Increase of land use efficiency



Source: BiogasDoneRight Position Paper, 2015

Figure 6: Dry residues that return to soils ante biogas with conventional biogas and with the BiogasDoneRight® model



Source: (BiogasDoneRight Position Paper, 2015)

In general, with the BiogasDoneRight® principles, farms are able to significantly increase their biomass potential production with soil use efficiency. Some examples in Italy demonstrate a possible increase of approximately 75 percent of organic residues returned to soil compared to conventional practices.

Co-benefits:
Biogas is a technology that generates more work between the available technologies for the production of renewable energy. Some examples demonstrate how BiogasDoneRight® is a chain that develops countless opportunities for sustainable jobs in agriculture and industry. It also strengthens the competitive and financial situation of the existing farms and helps maintain employment levels at farms that are experiencing crises (pig farming, beef cattle, milk for Protected Designation of Origin cheese, citrus, etc.)

In Italy, there are approximately 1,500 plants and a total installed electricity of about 1,100 MW. Most of the biogas plants in Italy are of agricultural biogas (about 1,150 plants for 850 MW). These figures allow Italy to be the second European producer after Germany and the third worldwide after China. The Italian market for biogas has today realized EUR 4.5 billion in investments and has created 12,000 stable jobs. Southern Italy also has good potential for the development of more biogas and biomethane.

Prospects

Key enabling factors:
These challenges are in line with the EU concept of a "circular economy," meaning they span the value chain and ensure the use of secondary resources in other industries or value chains. According to the Roadmap to a Resource Efficient Europe (COM (2011) 571 final), the EU could reduce the amount of net imports of resources by improving the conversion of waste and by-products through greater 'industrial symbiosis'.

Main challenges encountered:
To allow for the correct use of the described technologies, it is mandatory to increase the role of public participation for social acceptance and a better understanding of the characteristics of the biogas process and the way it can contribute to sustainability efforts. Innovative solutions can still face significant local opposition. Local opposition has resulted in high rejection rates of proposed biogas/biomethane projects in a majority of EU countries, limiting the growth of the biogas and biomethane sector as well as the introduction of connected innovative technologies like those mentioned in this chapter. There are also many challenges related to political and normative aspects: each European nation has different rules and standards that frequently prevent the exploitation of the huge potential of biogas chain and the correct use of digestate in agriculture.

Potential for scaling-up and replicability:
All of the practices illustrated in this example could be replicated anywhere in the world. In areas with fertile soils, they could improve rates of cultivation and in marginal areas, they could rescue the fertility of soils, avoiding desertification. There is no problem in scaling-up or down these practices: they could be applied both in large farms and in small farms. For example, CIB is involved with DIOUMA association in a BiogasDoneRight® project in development area of Senegal. In this case, the model helps improve hygiene, food safety and soil fertility in sub-Saharan Africa while producing energy, jobs and opportunities for students on a local agricultural schools (www.diouma.nl).

References and additional information

Contact Name: Guido Bezzi, Head of Agronomy Area

Affiliation / Organisation: Consorzio Italiano Biogas – Agronomia@consorziobiogas.it

Additional information:
CIB aggregates and represents the Italian area of biogas and gasification in agriculture. CIB is an instrument wanted by the producers for producers. It is the first voluntary Italian network that brings together manufacturers of biogas and syngas from renewable sources (mainly agricultural biomass), business or industrial companies that supply equipment and technology, bodies and institutions that contribute in various ways to achieve social purposes. CIB was founded in March 2009, and it has a national coverage. It is the Italian landmark in biogas and gasification sector that offers real indications to its members in order to improve the production process and guide the choices on national norms.

Today, CIB aggregates 548 ordinary members (farms with biogas plants – total power installed near 260 MW), 44 company members (manufacturers of biogas plants), 11 institutions and 60 partners (companies operating in the world of biogas).

Link with information about the good example:
http://www.consorziobiogas.it/Content/public/attachments/372-Biogasdoneright%20-%20LowRes.pdf

Publications:

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Heggenstaller A.H. (2008), Productivity and nutrient dynamics in bioenergy double-cropping systems, Agron. J., 2008, Vol. 100 – 1740-1748.

3.2 Biogas from livestock waste to reduce pollution in Lake Tai, China

Key lessons learnt

A combination of two different policy (promotion of biogas plants by the China government) and project (Japan International Cooperation Agency's [JICA] promotion of digestive juice for organic fertilizer) can reduce water pollution; just only the promotion of biogas plant is not enough.

Introduction

Geographic location: Jintan and Lake Tai, China

Figure 1: Map of Lake Tai, China

Source: OpenStreet Map

Type of example: Both a governmental policy implemented by Chinese government and a cooperative project implemented by JICA.

Status:
The Chinese government is now promoting the installation of biogas plants in piggeries. It wants to reduce water pollutant from pig waste as well as produce bioenergy in piggeries by forcing the installation of biogas plants.

However, the biogas plants not only produce bioenergy but also digestive juice, and the piggeries drain the juice into the watershed. This was not expected by the Chinese government, and the initial purpose of installing biogas plants to reduce water pollutant was not achieved.

Therefore, the JICA project that utilizes this digestive juice was launched in 2010. The purpose of the project is to utilize digestive juice produced from biogas plants in piggeries as liquid fertilizer in arable land or paddy fields.

In the project, at first, digestive juice was used as fertilizer in 0.1 ha of paddy field experimentally in 2010, and the amount of digestive juice used was 13.3 tonne. As a result, the yield of rice increased by 1.38 percent, and fertilizer cost was reduced by CNY 65. In 2011, the area of paddy fields applying the juice increased to 1.3 ha, and a pipe line system to supply the juice to paddy fields was constructed so that a piggery can transport the juice more conveniently and less expensively. After finding that the juice can increase the yield of rice while also reducing fertilizer cost and collecting other various useful and meaningful data, the project was completed in 2012.

Bioenergy and water relationships

Positive impacts on water quality:

In Lake Tai, the third largest lake in China, extraction of water for domestic use was suspended in 2007 due to the worsening quality of the water. Previous research shows that 77 percent of the pollutant comes from the Jiangsu province. In addition, high burdens of COD, T-N and T-P mainly come from the agricultural sector, the shares of agriculture in total amount are 45 percent, 54 percent and 68 percent respectively, and other sources are domestic sewage and industrial waste water (Mizuochi, 2009). Livestock breeding represents the main agricultural pollutant. Therefore, a reduction of water pollutants from agriculture, particularly from livestock breeding, is a necessary and important factor in improving water quality in China. However, even if piggeries install biogas plants for the sake of water pollution mitigation, the pollution will remain unless the digestive juice from the biogas plants is utilized. If it is not utilized, the juice is dumped into the water basin. Utilization of digestive juice from biogas plants for liquid fertilizer in paddy-fields contribute to water pollution mitigation.

Positive impacts on water availability:

The extraction of water for domestic use from Lake Tai was suspended in 2007 due to the worsening quality of the water. If water pollution is improved, it will be resumed, and water will be more readily available.

Co-benefits:

By supplying digestive juice as organic fertilizer for farmers, piggeries can reduce waste treatment cost, and the farmers can obtain organic fertilizer from piggeries free of charge. The farmers can reduce fertilizer cost.

Prospects

Key enabling factors:

- Governmental regulation of water pollution;
- Understanding of applying liquid fertilizer; and
- Economically feasible cost for applying liquid fertilizer for both piggeries and farmers.

Main challenges encountered:

- Application of liquid fertilizer to arable crops: rice paddy is easy to apply liquid fertilizer, but arable land is not.
- Currently, piggeries do not receive a reward from farmers: farmers benefit without paying any cost. The government has to think of how to balance the cost and benefit between piggeries and farmers.

Potential for scaling-up and replicability:

- There is enough arable land to accept liquid fertilizer near piggeries.
- How much digestive juice can be consumed depends on whether there is enough arable land to accept digestive juice near piggeries. There are two ways to supply digestive juice to arable land: pipe line supply and transporting by tank truck. Pipe line supply is less expensive but constrained by geographic condition such as slope, existence of valleys, rivers, waterways and major roads.

- Governmental enforcement or financial support for installation of biogas plants.

References and additional information

Contact names and affiliations / organisations:
Ministry of Agriculture, Forestry and Fisheries (MAFF) in Japan

- Deputy Director: Keiichi Sugita
- Section Chief: Atsushi Tabata
- Officer: Mihoko Yoshii

Authors' names and affiliations / organisations:
Policy Research Institute, MAFF

- Chief Researcher: Takashi Hayashi
- Researcher: Daisuke Kunii

3.3 Reducing GHG emissions from the energy sector through the utilization of organic waste for energy generation in agriculture, forestry and agro-industries in Argentina

Key lessons learnt

Lessons learnt from the project preparation phase:

- In the case of international cooperation, agency involvement in project design is very useful, but local involvement and ownership is essential. Projects must be conceived and prepared with the participation of local actors (institutions, experts and beneficiaries) in order to reflect local preferences and needs, reality and possibilities and be embedded in local policies.
- It is important to identify barriers. Project design must address barriers and take into account the different time frames involved in overcoming them.
- Institutional and financial barriers can be more important than technological barriers. However, the need to fine-tune technology (mature or proven technology elsewhere) to local conditions must be recognized and built into projects.
- There is a need for professionals that understand both the agricultural/agro-industrial sector and the energy sector.
- Knowledge of biomass availability is essential for good project design. Geographic location, type, quality, access, available infrastructure, distance and other parameters highly influence the possibilities for success.
- Information on demand is crucial, especially for systems not connected to the grid and self-supply projects.
- Agricultural producers are not energy producers; thus, business models adopted to agricultural/agro-industrial entrepreneurs must be conceived from the point of view of the agricultural/agro-industrial unit and must differ depending on the level and nature of direct involvement in the management of energy generation that can be expected of each subsector actor and scale of operation.
- Scale criteria are different in each sector. Large agricultural producers are generally small energy generators. Incongruous programmes can result from failing to recognize this distinction.

Introduction

Geographic location: Argentina, countrywide

Type of example: Policy with demonstrative projects and capacity building.

Status: The example has Global Environment Facility (GEF) PIF clearance, currently starting full project preparation. Project implementation expected to begin in December 2016 and last four years.

Bioenergy and water relationships

Positive impacts on water quality:
Reduction in contamination from accumulated and improperly managed waste; good practice in bioenergy generation and modern technology.

Current waste and manure management practices in Argentina are not adequate and compromise water quality. This is particularly true for wet biomass waste, resulting from livestock production, meat packing and dairy farms as well as sugar mills, among others. Studies of Argentine livestock farms have found contamination of farms' own water supply, with cases of animal disease resulting in economic losses and exposing people to contaminants in their drinking water. Agricultural and livestock production are important activities nationwide, and inadequate waste management is, therefore, a problem of significant magnitude, particularly in regions and specific localities where the biomass waste producing activities are most prevalent.

A few examples of current practices follow:

- It has been estimated that 69 percent of dairy farms discharge effluents to stabilization ponds. In the majority of cases, these ponds are not designed for treatment but are ditches left from farm construction; the remaining farms discharge to water bodies (10 percent), soil (9 percent), runoff water culverts (7 percent), and 5 percent re-use.[1]
- Confined pig operations also predominantly discharge to ponds, rarely properly designed, in general without separation of solids. The pond effluent is later scattered in fields.[2]
- Feedlot operations are also characterized by deficient waste treatment, with estimates of 46 percent of farms doing no treatment at all, and 34 percent disposing effluents in an "unspecified" way.[3]

Table 1 is an estimate of wet biomass generated per year.

Table 1: Estimates of wet biomass generated per year

Source	Efluent (annual)
Meat packing	5 mill de m^3 (3000 mg/lt BOD)
Sugar Mills	2,27 mill m^3 de vinasse (50.000 mg/l BOD)
Dairy Farms	12,4 mill m^3 (1.000 mg/lt BOD)
Pig Farms	9,7 mill m^3 (15.000 mg/lt DBO)
Feedlots	1,38 millones tn manure

Source: COPIME, Congreso 2014

Accumulation of dry biomass waste is also a problem, but the scale of the problem regarding water quality is relatively minor in comparison to wet biomass waste streams. Estimates of available and accessible dry biomass surplus can be found in Table 2.

[1] Herrero, M. A., Aguirre G., Camoletto J., Castillo A, Catracchia C., Charló V., González Pereyra V., Goransky R., Koror S., La Manna A., Salazar Sperberg F., Sardi G., Sardi G., Sharvelle S., 2009. Uso del Agua, Manejo de Efluentes e Impacto Ambiental. Asociación Pro Calidad de la Leche y sus Derivados (APROCAL). Terceras Jornadas Internacionales de Calidad de Leche.

[2] UNCPB 2008. Evaluación, diagnóstico y propuestas de acción para la mejora de las problemáticas ambientales y mitigación de gases de efecto invernadero vinculados a la producción porcina, avícola y bovina (feedlots y tambos). Universidad Nacional del Centro de la Provincia de Buenos Aires. Facultad de Ingeniería.

[3] UNCPB, 2008.

Table 2: Estimates of available and accessible dry biomass surplus

Source	Mt $_{dry\ matter}$/yr
Agriculture (sugar cane cultivation residues and rice straw) [a]	1.3
Pruning and renewal of perennial crops[a]	1.9
Sawmill residues from wood from forest plantations[a]	0.8
Processing industry (rice, sugar, peanut, olives) [a]	1.8
Forestry residues – forest plantations[b]	3.1
Partial use (5%) of forestry residues from native formations[c]	4.7
TOTAL	**13.6**

[a] WISDOM with data from 2007 [b] PROBIOMASA in 2014 [c] 5% of the amount of commercially available forestry residues from native formations estimated by PROBIOMASA in 2014.

Source: NAMA Probiomasa, Secretariat of Energy and Ministry of Agriculture, Livestock and Fisheries of the Republic of Argentina.

The example consists of a project to promote energy generation from waste from agricultural, forestry and agro-industrial sectors and thus is expected to result in a significant reduction of waste and effluents released into the environment. The project consists of three components:

- Strengthening of the policy and institutional framework through a proposal to improve the regulatory and institutional framework for bioenergy generation, off-grid systems, self-supply and connection to the grid and facilitate finance.
- Strengthening of the knowledge base and competences through the creation of a Technical Center of Excellence (TCE) dedicated to applied research, baseline information and data management, capacity building, project preparation and promotional campaigns. The center will establish design quality and technical performance standards.
- Demonstration of low-GHG energy generation technologies based on agricultural and agro-industrial waste utilization through the installation of three demonstrative cases of waste to energy generation, planned to cover different types of technologies and sectors.

The project will contribute to improved water quality through the transformational effect it aims to bring about in inserting waste-to-energy technology in the agricultural and agro-industrial sectors. Three demonstration plants are expected to reduce effluent streams and improve water quality in the sites they are installed through transforming the effluent and waste streams of a sector into an energy source. This will result from policy reform and knowledge and competence components (1 and 2) that are to complement the demonstrative plants (component 3).

Bioenergy generation plants also have their own waste and effluent streams. The project will promote best practices, including in bioenergy plants' waste and effluent management so that water quality will not be compromised from these sources.

<u>Positive impacts on water availability</u>:
The project is expected to bring about improvements in water availability as a result of its promotion of best practices. Process improvements and water efficiency can be expected to occur as a result. In addition, water availability should also result from the substitution of water-intensive energy sources (mainly diesel-oil, oil and natural gas).

<u>Positive impacts on biomass/bioenergy production</u>:
Since this is a waste to energy project, no increments in biomass availability are expected nor sought.

Co-benefits:

Co-benefits include: diversification of the energy matrix; energy security and local reliability; reduced dependence on imported fossil fuels; support for the national grid through decentralized electricity generation; local development; establishment of new skills and competences in the value chain of waste-to-energy technologies; creation of a new goods and services sector; promotion of private sector investment; reduction of GHG emissions and compliance with Intended Nationally Determined Contributions (INDCs); general improvements in environmental quality and health; and reduction of community conflict due to waste and odours.

Prospects

Key enabling factors:

The main enabling factors for the project are:

- The existence of incipient legislation to facilitate connection to the grid.
- The existence of public programs to promote the use of non-conventional renewable energy (NCRE) and bioenergy, such as PROBIOMASA program, GENREN program (preferential tariffs); PERMER (off-grid renewables); Act 26.190/2006 (to increase NCRE in grid); National Institutes of Agricultural Technology and of Industrial Technology programs.
- Cost of reliance on imported fossil fuels.
- Waste as a generalized problem of agricultural and agroindustrial sector, including forestry and wood mills. Conflict with communities.
- Tightening of legislation and controls regarding waste and effluents from agrosources in the provinces where production is most significant.
- Solving problems of local energy reliability and security.
- Expected local economic development and adaptation benefits.
- Agriculture/LULUCF and energy as main GHG emitters.
- Availability of biomass waste and Argentina's under-utilized potential for generating energy from this source.

Main challenges encountered:

Table 3: Main challenges encountered while implementing the policy and demonstrative projects

Type of Barrier	Description
Regulatory Barriers	• Complex regulation and diverse transport tariffs at the provincial level for electricity distribution.[4] • Complex process for admission to the electricity wholesale market, particularly affecting medium and small projects. • Delayed introduction of the simplified "fast track" mechanism allowing the inclusion of renewable energy projects up to 2 MW.
Economic Barriers	• Prevalence of low energy and electricity tariffs.
Financial Barriers	• Scarcity of local financial resources for renewable energy projects: high interest rate, restrictive terms, lack of experience and tools necessary to perform technical evaluations of bio-energy projects. • Insufficient financial mechanisms or incentives for bioenergy projects (trusts, mutual funds, specific lines of funding, grants, etc.).

[4] Electricity distribution is largely driven by provincial companies.

Type of Barrier	Description
Institutional Barriers and Promotion	• Limited awareness of bioenergy options by the private sector. • Need for awareness and outreach programmes. • Need to demonstrate proper utilization of biomass for energy generation, thereby avoiding bad practices. • Limited inter-institutional coordination and collaboration of agencies, institutes and universities working in the bioenergy field.
Technology Barriers and Delivery Skills	• Limited accurate information on biomass at local level. • Scarce qualified professionals and technicians in industries affecting project design and adding to technical and perceived risks[5]. • Limited experience on the preparation and evaluation of full feasibility studies for bioenergy projects. • Limited experience with bioenergy projects (affects project maturity and potential advantages of biomass energy over other sources).

Potential for scaling-up and replicability:
The project is replicable as it addresses a common problem of most societies, which is the disposal of waste and the health and environmental risks associated with it. It is a waste-to-energy project, targeting the agricultural sector, which also is an important sector in most developing economies.

The barriers identified are common in many developing countries: legal, institutional and financial as well as technological. The project is designed to address all barriers either directly, or by complementing other policies, and specifically includes non-structural components (legislation, institutions, finance, skills and capacities) as well as structural (construction of three demonstrative waste-to-energy plants). Scaling-up is made possible through this multiple focus approach, which aims to generate the conditions for private-sector investment. Thus, it is expected that a new waste-to-energy sector can be established and eventually become self-sustaining.

References and additional information

Contact name and affiliation / organisation: Miguel Almada, National Coordinator of the Project for the promotion of energy from biomass (PROBIOMASA)

Additional information:
The project consists of a GEF grant of US$ 6.000.000 and US$ 27.000.000 of co-financing, involving Argentine public funds in the amount of US$ 6.800.000), funds from financial institutions, and private investment. The GEF Grant Implementing Agency is the United Nations Industrial Development Organization, and the main executing partners are the Ministry of Agriculture, Livestock and Fisheries and the Secretariat of Energy through the PROBIOMASA Program.

Link with information about the good example: www.probiomasa.gob.ar

Publications:
GEF Project PIF https://www.thegef.org/gef/project_detail?projID=9053

[5] Especially in small and medium industries, project risks are perceived as high by external capital providers, making access to bank financing or government subsidies difficult.

3.4 Management of water resources in the sugarcane agro-industry in Brazil

Key lessons learnt

- The self-imposed goals of the sector are voluntary since there is no restriction on the use of water when used correctly.
- These goals have become standards of some certifications, such as Bonsucro and Green Ethanol in São Paulo.
- The level of investment required is about US$ 2 million per ethanol/sugar plant, with treatment and complete closure of the water systems.
- In order to achieve the lowest levels of 0.5 m^3 per tonne the water inside the sugar cane should be re-used, which requires more advanced and costly technologies (investment of at least US$ 20 million per plant)
- The cane planting in Brazil is essentially rainfed as opposed to several other countries, which often is beneficial from a sustainability point of view.
- Normally fertigation and rescue irrigation occur with effluent reaching up to one third of the sugar-cane area with very low water layer (60 to 120 mm).
- In the northeast there is a larger use of water resources for irrigation due to water deficit, using supplemental irrigation (200 to 400 mm per year), even then only in a part of the plantation.
- Intended mainly to reach a productivity similar to central-south region of 90 tonnes per ha, much higher than the average in the region, in which rainfed production is below 50 tonnes per ha.

Introduction

In Brazil, there are two sugar-cane producing areas. One is located in the north-northeast and accounts for about 12 percent of the production area of sugar cane (a part with irrigation), and the other is in the center-south with the remaining 88 percent, (essentially rainfed production).

In the center-south, the harvest takes place from April to December, and in the north-northeast, the harvest begins in September and ends the following year in March.

This project deals with an approach to the uses and re-uses of water in the Brazilian sugar-cane industry. It will be partially implemented in a majority of Brazilian mills, and it will be fully implemented in some units.

Bioenergy and water relationships

<u>Positive impacts on water quality</u>:
With respect to water quality, the "Management of Water Resources in the Sugarcane Agro-Industry" calls for a zero goal in the discharge of effluents. The extraction of water in the sugar-cane industry has decreased rapidly as a result of environmental legislation and the imminent implementation of a system for charging for the use of water resources, with the promulgation of the Constitution of 1988. Water extraction, which had been 15 to 20 m^3 per tonne of cane around three or four decades ago, has been minimized with the rationalization of water use via re-utilization and the closing of these systems. On average, water extraction for the industrial process in the sector is 2.0 m^3 per tonne of cane. Considering the inherent losses stemming from evaporation and incorporation, the final effluent

is about half, i.e. 1.0 m^3 per tonne of cane and also more highly concentrated with organic material than in the past, which allows for the re-use of effluents from the cane field together with the vinasse and promotes fertigation.

As a result, the pressure on water resources is reduced, along with the costs associated with the treatment of effluents and costs stemming from charges for the use of water for the release of organic discharge. The remaining organic material (Chemical Oxygen Demand [COD]) stays in the cane soil, and the layer of water applied to the crop in the dry season (the cane harvest and consequent industrial production take place in the winter) promotes an irrigation that saves the remnant cane roots and helps with their budding.

The great beneficiaries are the water resources that do not receive any remaining pollution load, not even the limited amount allowed by environmental law, promoting in this way the quality of surface water.

Positive impacts on water availability:
With respect to the quantity of water, "Management of Water Resources in the Sugarcane Agro-Industry" produces a huge positive impact with the catchment goal of 1.0 m^3 per tonne of cane. To confront the needs of the industrial process in the production of sugar and ethanol, the mills and distilleries have an estimated average use of approximately 22 m^3 per tonne of cane. Looking at the past, this was the level of water extraction, since the practice was to release all of the generated effluent without worrying about its re-use. Currently, this is not what happens in the vast majority of producing units in the sector. Due to the reutilization of water in various systems, with or without treatment, and also the rationalization of water use, the resulting rate of water catchment is considerably less, according to the technological stage in which the industrial unit finds itself.

Just four large systems represent nearly 90 percent of the need for industrial water. The greatest percentages of water use are associated with the cooling of equipment, such as evaporators and heaters (36 percent) and in the cooling of the distillery (vats, cane juice and condensers) whose portion of use is 35 percent.

There is also a large amount of water use in the scrubbing of gases from the chimney (5 percent) and in the cleaning of the cane (10 percent), with the latter constantly diminishing with the abandonment of burning cane in the harvesting process, implying a dry cleaning process without the use of water.

With the aim of reducing the pressure on water resources, the sector established a goal for water extraction at 1.0 m^3 per tonne of cane processed. As for effluents, the goal is to reduce their release to zero via the utilization of waste in the fertigation of the crop together with the vinasse. In this scenario, the consumption of water, which is the difference between the intake and the release, would be roughly equal to the extraction level, i.e. 1 m^3 per tonne of cane. In reality, this consumption level is slightly higher since the cane itself brings with it around 70 percent of the water that indirectly is also consumed in the process. The utilization of the water contained in the cane could be re-used with tertiary treatment, inaugurating a new concept for the industrial process, i.e. the "Water Mill," which could lead to a technological leap in this area.

Recent data indicate that the goal of water extraction of 1.0 m^3 per tonne of cane already is a reality in a large share of the mills. It can be said that the sector tends to have an average re-use index of 95 percent, which is the extraction of only 1.0 m^3 to replace the losses from the 22 m^3 of water needed in recirculation. Technologies currently in development, and upon being developed, will make it possible to take better advantage of the water contained in the cane. They will also make it possible to achieve a level of water extraction below 0.5 m^3 per tonne of processed cane, and naturally with the technical and economic viability of these new technologies, making it possible to achieve a level of water re-use of 98 percent.

Positive impacts on biomass/bioenergy production:
The current average water draw, primarily on the part of mills in the south central cane-growing region, is close to 2 m^3 per tonne of cane. However, several mills are at a more advanced technological stage, capturing only 1 m^3 per tonne of cane with the "Management of Water Resources in the Sugarcane Agro-Industry."

In the balance of water catchment and utilization, the industry practices a re-use index in its industrial process of 95 percent. This results in less pressure on new sources of water supply, and at the same time, the practice of agricultural re-use of the waste and residues in the fertigation of the sugar-cane crop contributes to maintaining the quality of water sources, which do not receive the remnant pollution.

The recovery and treatment of industrial waste at the mills and distilleries are basically composed of internal controls associated with their management and type of use. The techniques employed comprise: recirculation; reutilization of waste materials; the use of more efficient equipment and less-polluting processes; and the employment of crop fertigation. As a result, one gets: less water and pumping energy spent; better use of the raw material; less spent on external control; use of nutrients (potassium and nitrogen) and organic material in the field with productivity gains; and soil improvement.

The treatment of water effluent from washing cane is done via decantation and the effluent from the gas scrubber in the chimney via decantation-flotation. Effluents from cooling systems have their temperature adjusted, and effluents from cleaning the floors and equipment are treated in sandboxes and oil separators. Waste from communal housing and work areas is treated as recommended by established environmental standards.

Co-benefits:
As for international environmental certifications, the sector has adopted the Bonsucro standard, which evaluates the continuous improvement of water resources. This standard establishes that, in the industrial area, the captured water be less than 20 litres per kg of sugar produced and 30 litres of water per kg of ethanol produced (~37.5 L/L ethanol). In agriculture, captured water for irrigation should be less than 130 litres per kg of harvested cane, i.e. 130 m^3 per tonne of cane. In the case of Brazil, with an estimated average agricultural yield at 85 tonnes per ha, the sustainable limit of water irrigation recommended by Bonsucro is high, around 1,100 mm per year, which is way beyond the amount used as supplemental or crop-saving irrigation in a small number of cases in Brazil's sugar-cane sector.

The limits recommended by Bonsucro for industrial water capture for the process of fabricating sugar and ethanol, assuming average industrial productivities of 100 kg of sugar per tonne of cane and 85 litres of ethanol per tonne of cane, are approximately 2.0 and 3.2 m^3 of water per tonne of cane. With the statistics presented in this document, one can see that Brazilian mills are in a position to meet these international standards, and the majority of mills take the step of obtaining Bonsucro certification, demonstrating environmental sustainability in the use of water resources.

Prospects

Main drivers for implementing the practice:
The main challenge for the sector concerning water is undoubtedly financial in nature since technologies are already sufficiently developed. The sector's self-imposed goals of catchment of 1.0 m^3 per tonne of cane, zero release of effluent and consequently consumption of 1.0 m^3 per tonne of cane, are of a voluntary nature, since there is no restriction on water use when employed properly, but there is the need to control pollution in accordance with legislation. At any rate, the sector has gradually sought to meet the goals, seeing that the average catchment at the national level is around 2.0 m^3 per tonne of cane, with exemplary cases of industrial units with water catchment and consumption below the self-imposed goal. The level of investment for units falling outside of these parameters is approximately US$ 2 million with the treatment and complete closing of water systems, which is certainly not very attractive given the sector's current crisis situation. In order to advance even further on the water question, attaining lower levels of 0.5 m^3 per tonne of cane with the reutilization of water contained in the cane itself, the more advanced technologies needed are much more costly. The concentration of vinasse with the use of condensed water and the tertiary treatment of effluents aimed at their re-use in the industry, demand investments of at least US$ 20 million, amount much higher than the industry can support under current economic conditions.

Potential for scaling-up and replicability:
The efficient "Management of Water Resources in the Sugar-cane Agro-Industry" is applicable to all of the approximately 400 industrial units in Brazil. It is even relevant for those developing countries in the Americas and Africa that have a vocation for the production of ethanol from sugar cane for internal consumption as well as export to those markets with the requirement of blending ethanol with fossil fuels to meet GHG reduction goals. Currently, any new unit that is planned for construction in Brazil should take into consideration the extraction and water-use goals outlined in this document, with the goal of meeting international certifications, principally that of Bonsucro. They must do so to have full access to external markets, which undoubtedly increases the investment costs for new units.

References and additional information

Contact name: André Elia Neto

Affiliation / Organisation: Brazilian Sugarcane Industry Association (UNICA)
UNICA is the largest association of producers of sugar and bioethanol in Brazil. With more than 120 members, it represents more than 50 percent of the ethanol and 60 percent of the sugar produced in Brazil. Its mission is to create the conditions for improving the institutional environment so as to favour the competitiveness of the sugar-energy sector in Brazil, with a vision based on:

- The production of sustainable energy and food for people;
- Contributing to the environmental, social and economic sustainability of the country; and
- Promoting energy and food security for the planet.

Additional information: http://www.unica.com.br/download.php?idSecao=17&id=22413381

Publications:
Management of Water Resources in the Sugar-cane Agro-Industry

3.5 Sustainability in movement: Water energy nexus in southern Brazil

Key lessons learnt

- Need of a modern regulatory framework to attract investors;
- Need of technology tropicalization to reduce costs, focusing on the ratio on implementation, operation and maintenance;
- Need of appropriate technology on refining processes;
- Need of knowledge on biomethane compressing and decompressing; and
- Need of specialized laboratories to make analysis of the biomethane quality.

Introduction

Biomethane is a fuel produced with animal or vegetal residues, which makes it a renewable energy source. Its production process, besides providing rural sanitation, is simpler than fossil fuels produced with oil. Therefore, biomethane becomes competitive for those who can produce their own fuel. Its performance is 20 percent higher than gasoline and 100 percent higher than ethanol. The final cost of biomethane per kilometer is 40 percent less than gasoline.

Figure 1: Scania Euro 6 bus running with biomethane at ITAIPU Binacional premises

The International Center on Renewable Energy-Biogas (CIBiogás) developed a project in partnership with ITAIPU Binacional, Scania do Brasil, Haacke Farm and the Itaipu Technology Park Foundation. Haacke Farm is one of the partners of CIBiogás, in the context of the Demonstration Units of Biogas supported by the Center. Haacke Farm is located in Santa Helena, Paraná in southern Brazil, and it has 84,000 laying hens and 750 heads of cattle.

Since 2013, around 35 m³/day of liquid effluents have been directed to a covered lagoon biodigester for anaerobic digestion of residues, yielding a daily production of 1,000 m³ of biogas. The unit uses this biogas for electric energy generation with a 112 kVA aspirated power generator.

The electric energy generated at Haacke Farm is used during peak hours when energy costs are higher. The Farm also has a standby system that ensures perennial provision of electric energy to control the laying hens' temperature, preventing sudden energy supply interruption and the resulting death of animals. The Farm also produces biomethane for mobility. The purpose of the project, “Sustainability in Movement,” is to prove that biogas is a highly efficient energy source, able to produce electricity, thermal energy and biofuel. The quality of the produced biomethane has been evaluated and approved by tests conducted with a Scania Euro 6 bus that has been operated in the Itaipu Dam premises for 21 days.

Figure 2: Laying hens at Haacke Farm

Table 4: Technical data of the project

Location	**Santa Helena/PR**
Beginning of biogas production	**2013**
Activity	**Laying hens / beef cattle**
Capacity	**84,000 laying hens and 750 heads of beef cattle**
Effluent Output (m^3/day)	**35**
Biogas production (m^3/day)	**1,000**
Biogas utilization	**Electricity (generator) and Vehicle (biomethane)**
Biofertilizer utilization	**Yes**
Monitoring	**Residual Biomass / Biomass Composition / Biogas and Biomethane Quality Control**

Table 5: Results of the Scania Euro 6 performance

Distance covered	**1.512 Km**
Transported passengers	**3.250**
Amount of CO2 emission prevented	**20 tones**
Results	**The yield of the fuel originated from biogas was similar to the one of diesel vehicles, with an average of 1.92 km/m3.**

CIBiogás is providing biomethane to supply part of the ITAIPU Binacional vehicle fleet. Actually, Itaipu counts with 250 official vehicles, among which 106 are flexible, running with gasoline and/or ethanol; 53 running with electricity; 48 with diesel; and 43 with biomethane. ITAIPU Binacional's purpose is to have 50 percent of its fleet running on renewable fuels by 2020.

Figure 3: Itaipu vehicles running with biomethane

The biomethane produced to supply Itaipu vehicles is produced at Haacke Farm, where it is compressed and put in cylinders. Then, the cylinders are transported to a biomethane station located at the Itaipu Technology Park, which is inside ITAIPU Binacional area.

Figures 4 & 5: Biomethane station and cylinder

Bioenergy and water relationships

The biogas production and its refinement to produce biomethane is directly related to water as the agricultural residues and animal dejecta, the main biogas source, are extremely pollutant to hydro resources. In general, those residues and dejecta are treated in a precarious manner, which directly affects the environment, soil and groundwater. Removing this animal or vegetal biomasses from the environment to produce biogas and biomethane provides rural sanitation, and it is also an excellent energy source.

It is important to highlight that rural sanitation is extremely important in countries that have high agricultural and livestock production, such as Brazil. According to the United Nations, Brazil will be the biggest animal protein exporter by 2025. For Brazil to reach this goal it will need to double the number of confined animals, which would not be allowed at present time due to environmental regulations. Nevertheless, if this organic matter is removed from the environment to produce biogas and biomethane, the following goals could be simultaneously achieved:

- Rural sanitation;
- License to increase number of confined animals;
- Energy self-production;
- Income and job generation;
- Distributed generation enhancement;
- Increased renewable energy supply to the national energy matrix; and
- Reduction of rural exodus;
- Reduction of greenhouse gases emission

All of those aspects are also directly related to the enhanced social conditions of farmers and their families. There would be a reduction in the bad smell from the organic material as well as the mosquito population. Rural exodus would also decrease once the farmers' children face a more comfortable environment, with new possibilities to increase their incomes through becoming an energy producer, besides their traditional productions.

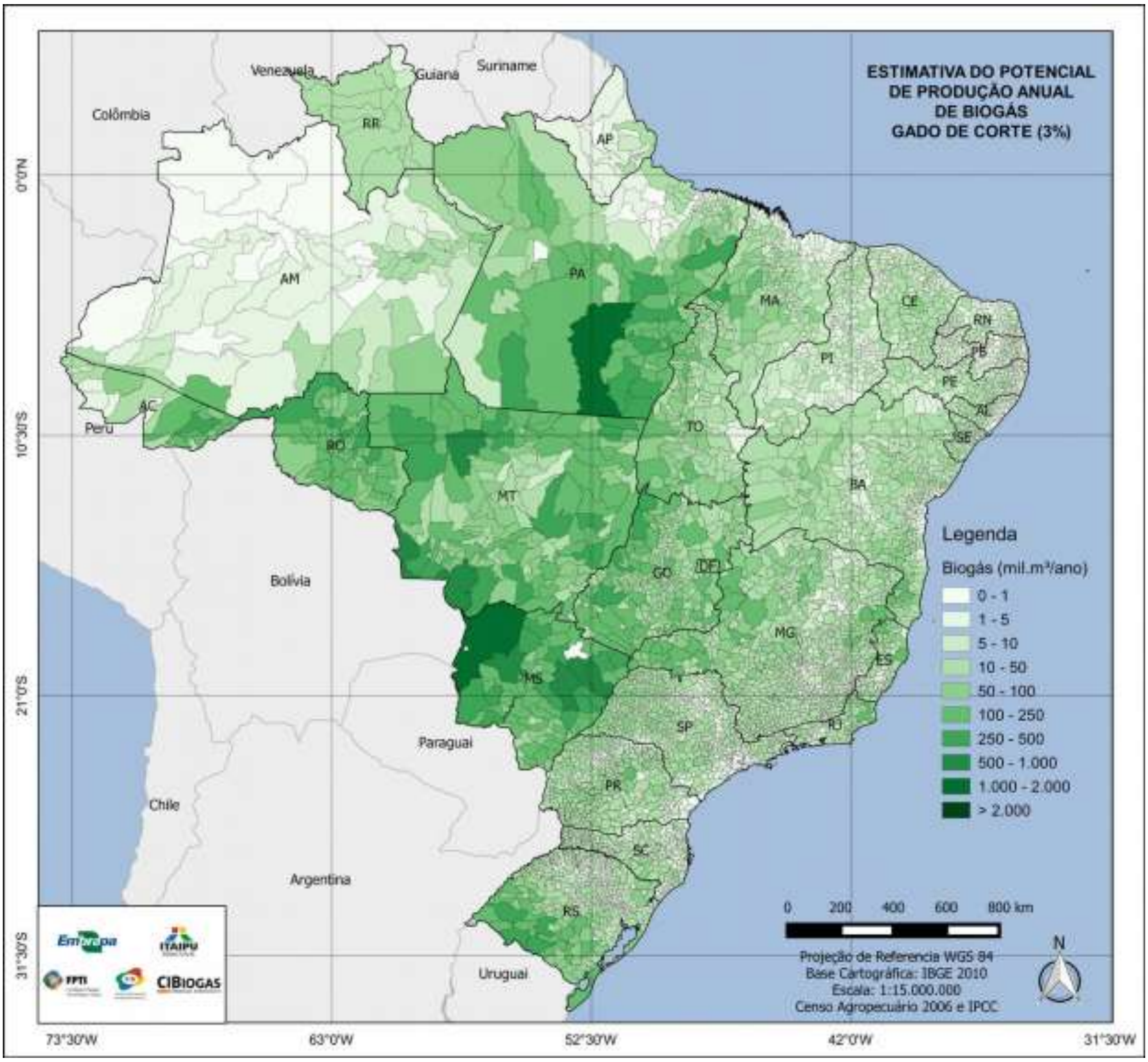
At the present time, it is easy to see that farmers' children are moving to cities due to the lack of comfortable conditions they experience by staying in the field. Nevertheless, the valuation of biogas and biomethane have shown different results in the CIBiogás Demonstration Units, where farmers' children are returning to the rural areas thanks to the possibility to include a new product in their portfolio, the energy, in addition to the traditional animal and/or agricultural ones provided by agribusiness.

Finally, the world is rapidly entering the era of gaseous fuels. Not only with the fossil fuels from the oil chain, but also with the so-called unconventional gases. Biogas is one of the options that Brazil can utilize to enter this era of gases without the environmental and social consequences of fossil gas. Based on the residual biomass that is a characteristic of Brazilian development, which produces organic waste on large scale, that is the prime driver for biogas production.

Prospects

To replicate this initiative in a broader perspective, CIBiogás-ER established a project with the Brazilian Agricultural Research Corporation (EMBRAPA) to conduct a review of all the biogas potential in Brazil and the possibility of replication of this proposal. The map below can be used to explore all the biogas potential in Brazil to replicate this proposal in the country where the darker areas represent the Brazilian replication potential.

Figure 6: Map of Brazilian biogas potential



References and additional information

Contact name: Marcelo Alves de Sousa, *Institutional Relations Manager*

Affiliation / organisation: International Center on Renewable Energy - Biogas | CIBiogás-ER, www.cibiogas.org

Additional information:

Link to the project Biomethane for Mobility: https://cibiogas.org/en/haacke_farm

Link to the presentation video on the project: https://www.youtube.com/watch?v=q6TG-5vAOi0

NB. Please, enable the subtitles by clicking the subtitles icon

3.6 Vinasse concentration for water use reduction in Piribebuy, Paraguay

Key lessons learnt

- The implementation of this project brings simultaneous solutions to both the environmental impacts of vinasse management and the poor productivity of soils for sugarcane cultivation.
- Vinasse is normally stored in lagoons with the possibility of contaminating watershed and rivers.
- Permeate output is pure water and reject output is concentrated vinasse.
- Permeate output has the ideal acidity to be re-used in the fermentation process at ethanol plants.
- Concentrated vinasse can be used to increase sugarcane yield.

Introduction

Vinasse is a by-product of the ethanol distillation process. The production ratio of vinasse to ethanol is around 15:1 in volume. This project consists of a vinasse concentration unit at a sugar-cane ethanol plant.

The final products are water, which is re-used in the fermentation process, and concentrated vinasse, which is utilized for fertigation. Total Investment in this project is US$ 400,000, and it is 100 percent private. The producer is a small plant, and sugar-cane suppliers are small farmers. The unit equipment is made in India under German licensed technology.

This example is of a specific project that has been implemented, and the vinasse concentration plant has been operational since May 2012. The project is located in the city of Piribebuy, Paraguay, which is 72 km from the capital, Asunción.

Figure 1: Map of geographic location of project

Bioenergy and water relationships

The implementation of the vinasse concentration unit that utilizes reverse osmosis as well as a plate and frame membrane module system allows the ethanol production company to avoid watershed contamination.

The implementation of this project simultaneously brings solutions to both the environmental impact of vinasse management and the poor productivity of soils for sugar-cane cultivation.

Vinasse can have up to 25,000 ppm of COD and up to 10,000 ppm of BOD. It is stored in lagoons that could potentially contaminate watersheds and rivers.

Permeate output is pure water with 150 ppm max COD and 30 ppm max BOD, and reject output is concentrated vinasse with a density value of 30-45 Brix.

The plant's capacity is 156 m^3 per day of vinasse.

Permeate output has the ideal acidity to be re-used in the fermentation process at the ethanol plant, which means that less make-up water needs to be pumped from the watershed or river.

The recovery of the RF PO (vinasse concentration unit) permeate conservative value is 75 percent, which represents 117 m^3 per day of pure water that is re-used at the ethanol production plant in the fermentation process. This reduces the need to pump water from the watershed or river.

Furthermore, fertigation with reject concentrated vinasse saves energy and money in the pumping and distribution system. Only 25 percent of the original volume used for fertigation needs to be distributed through pipes and trucks.

The application of vinasse as fertilizer and irrigation input increases soils' productivity along with sugar-cane yields, resulting in more tonnes per ha and more ethanol production using the same sugar-cane cultivation area. Up to 50 percent yield increase is expected in a five-year time frame.

Prospects

The main driver in the implementation of this project is the environmental framework in place in Paraguay regarding watershed contamination at ethanol plants.

The selected technology was considered to be the best alternative for this particular application, considering results in similar applications in Latin America and India as well as operational issues like steam availability at the plant.

RO membrane module systems are based on the plate and frame membrane module system, which is an open channel filtration system that allows for the application of membrane based separation systems to treat high COD/BOD streams without inherent problems of membrane fouling.

This module is the world's only series flow module, thus, ensuring the highest resistance to membrane fouling. Unlike other membrane modules, only a single flow path ensures 100 percent clean open channel.

These membrane units have been in use worldwide for the past three decades, with a large percentage of them being used to treat effluents with high COD/BOD – some of them even exceeding 140,000 ppm.

The main reason for this project's implementation is to avoid being legally prosecuted for watershed contamination because of the vinasse discharge. There are strict legal regulations regarding watershed contamination at ethanol plants in Paraguay.

It is more economical to pump highly concentrated vinasse (45 Brix) than vinasse (5 Brix), which contains a lot of water. The permeate water can save money at the plant through its re-use at the fermentation process. Thus, permeate recirculation and fertigation, which also reduces sugar-cane cost thanks to the yield improvement, will improve competitiveness of sugarcane-based ethanol against corn-based ethanol.

In that way, key enabling factors are environmental and economic.

The most important challenges were technical as this is a new wastewater treatment technology at ethanol plants. Traditional methods in place at ethanol plants in Paraguay are fertigation without concentration or aerobic treatment.

There have been several cases where vinasse was directly pumped into watersheds or rivers, accidentally or on purpose.

Among the challenges encountered, it was quite hard to convince the ethanol plant owner to invest in this technology. Another important issue was the operation and maintenance costs, particularly the membrane cost. The feasibility study focused on the economic outcome, so it was important to have a good estimation of these costs.

The membranes' performance and useful life is a function of operation variables, especially operating pressure and operation continuity. The correct maintenance and cleaning of membranes is also critical. The system is designed to operate 22 hours per day with two hours per day for maintenance and cleaning.

As the system has a modular architecture, up-scaling inside the plant and replication at other plants is easy. It is possible to implement the system in steps, taking at the beginning only 50 percent of the vinasse volume and utilizing other traditional methods for the remaining 50 percent. It is also possible to take the results from a small plant and scale it up for a bigger plant in a linear way.

Another important technical aspect is the possibility of increasing the reject concentration by increasing the number of passes through the RO-PT membranes.

The system works as an independent unit. It does not require steam from the process, and it does not need to be connected to existing equipment. It is necessary only to connect the output of the vinasse in the distillation column to the input of the unit and to power the unit. In that way, this complete modular system can be easily installed at any ethanol plant. Process connections are the same.

The following tables show that results can be readily achieved by increasing the RO plant recovery from the current conservative 75 percent to the theoretical maximum of 90 percent.

Table 1: Input product for ethanol plant

Input Product		
Item	**Value**	**Unit**
Name	Vinasse	
Input Flow Rate	156	m^3/day
Concentration	<2	Brix
Conductivity	<5.000	μS/cm
COD	25.000	ppm max
BOD	10.000	ppm max

Table 2: Permeate output for ethanol plant

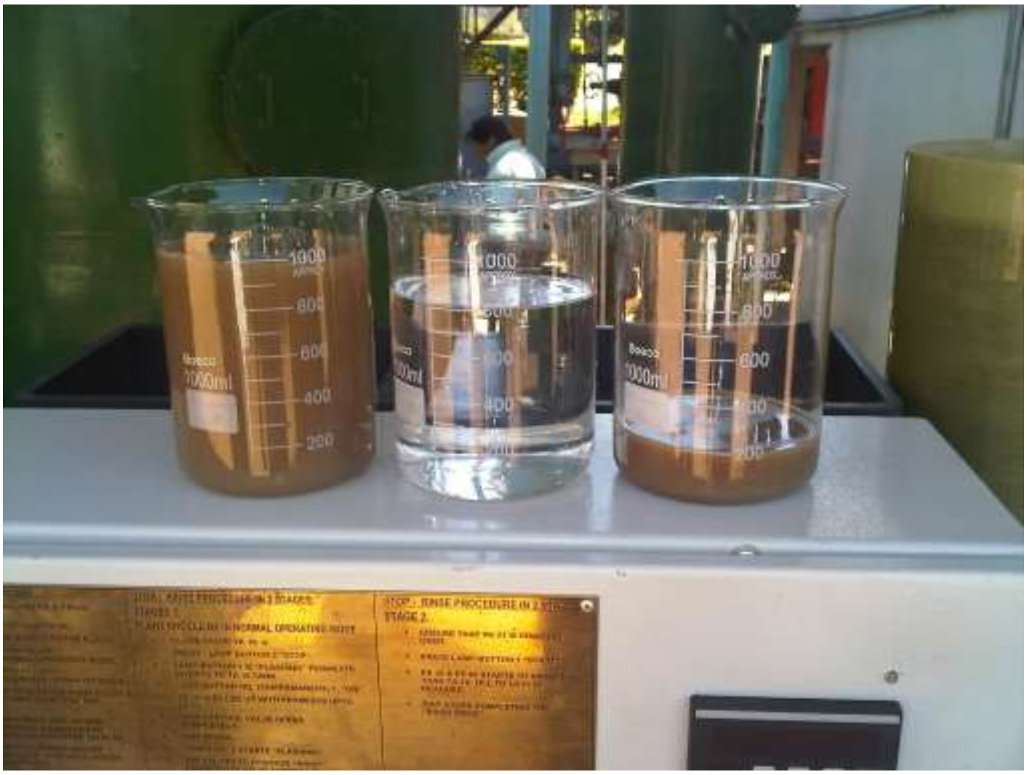
Permeate Output		
Item	**Value**	**Unit**
Name	Water	
Aspect	Colourless	
Output Flow Rate	140	m^3/day
Conductivity	<250	μS/cm
COD	150	ppm max
BOD	30	ppm max
RO Plant Recovery	90	%

Table 3: Reject output for ethanol plant

Reject Output		
Item	**Value**	**Unit**
Name	Concentrated Vinasse	
Input Flow Rate	16	m^3/day
Concentration	30-45	Brix
Conductivity	44.000	μS/cm

Figure 2: Modular equipment PT-RO

Figure 3: Results for RO plant recovery of 75 percent



References and additional information

Guillermo Parra Romero is the former Paraguayan Focal Point for GBEP. He served as the Manager of the Biofuels Multi-sectorial Board at REDIEX, the Investment and Exportation Network at the Ministry of Industry and Commerce from 2006 to 2010. He worked at Petropar for 21 years in several positions with emphasis in the bioenergy sector. Petropar is the state owned oil and ethanol producer company.

He is an electro-mechanical engineer and holds a Master of Science degree in control systems engineering from Oklahoma State University. He has more than 20 years of experience in the bioenergy sector.

Guillermo Parra Romero visited Rochem Separation Systems in India and was part of the project team for the two vinasse concentration units in Paraguay: at Petropar and Alcoholera Mussi. The following link corresponds to the presentation of Guillermo Parra Romero at the Bioenergy Conference related to these projects:

http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/2011_events/Bioenergy_Conference_Rome_10-12Nov2011/9_Day2_Parra.pdf

3.7 Use of vinasse in biogas production through anaerobic digestion in the Brazilian sugar-cane industry

Key lessons learnt

Cetrel's project's achievements can be summarized as follows:

- Demonstration of the applicability of anaerobic technology to the generation of electricity – provision of decentralized energy from a sustainable source to contribute to the national energy matrix;
- Full use of the biodegradable organic fraction contained in raw vinasse, which is usually lost to the atmosphere in the fertigation process – and reduction of GHG emissions related to sugar-cane crops;
- Contributions to the maintenance of surface water and groundwater quality by reducing raw vinasse's polluting load put into the fertigation process – loads that would otherwise percolate through the soil down to subterranean water resources or runoff to surface resources; and
- Possibility of re-using treated vinasse through the utilization of recovered water in a number of industrial processes, broadening the perspectives of a more rational use of water resources.

Introduction

Enterprise *Cetrel Bioenergia* (Cetrel) was created to act in the field of decentralized energy, utilizing residues and effluents of several origins. These are coproducts of other productive processes, and they can (if not must) be used energetically.

The choice of the sugar-cane industry as the stage for Cetrel's technology was strategic due to Brazil's international position of privilege in the sector as well as the sector's on-going remarkable national expansion.

In 2008, a research project was initiated with focus on the energetic appreciation of sugar-cane by-products. This project evolved from the laboratory scale, to pilot scale, and finally to semi-industrial (or demonstration) scale. In 2010, the semi-industrial scale project was initiated and was meant to produce about 0.87 MW of energy to be sold on the grid. After the establishment of a partnership with one of JB Group plants, the unit was installed adjacent to a sugar-cane plant in the city of Vitoria de Santo Antão, Pernambuco. The inauguration took place in April 2012.

The differential found in Cetrel's proposal is set on the efficiency and quality of the biogas generated, which utilizes a more anaerobic technology that is more adapted to the characteristics of the vinasse. This process was developed from a study on the properties and potentials of the referred by-product. The resulting biogas possesses a concentration of methane higher than 70 percent. When compared to biogas obtained from other sources, such as landfills (concentration around 50 to 60 percent), the quality of the Cetrel's biogas allows for a higher energetic gain concerning its use in internal combustion processes.

Bioenergy and water relationships

In classic fertigation, vinasse is canalized, dispersed and destined for wide distribution systems in sugar-cane fields, taking advantage of its potential as a fertilizer and soil conditioner (potassium, nitrogen and humus).

Impacts of fertigation on the environment, however, are not negligible: contamination of groundwater (water table, aquifers) due to infiltration; contamination of surface water due to surface runoff; and atmospheric emissions (CO_2 and CH_4) as a result of vinasse's organic material degradation by microorganisms in more superficial soil layers.

Furthermore, due to inefficient supervision, sugar-cane plants usually dispose of greater volumes of vinasse in the surrounding soils than is recommended. Depending on the type of soil, region's level of water tables and presence of surface water resources, this unregulated disposal is likely to have severe impacts on the region's water quality as well as on the most important uses of it. Raw, untreated vinasse's application to the soil improves its fertility, but if done excessively, it might also unbalance the soil's sorption complex and consequently contaminate water tables and surface water resources (by organic material runoff). Raw vinasse is considered highly noxious to fauna, flora and microflora when distributed directly in water resources.

In the project developed by Cetrel, the organic fraction of sugar-cane vinasse is used as raw material for anaerobic biodigestion with bacteria. The process has existed for a while as an alternative for treating vinasse; it transforms vinasse's polluting organic content into biogas while maintaining most of vinasse's nutrients, such as potassium, nitrogen and phosphorus. Cetrel, in turn, has developed a customized process that makes higher quality biogas production possible.

Biogas produced in this process presents higher levels of methane (> 70 percent), which is converted into electricity. The electricity is sold to local concessionaires for direct distribution.

The use of this process for biogas production and energetic use of methane enables a significant depletion in vinasse's organic material as treated vinasse presents improvements in its level of neutral pH. The replacement of raw vinasse for treated vinasse causes no damage to the soil's fertilization (for treated vinasse also presents improvements in nutrients levels) but reduces the possibility of water table and surface water contamination by leaching. In summary, the application of treated vinasse in fertigation reduces impacts on agricultural soils and protects water resources in the region.

Besides that, this process prevents natural (by bacteria present in the soil) methane generation to the atmosphere. Therefore, the positive impact on the reduction of the greenhouse effect should also be considered, especially since methane is 21 times more powerful as a GHG than CO_2.

Alongside researching vinasse biodigestion, Cetrel has studied the reutilization of treated vinasse for industrial goals.

Water accounts for 90 to 95 percent of raw vinasse's volume, all of which is dispersed over sugar-cane fields during traditional fertigation. Through the application of existing and underdeveloped technologies, though, disposed water can be recovered and used in industrial processes, saving surface water. Meanwhile, concentrated vinasse does not lose its fertilizing properties; it can be destined for sugar-cane fields without productivity losses.

Thus, aside from being an excellent fertilizer, the reutilization of raw vinasse's water volume should also impact availability. The sugar-cane industry consumes large quantities of water during several processes, such as sugar-cane cleaning and soaking as well as the overall cleaning, dilution and cooling of boilers.

In partnership with 33 Asset Management (representative enterprise of global largest industrial membrane producer Rochem), Centrel ran tests using membranes in a laboratorial unit for reverse osmosis. Excellent preliminary results were obtained: recovery of around 60 to 70 percent of water with enough quality to be reutilized in floor cleaning, dilution and even in cooling processes and steam generation. This accounts for contributions to sugar cane's productive cycle, reducing waste and adding value to the sugar-cane industry.

Prospects

There are currently three uses for the residues generated by the sugar-cane industry in Brazil: sugar-cane bagasse is incinerated in boilers; sugar-cane straw is burned directly on the field; and vinasse is used in fertigation processes. Several studies have shown evidence of energy losses in all three of these uses.

The starting point of Cetrel's project was the acknowledgement of both the energetic potential contained in non-treated vinasse's high levels of organic matter and the need to implement biological processes that would value and optimize the referred potential.

The relevance of vinasse-based energy is set on the possibility of feeding clean and decentralized energy into the Brazilian power grid. The country presently faces a deepening of its energy crisis, which is firmly rooted in the nonexistence of public policies that widen the national energetic matrix and encourage the development of sustainable power sources. Brazil lacks long-term integrated actions and planning. This set of factors represents a major obstacle and great limitation to the country's growth, given that national power generation is left to be highly dependent on climatic dynamics.

Brazil's power generation relies heavily on hydropower, which, in turn, suffers from the ups and downs of rainfall regime. For instance, water reserves in the country's most populous city, São Paulo, have been running perilously low. The drought raises fears of a declared energy crisis.

This rather quick, although elucidative overview, provides great insights on both the urgency and the opportunities comprised in Brazil's situation. The development of studies on the realization of sustainable power generation alternatives would support the decentralization and diversification of the national energy matrix. By better utilizing vinasse's energy potential, while also minimizing environmental impacts related to quality and availability of water resources, this technology offers great benefits to the society as a whole. A more rational and sustainable use of the vinasse produced by the sugar-cane industry represents prodigious energy and economic efficiency gains to the sugar-cane industry itself and concurrently to the national energy matrix.

To do so, Cetrel established a partnership with JB Group, an enterprise that lent the share of land on which the project was implemented as well as conferred the vinasse and adjunct logistic support from construction until operation.

The financial resources were made available by the national Studies and Projects Funding Agency (Finep), a body of Brazilian Ministry of Science, Technology and Innovation (MCTI), through the submission of the project "Development of biological and thermochemical processes to energetic use of straw, vinasse and bagasse". The National Bank for Economic and Social Development (BNDES) financed part of the resources concerning the demonstration-scale stage.

Nevertheless, great difficulty was encountered in the acquisition of these resources. Brazil lacks platforms that acknowledge the importance of integrating research and basic market necessities, both within public and private initiatives. Generally speaking, Brazil misses entrepreneur-friendly lines of investment with a sustainable appeal and technological innovation nature.

Further on into discussing difficulties, being the vinasse production part of a penta-centenary industry, deeply rooted in the origins of Brazilian social and economic systems, there were various conservative paradigms to be overcome concerning the introduction of environmental technology (e.g. does this technology conserve vinasse's fertigation features?). There is still a lot of insecurity surrounding the remodelling of the sugar-cane industry's traditional processes, and technology aimed at improving sustainability is often still seen as "interference."

Additional government faults must be enumerated:

- Lack of public policies that encourage the development of this kind of sustainable, renewable and clean energy source;
- Lack of environmental legislation that regulates the adequate use of effluents and by-products to energy generation purposes; and
- Instabilities in the deregulated national electricity market.

The Cetrel's unit in Vitória de Santo Antão operates at an installed capacity of 0.87 MW using around a quarter of the vinasse produced by the JB plant. Hence, the availability of vinasse resources makes it possible to expand this capacity up to four times.

Most of medium/large distilleries and sugar mill plants are eligible for the implementation of the technology developed by Cetrel, with gains to the national energy matrix and environmental benefits as a higher quality of water resources, soil quality and GHG emissions reduction.

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Contact names and affiliations / organisations:

- Professor André Felipe de Melo Sales Santos – Cetrel Bioenergia Ltde. (Odebrecht Ambiental Ltde. Group) & Federal Rural University of Pernambuco (UFRPE)
- Professor Márcia M. G. Alcoforado de Moraes – Federal University of Pernambuco (UFPE)
- Julia Torreão Pecly – Masters Student at Federal University of Pernambuco (UFPE)

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3.8 Development of a scalable algae cultivation system that enhances water sustainability in algal biofuel production in the United States

Key lessons learnt

- Algal biofuel production, a water intensive process, needs to drastically reduce its water footprint to become sustainable.
- A novel cultivation system has been designed to reduce water usage five-fold compared to traditional systems and minimize evaporative water losses while incurring low capital and operating costs.
- Prototype units were manufactured and tested in Florida under real-world conditions over extended periods of time to document high algae biomass productivity and operational robustness.
- The system is strain-agnostic, so it can serve the entire algae industry.

Introduction

Geographic location: Florida, USA

Type of example:
It is a technology development and commercialization project. It pertains to a novel horizontal bioreactor (HBR) for low-cost outdoor algae cultivation and production of sustainable biofuels and bioproducts. The bioreactor is designed to achieve high algae productivity while minimizing water and energy use. It can be deployed to produce algae on pieces of land and bodies of water that have no use for human activities. The technology is the result of a public-private partnership between the University of South Florida (USF) in Tampa, FL and Culture Fuels Inc. in New York, NY and involves engineers and scientists from the United States and the European Union.

Status: The reactor was successfully operated under real-world conditions on a small scale from 2013 to 2015. Currently, it is in scale-up testing to pre-commercial scale (50-200 m^2 per module).

Bioenergy and water relationships

Positive impacts on water availability:
Replacing fossil fuels with renewable ones will require production of biofuels in the billions of litres annually. Traditional algae cultivation systems for biofuel production are either open ponds (low cost and low productivity) or photobioreactors (high cost and high productivity). Unfortunately, these traditional systems utilize large amounts of water, which is a major challenge for algae-to-biofuels technologies. The developed horizontal bioreactor is a technology enabler as it combines the positive features of the two systems while, by design, reducing water usage five-fold over traditional systems. This results not only in significant water conservation, but also in lower downstream processing cost as less water needs to be handled. The technology aims at making algal biofuels a sustainable and cost-effective reality.

Co-benefits:
Along with water conservation, the bioreactor is also engineered to minimize energy use during: cultivation thanks to a low-power culture mixing system; and downstream processing as less energy is required to separate and recover algae cells from the surrounding water. Additionally, the design is enclosed with inexpensive plastic film to minimize the risk of contamination and evaporative water losses.

Figure 1: Schematic of the HBR for algal biomass and biofuel production

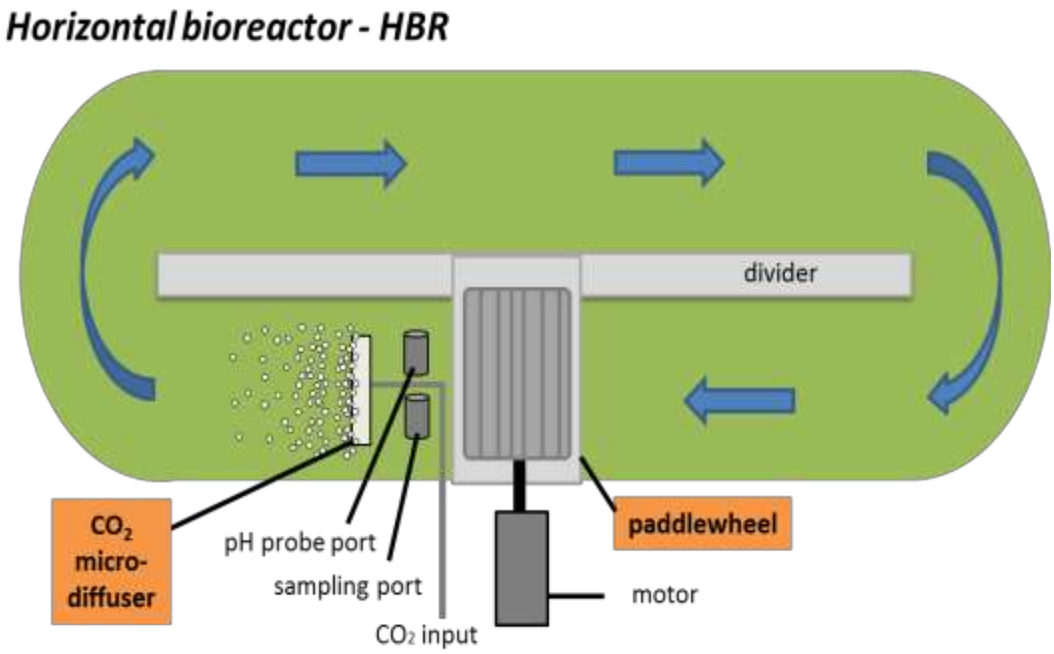

Figure 4: HBR performance

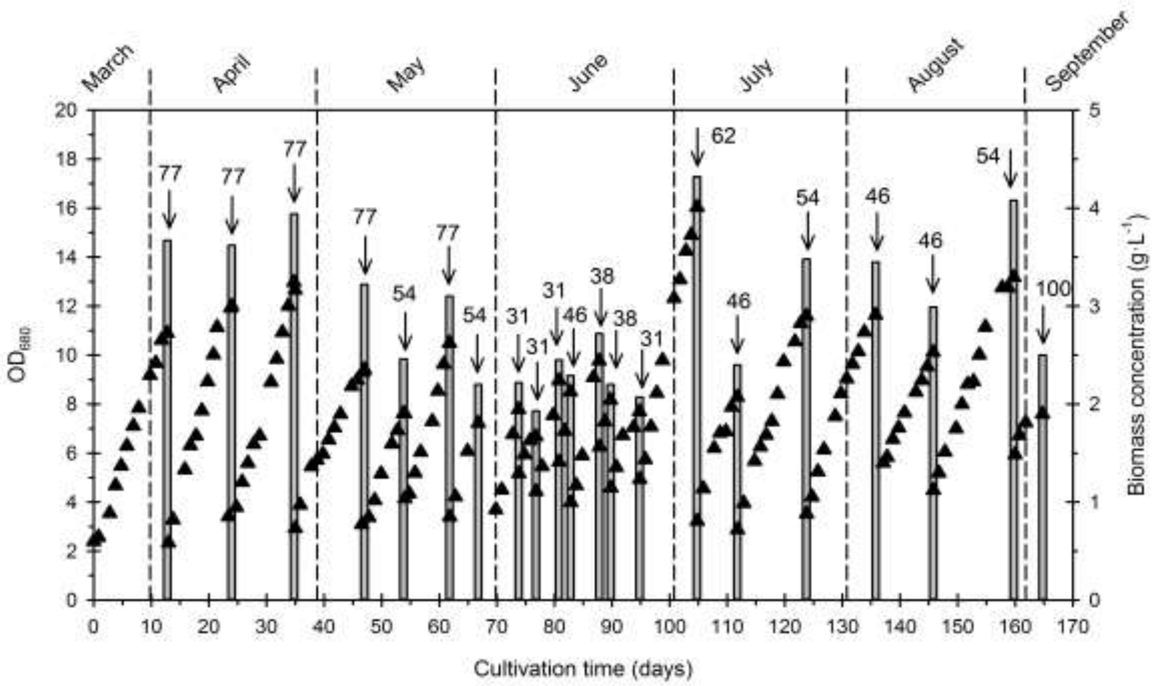

Figure 2 shows HBR's performance during outdoor semi-continuous cultivation of the marine alga *Nannochloris atomus* under real-world conditions in Florida. Optical density (OD_{680}, ▲) and biomass concentration (grey bars) of the algal culture were monitored. Arrows and the adjacent labels mark culture harvests and the percentage of culture volume harvested, respectively.

Prospects

Main drivers:

Lowering carbon emissions and enhancing energy security depend heavily on domestically produced low-carbon transportation fuels instead of imported fossil fuels. Algae provide a renewable source of biofuels but suffer from a significant water footprint. The developed technology aims at reducing water consumption (and energy utilization) to conserve water resources while advancing low-carbon fuel and bioproduct manufacture from algae.

Key enabling factors:

There is strong private and public interest in sustainable biofuels that have a minimal water and energy footprint. Freshwater shortages around the world, including the United States and the European Union, have created a fertile ground for green technologies that are water-efficient. Moreover, the low cost, simplicity of operation and versatility of the developed bioreactor, which can accommodate practically any algae species, makes the technology attractive across the algae sector.

Main challenges:

Difficulties attracting capital during the financial crisis slowed down testing and deployment. The lack of long-term policy for low-carbon transportation fuels in the USA and EU hampers investment and deprives the private sector from opportunities, such as this algae technology, to contribute to climate change mitigation and development of a sustainable economy.

Potential for scale-up:

The strongest advantage of the technology is its easy scalability. The algae cultivation system is highly modular and hence readily scalable. At commercial scale, the required number of units (modules) will be connected in series and in parallel to accommodate the desirable size of operation. Private companies from several countries have inquired about purchasing and licensing the system.

References and additional information

Contact Name: George Philippidis, Ph.D., Associate Professor

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Email: gphilippidis@usf.edu

Publications:

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Patent application pending with the United States Patent and Trademark Office.

4. Agroforestry, Intercropping and Rotational Cropping

4.1 Impacts of switchgrass intercropping in traditional pine forests on hydrology and water quality in the southeastern United States
Devendra Amatya, George M. Chescheir & Jami Nettles

4.2 Alley cropping systems with fast growing trees in Germany
Manuela Bärwolff

4.3 Integrated tree crop systems in south-western Western Australia
John McGrath & John Bartle

4.4 Integrating perennial bioenergy crops to enhance agricultural water quality in the north central and northeastern United States
Kenneth J. Moore, Tom L. Richard & William Goldner

4.5 Introduction of switchgrass in agriculture landscapes to reduce stream nutrient and sediment concentrations in the southeastern United States
Esther S. Parish & Virginia H. Dale

4.6 Extensive bioenergy cropping systems as a means of water body protection and biotope network protection in Germany
Jörg Böhmer, Ulrike Kirschnick, Frank Wagener & Peter Heck

4.7 Lignocellulosic plants as buffer zones in the Indian Creek watershed of the United States
M. Cristina Negri, Herbert Ssegane, Patty Campbell & Colleen Zumpf

4.1 Impacts of switchgrass intercropping in traditional pine forests on hydrology and water quality in the southeastern United States

Key lessons Learnt:

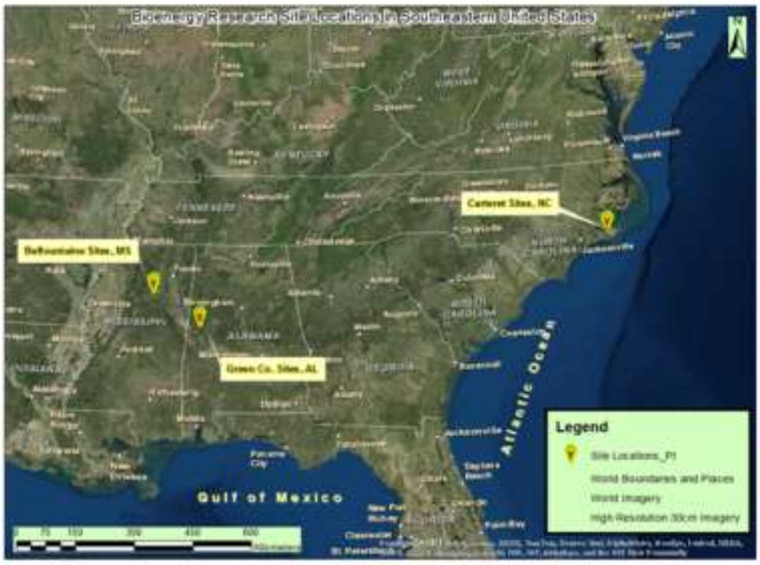
Preliminary results indicate that switchgrass (*Panicum virgatum* L.), grown as a cellulosic biofuel between managed loblolly pine (*Pinus taeda* L.) beds on the Atlantic Coastal Plain forests has no significant effect on shallow ground water table and stream outflows. Although management operations (e.g. harvesting, shearing between pine rows, raking, and bedding) implemented for pine and switchgrass establishment can lead to increases of nitrogen export, the magnitude of increases was lower than those usually observed on agricultural drainage waters in the region. Final results of study will soon be available. An adequate length of study period should be allocated for accurately quantifying effects of switchgrass intercropping on water quantity and quality from pine forests.

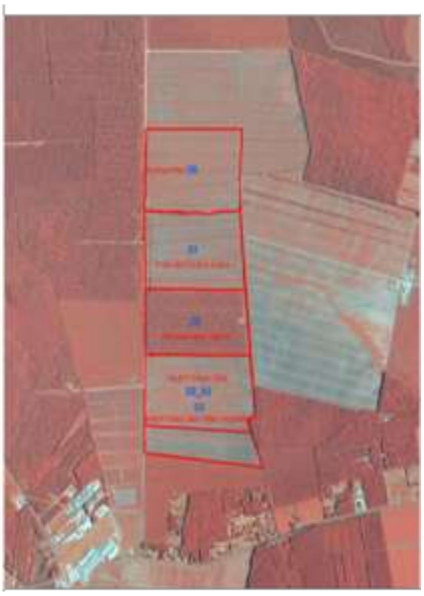
Introduction

There are approximately 15 million ha of pine (*Pinus* spp.) plantations in southeastern USA. Switchgrass (*Panicum virgatum* L.), as a cellulosic biofuel crop, intercropped in between pine (*P. taeda* L.) tree rows has potential for producing a cellulosic energy crop without using land currently in food production. Recent studies have shown that switchgrass has potential for long-term sustainability and for reducing environmental effects of bioenergy production compared to corn/row crops (George et al., 2008; Sanderson et al., 1996). This novel intercropping technology may not only reduce dependency on fossil fuels, but also benefit the American agricultural economy (Sanderson et al., 1996). Space, nutrients, and water between pine beds can be used by switchgrass to increase overall bioenergy production potential of pine forest land, possibly making it economically viable. The pine/switchgrass intercropping practice is also hypothesized to increase site nutrient uptake, thereby improving water quality compared to traditionally managed pine forests.

In 2009, Catchlight Energy LLC, a Chevron|Weyerhaeuser Company joint venture, established a regional research project to evaluate environmental effects of biomass cultivation in managed forests in the southeastern USA. The water related research was conducted in three states – North Carolina (NC), Alabama (AL), and Mississippi (MS) (Figure 1A). The example presented here is from NC, a coastal site with a long history of silvicultural and water management research (Figure 1B) (Amatya and Skaggs, 2011). Operations necessary for successful switchgrass establishment and growth include site preparation, planting, fertilizing, mowing and bailing and may affect hydrology and nutrient runoff. The main objectives of this study were to characterize temporal effects of management and use pre-treatment (pine forest) data to predict those treatment effects on downstream water quantity and quality. Treatment watersheds (~25 ha each) were: a pine/switchgrass intercropped site (D1), a mid-rotation thinned pine with natural understory (D2), and a switchgrass-only, a mid-rotation thinned pine with natural understory (D2), and a switchgrass-only site (D3) (Figure 1B).

Figure 1A: Location map of watershed study sites in NC, AL and MS in the southeastern US; and Figure 1B: Layout of the experimental watersheds (D0, D1, D2 and D3) for switchgrass-pine research in coastal NC





Source: 1A) Dr. Sudhanshu Panda & 1B) Cliff Tyson, Weyerhaeuser Company

Bioenergy and water relationships

<u>Positive impacts on water quality</u>:

Figure 2 below shows various silvicultural operations (harvesting, site preparation, shearing, bedding, raking and planting) necessary for a successful switchgrass establishment and growth in a pine forest, which may affect site hydrology and nutrient runoff.

Figure 2: Various silvicultural operations for switchgrass establishment in a pine forest in coastal NC

Source: Cliff Tyson, Weyerhaeuser Company

Figure 3: Thinned pine forest, switchgrass intercropped between pine rows and switchgrass only stands in NC

Source: Cliff Tyson, Weyerhaeuser Company

Muwamba et al. (2015) found that although management operations implemented for pine and switchgrass establishments can lead to increases of N export, values were lower than those usually observed on agricultural drainage waters in the region. The authors also showed the importance of considering water quality effects associated with intensive management operations required for switchgrass establishment or other novel forest-based biofuel systems. Preliminary results indicated no significant effects of switchgrass growth on nutrient parameters for intercropped D1 site (Table 1).

Table 1: Effects of switchgrass establishment (2010 – 2012) and growth (2012 – 2014) treatments compared to traditional pine forest on drainage water nutrient loads.

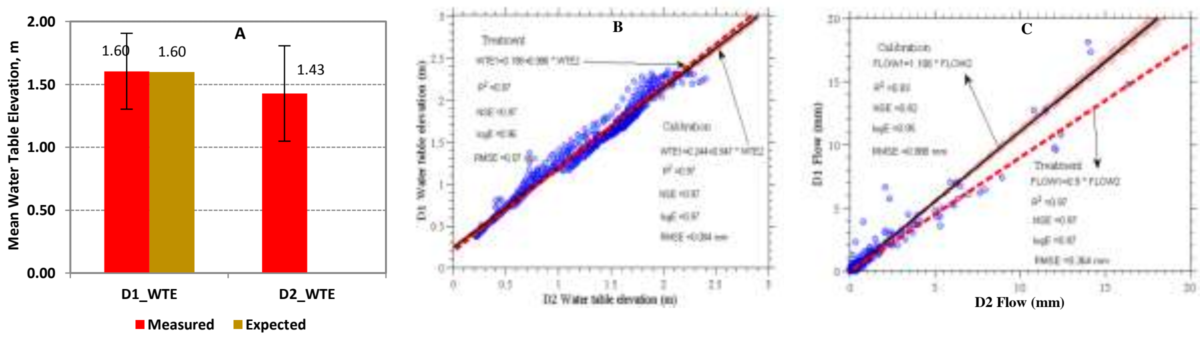
Watershed	Load, kg ha^{-1} (Site Preparation)			Load, kg ha^{-}1 (Switchgrass Growth)		
Nutrients ---→	TKN	NO_3-N	PO_4-P	TKN	NO_3-N	PO_4-P
Switchgrass Intercrop(D1)	0.55±0.50	1.93±0.77	-0.87±0.52	0.50±0.32	0.23±0.09	-1.33±0.51
Switchgrass only (D3)	0.71±2.42	0.81±1.24	-0.42±0.17	3.21±1.33	1.13±0.26	-0.68±0.22

*Growth effects are preliminary only

<u>Positive impacts on water availability</u>:

This is being evaluated using measured water table and flow data from switchgrass treatment watersheds compared to the traditional pine forest using a paired watershed approach (Ssegane et al., 2015). Preliminarily, there is no significant effect of switchgrass intercropping on daily water table elevations and flows for switchgrass intercropped pine (D1; Figure 4). Complete data are being analysed for final results of the hydrologic and water availability study.

Figure 4: (A) Measured and expected mean annual water table and calibration and treatment regressions for (B) daily water table elevation and (C) daily flows for switchgrass intercropped pine (D1)



Source: 4A) Devendra Amatya ; 4B) Dr. Herbert Ssegane, Argonne National Laboratory; & 4C) Dr. Herbert Ssegane, Argonne National Laboratory

<u>Positive impacts on biomass/bioenergy production</u>:

This system could not only provide a reliable source of biomass but could also increase financial returns on forestry, which would, in turn, encourage forest establishment. Switchgrass is a native C4 plant with high water use efficiency, dense root system that resists erosion and as a perennial, does not have the soil impact of an annual crop. An intercropping system would mean no additional land would be needed, boosting dedicated energy crop supply beyond predictions without removing land from food production.

Prospects

<u>Main drivers for implementing the project</u>:

This study is evaluating possible biomass production scenarios that could affect millions of hectares of forest land in the southeastern USA (Figure 1A). While cellulosic biofuel crops are just beginning to be planted on a large scale, there is an immediate need for information on environmental effects of these crops. Growing and harvesting such crops on forestland appears to be a very attractive option, but for these biofuel technologies to be viable, effects on water resources must be quantified and compared to those of existing land uses. This study is expected to provide short and long-term assessments of hydrologic and water quality impacts of practices that represent a range of intensive biofuel practices on forest lands.

Key enabling factors:

- Catchlight Energy's willingness to investigate a novel approach of land use design by intercropping switchgrass between pine used for timber production, substituting the natural understory for a biofuel to displace fossil fuel with a potential of generating an income while waiting for final harvest of crop trees.
- A research need to investigate hydrology and water quality of sites affected by land use and management changes to comply with state and federal water quality regulations on discharges to downstream waterbodies.
- Research funding made available by Catchlight Energy LLC, which was later supplemented by additional funding through US Department of Energy to North Carolina State University.
- A strong, committed multi-collaborative research partnership joined by multidisciplinary cooperators from academia, government, industries, and other agencies.
- A history of long-term research on the Carteret site (Amatya and Skaggs, 2011), which includes many peer reviewed publications, validated models, productivity, weather and water quality data, highly qualified technical support and collaborative relationships. Understanding existing forest and water relations and site monitoring has been very helpful to testing a novel system such as this study.
- In-kind contributions from all cooperating agencies.

Main challenges encountered:

- Selection of suitable sites for experimental studies.
- Initial experimental design due to a novel idea of switchgrass intercropping in a pine forest.
- Land acquisition and establishing paired watershed calibration for assessing treatments.
- Complexities of hydrogeologic features for an accurate watershed water balance.
- Limited resources (funding, manpower, time) for operational management at study sites and measurements of suite of environmental variables during treatments in complex pine-switchgrass ecosystems for comprehensive and accurate assessments.
- Site preparation in a forestland and uncertainty in weather pattern for switchgrass establishment.
- Malfunctioning of instruments/sensors/loggers during research period due to unforeseen causes.

Potential for scaling-up and replicability:

The above study is being replicated as paired watershed (8 to 27 ha) studies on Weyerhaeuser Company lands in Greene County, AL (Bennett, 2013) and Calhoun County, MS in USA (Figure 1A). An additional study is being performed at the plot scale (0.8 ha size) in Lenoir County, NC (Albaugh et al., 2014). Treatments on all of these three studies are similar to those described above for the NC site (Figure 1B) (Muwamba et al., 2015; Ssegane et al., 2015). The system was scaled-up operationally, but ultimately not implemented (Nettles et al., 2015). Regional scale effects of the intercropped system on water quality will be examined at the completion of the paired watershed study, and a simulation study was conducted for water quantity (Christopher et al., 2015). In that study, a widely used hydrologic model (SWAT) calibrated with data from the above experimental studies, was applied on ~ 5 million ha of the Tombigbee Watershed located in MS and AL to examine water quantity effects of various land use change scenarios ranging from switchgrass intercropping a small percentage of pine forest land to conversion of all pine forests to only switchgrass. Results showed that maximum conversion of pine to switchgrass increased annual stream flow by 7 percent. Conversion of young (≤ 4 years) and old (≥ 16 years) pine to switchgrass only increased stream flow by 2 percent. Change in annual flow was driven by change in ET. Projecting stream flow change will provide guidance to public policy makers as they plan for large-scale production of cellulosic biofuels while sustaining water quality and quantity.

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Contact name: Devendra M Amatya, PhD, PE

Affiliation/Organization: United States Department of Agriculture (USDA), Forest Service, Southern Research Station, Center for Forested Wetlands Research (CFWR), Cordesville, South Carolina (SC).

Additional information:
The CFWR's hydrology/water quality program is designed to address important water and water management issues including the impacts of natural and anthropogenic factors in low-gradient forested landscapes, using both the monitoring and modelling approaches. The CFWR's Research Hydrologist Devendra Amatya is conducting research to quantify and evaluate the effects of cultivating loblolly pine, switchgrass as a biofuel source, and switchgrass-pine intercropping on hydrology and water quality of pine forests in North Carolina in partnership with North Carolina State University, Weyerhaeuser Company, University of Georgia and University of North Georgia.

4.2 Alley cropping systems with fast growing trees in Germany

Key lessons learnt

- Alley cropping systems with fast growing trees on arable land show high potential to reduce negative side effects of high productive agriculture, such as soil erosion and loss of biodiversity.
- Positive impacts for water quality result from a reduction of fertilization and pesticide use as well as from a reduction of erosion, which results in lower sediment and nutrient input in water bodies.
- Higher water availability for adjacent crops is possible due to a reduction of wind speed and evapotranspiration. On the other hand, short rotation coppice (SRC) trees are known for their high water consumption and evapotranspiration. Both effects are interlinked with temperature and wind-speed conditions as well as water availability (groundwater, precipitation and runoff water) and site conditions. For these reasons, a general quantification of water availability in alley cropping systems is hardly possible.
- SRC strips on arable land provide a sustainable source of (energy) wood for at least 20 to 40 years.
- The economic outcome of the alley cropping system compared to monoculture is hardly quantifiable due to the complexity and size of the system. A higher profitability seems unlikely under current market conditions.
- The current agriculture policy conditions in Germany (administrative constraints, lack of subsidies) discourage farmers from establishing alley cropping systems.

Introduction

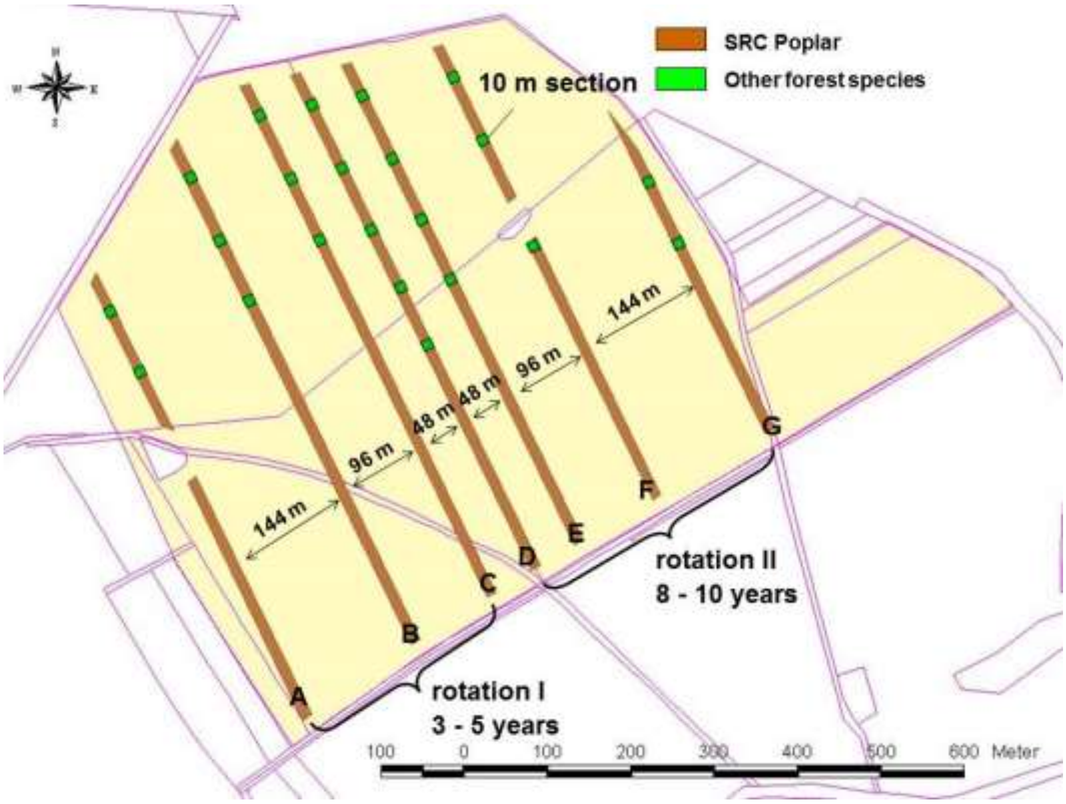
Geographic location: Germany, Federal State Thuringia, Jena

Type of example: Scientific project: "AgroForstEnergie - Economic and ecological evaluation of agroforestry systems in farming practice", practice area of 50 ha near Dornburg/Saale.

Status: The project ran from July 2007 to August 2015. A subsequent project with a slightly different focus will run from 2015 to 2018, but a longer duration is intended.

Figure 1: Impression of the alley cropping system in Dornburg during harvest of spring barley

Figure 2: Field design of the alley cropping system in Dornburg



Bioenergy and water relationships

Positive impacts on water quality:

On our 50 ha alley cropping field, 10 percent, approximately 5 ha, are cultivated with fast growing trees, mostly poplar. The remaining 45 ha are cultivated with a site-typical crop rotation (spring barley, winter rape, winter wheat), which is intensively managed. The integrated SRC-strips require a minimized management (no fertilization, no pesticides, herbicides only during establishment). Therefore, the amount of substances that may negatively affect water quality if they enter water bodies is reduced by 10 percent.

Additionally, the SRC strips may reduce wind and water erosion by reducing wind-speed and working as buffer strips against water erosion. This leads to a reduction of sediment and nutrient shift, which, in the long term, results in lower sediment and nutrient input in water bodies.

Positive impacts on water availability:

In our project, SRC strips are integrated on a field with site-typical crop rotation (alley cropping). Tree strips are located against the prevailing wind direction to reduce wind-speed in this originally structurally poor agrarian landscape. The reduction in wind-speed was measurable. Reduced wind-speed is assumed to lead to lower evapotranspiration rates and therefore higher water availability. Slightly higher soil water contents in the upper soil compared to the control were measured, especially during dry conditions. This leads to the assumption of higher water availability for adjacent crops. However, SRC trees are known for their high water consumption and evapotranspiration so the competing effects can hardly be quantified. The influence of SRC strips on water relations in agricultural areas is very complex and linked to temperature and wind-speed conditions as well as to water availability (groundwater, precipitation and runoff water).

Figure 3: Soil water content

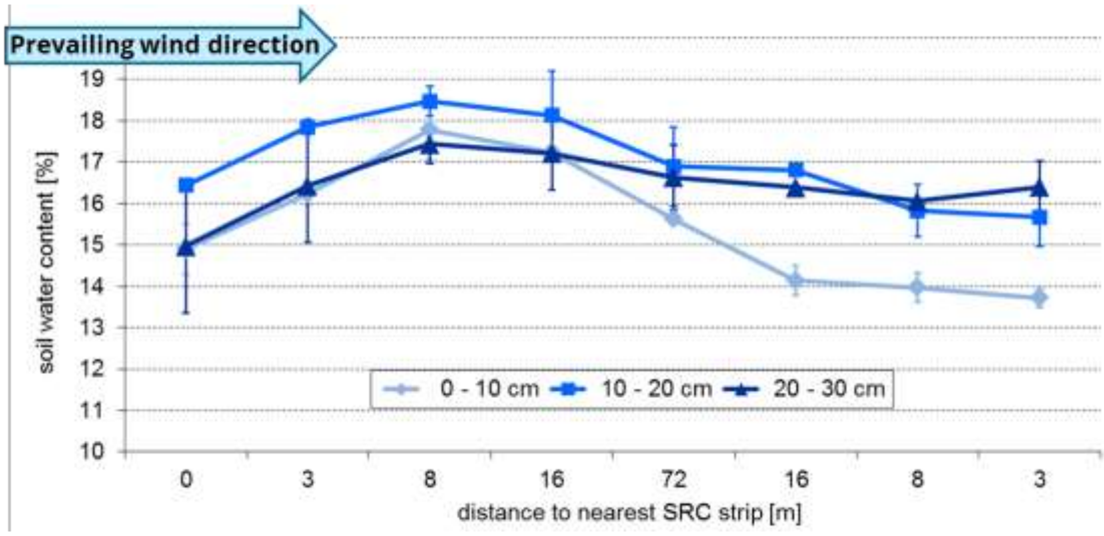


Figure 3 shows that the differences along a 144 m crop alley under dry conditions, especially in the upper soil layer (0-10 cm) higher soil water content in the sheltered area up to a distance of 72 m was detected. In periods with higher general water availability this effect was not found. (Measuring date: 20.03.2014; gravimetric measurement, soil depth: 0-10 cm, 10-20 cm, 20-30 cm, averages with standard errors; Ø tree height: 6.30 m).

Positive impacts on biomass/bioenergy production:

SRC strips can provide a sustainable source of wood energy for at least 20 to 40 years. The produced wood chips or fuelwood can be used for local heating or heating plants. A material use of the wood is also possible and should be preferred with a view to a more sustainable cascaded utilization.

Due to edge effects, the outer tree rows show distinctly higher growth rates compared to the inner rows. Since tree strips have a higher proportion of edges than more square plantations, wood yields are higher in tree strips compared to square plantations.

Co-benefits:
The study investigated the occurrence of flora and fauna (birds, butterflies, ground beetle) in the alley cropping system compared to a control field. Biodiversity was significantly enhanced by providing a habitat for additional plant and animal species.

Figure 5: Plant species occurrence in different system compartments of the alley cropping system

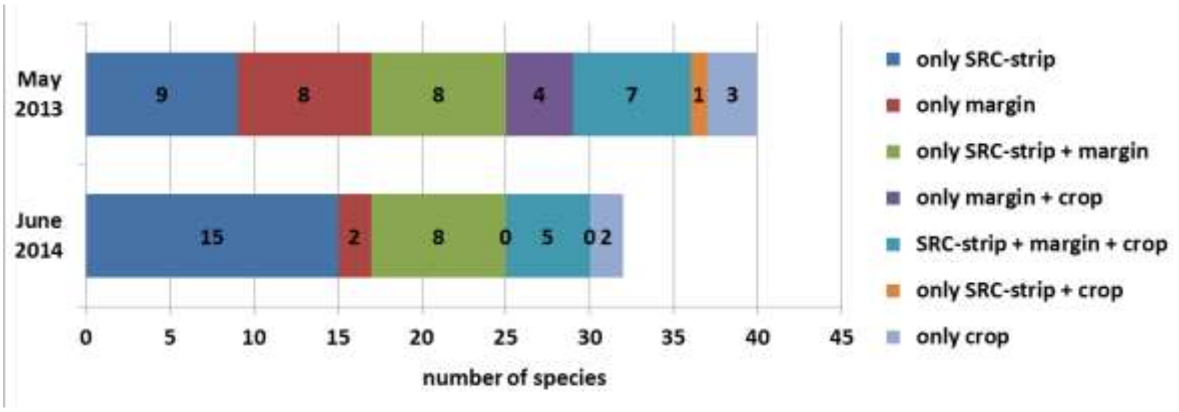


Figure 4 shows that each year 25 species occurred only in SRC-strips and margins. It can be assumed that these species would not occur in absence of SRC strips. (Data collection in sampling plots (2 m^2); crop 2013: winter rape, crop 2014: winter wheat; Ø tree height 2013: 5.10 m, 2014: 6.30 m; number of species in reference field: 8 in 2013 and 2014 resp.).

The study investigated as well the economic outcome of the alley cropping system. Due to higher operating costs compared to a conventional crop, a significant higher yield would be necessary to compensate. In this stage of the investigation, it seems that higher yields of trees and crops compared to a monoculture are possible due to a better utilization of resources and changes of the microclimatic regime but can hardly be measured because of the complexity and size of the system. Additionally, site location and climatic condition seem to have a prominent impact on the yield of alley cropping systems compared to conventional monoculture.

Prospects

Main drivers for implementing the project:
Alley cropping systems with fast growing trees may help to structurally enhance poor agrarian environments by integrating structural elements. This also leads to benefits for biodiversity by providing a habitat for plants and animals.

Alley cropping systems may positively alter wind-speed, soil water content and soil fertility. In the long term, they may contribute to the conservation of soil productivity and insurance of food production for many decades to come.

Alley cropping systems are believed to adapt better to the impacts of climate change compared to conventional agriculture, since they seem to adapt better to changing environmental conditions (increased occurrence of droughts, increased number of flooding events, elevations in temperatures).

SRC strips can provide a sustainable source of wood energy for at least 20 to 40 years. The produced wood chips or fuelwood can be used for local heating or heating plants.

Furthermore, the production of wood leads to greater income diversification for the farmer.

Key enabling factors:
The arable land on which the alley cropping system was implemented was provided by a local farmer. The implementation of the SRC strips was founded by the Thuringian Ministry of Agriculture.

The scientific work was made possible due to the funding of the Federal Ministry of Food and Agriculture under the program "Renewable raw materials" of the Agency Renewable Resources.

Main challenges encountered:
Agroforestry systems like alley cropping are ecologically advantageous. This was recognized in European policy, which allowed farmers to potentially have access to subsidies for their establishment. It also names agroforestry as an ecological focus area. In spite of this, Germany did not set up the necessary conditions for German farmers to use this opportunity.

Since there are high upfront costs associated with establishing SRC strips, few new agroforestry systems will be established in Germany without subsidies.

Potential for scaling-up and replicability:
The studied system can be scaled up and replicated easily, given the circumstances of providing financial incentives for the farmers in compensation for achieved ecosystems services.

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Link with information about the good example: www.agroforstenergie.de/en

Publications: www.agroforstenergie.de/en/publications/

4.3 Integrated tree crop systems in south-western Western Australia

Key lessons learnt

- Dryland salinity is extensive across southern Australia.
- The program has contributed to the understanding of the hydrological processes involved in the development of salinity and the mechanisms to address the issue.
- The large scale and cost of salinity mitigation mean multiple actions are required to address the issue. Revegetation with high water use perennial species will be one of the mechanisms.
- Biomass production based on integrated tree crops like mallee eucalypts could provide the resource for commercially viable bioenergy industries that help correct the hydrologic imbalance in current agricultural systems at no additional cost.
- The current political and economic uncertainties relating to bioenergy have slowed commercial development.

Introduction

Geographic location:
The work has focused on the dryland agricultural region of south-western Western Australia (WA) where the hydrological imbalance from annual agricultural systems has resulted in extensive dryland salinity. The total farmland area in WA is 18 million ha, some 16 million ha of which is in the higher salinity risk wheat belt region (< 600 mm rainfall). The systems developed are relevant to wider regions across southern Australia where dryland salinity is also an issue.

Type of example:
Development of tree crops was driven by favourable natural resource management (NRM) policy settings. It is a practice/approach for improving stewardship of natural resources and consists of specific project areas to develop biomass supply systems. This included the development of mallee as a crop integrated into agricultural systems, supply chain technologies and research into processing for bioenergy with the objectives of delivering both commercial and environmental outcomes (mitigate climate change, improve water quality and benefits for biodiversity).

Status:
Extensive research and development on growing, harvesting and delivery systems for biomass from integrated tree plantings was undertaken between 1990 and 2015, supported by economic modelling of tree crops in whole farm systems and of supply chain logistics. Efficient operational practices for large-scale biomass supply can now be specified. However, the anticipated development of commercially viable biomass processing opportunities has not yet eventuated due to changed international and national commercial conditions and a weakening of policy support. These conditions have stalled planting since 2007. The policy position for bioenergy and climate change mitigation has further deteriorated recently. However, the current potential supply of mallee biomass is attracting the attention of small regional industries that require production of combined heat and power. The development of pyrolysis for biofuels has advanced to the stage of testing pre-commercial prototypes with the strong local input by the Centre for Fuels and Energy Technology at Curtin University and continuing international investments in developing effective biofuel conversion technologies.

Bioenergy and water relationships

Positive impacts on water quality:
In southern Australia, 'dryland' salinity results from reduced plant water use under annual crops and pastures. Recharge to soil water storage and groundwater systems increases from 0.5 to 5 mm per year under native woodland to 15 and 150 mm per year under the annual pasture and crop systems. In this process ancient soil salt storage is mobilized, extensive shallow groundwater systems form in the broad valleys of the low relief landscape and deliver perennial saline seepage into streams. It is estimated that of the 16 million ha of farmland in the WA wheat belt some 1 million ha of land has been salinized and by the time a new equilibrium is reached a further 3 million ha may be degraded. All the rivers that rise in this region are salinized all the way to the coast, and their natural resource values are greatly diminished. Up to 500 endemic species are at risk of extinction from salinity.

The scale of land and water degradation from salinity is so large that in the absence of commercially viable options, the protection and restoration of assets has to be prioritized, with assets that are both valuable and able to be protected given priority. The scale of the salinity issue and the cost of remedial activities also dictate that a range of mitigating treatments will be required to successfully address the salinity issue. Key examples of multiple treatments has been through government sponsored program to focus the recovery effort on a series of Natural Diversity and Water Supply Recovery Catchments. The Natural Diversity Recovery Catchment programme identified a range of critical wetlands in the agricultural region of WA and developed and implemented plans to address the degradation issues in these catchments. Toolibin Lake, which is listed under the Ramsar Convention, is one of few remaining freshwater wetlands in this region, and it provides an example of an area where multiple actions have been implemented to prevent salinization progressing. Saline inflows are diverted before entering the wetland, the groundwater is maintained at a level below the surface through groundwater pumping and the planting of integrated trees on farms surrounding the catchment contributes by reducing the groundwater recharge. Individually these activities would not prevent the lake becoming saline, but together they demonstrate what is required to maintain the lake in a fresh condition.

Positive impacts on water availability:
The objective of improving water quality by reducing discharge of saline groundwater inevitably leads to a reduction in stream flow volume. This is the desired outcome for the wheat belt region with its already salinized waterways but run-off from the higher rainfall areas (> 1100 mm per year) to the west and south of the wheat belt is an important source of potable water.

Several streams with catchments that are mostly confined to this zone have been designated as Water Supply Recovery. Some of these streams have catchments that extend into areas with less than 1100 mm of rainfall where agricultural development has occurred and water resource quality has been degraded. Beginning in the 1970s there was considerable investment in these catchments to recover their water resource values. This involved compulsory acquisition of land and a plantation forestry approach to reforestation. This proved politically troublesome and demonstrated the need for an alternative process for the large scale revegetation required in the wheat belt. This experience helped guide the later development of mallee as a tree crop for the wheat belt. A process was developed to make it economically attractive for farmers to use mallee as an integral part of farm practice and business. Hydrological field experiments and whole farm economic modelling indicated an optimum format with mallee planted in contour arrays occupying up to 6 percent of paddock area.

Positive impacts on biomass/bioenergy production:
The extensive research and development on the growing, harvest and delivery systems for biomass on integrated tree planting undertaken between 1990 and 2015 was supported by economic modelling of tree crops in whole farm systems and of supply chain logistics. As a result of this work, efficient operational practices for large-scale biomass supply can now be specified. The anticipated development of commercially viable biomass processing opportunities has not yet eventuated due to changed international and national commercial conditions and a weakening of policy support. However, the strong understanding of the technical, economic and environmental aspects of the biomass production system available from this program indicates that there are strong development prospects when the economic and political uncertainties are resolved.

Co-benefits:
Expanding forest resources is one of the mechanisms identified by successive Australian governments to mitigate GHG emissions through the substitution of bioenergy for fossil fuel and through the sequestration of CO_2. Establishing tree crops within existing agricultural systems provide the potential to mitigate climate change both through the use of bioenergy and the sequestration of carbon.

Prospects

The two main drivers for the project were:

1. Mitigation of dryland salinity to:
   (a) maintain the agricultural productivity of the region; and
   (b) protect and restore the terrestrial and aquatic biodiversity of the region.

   Land development for agriculture was a national imperative following the gold rush period of the late 1800s. This involved conversion of the native forest and woodlands to annual crops and pastures. As early as 1907 there were indications of hydrologic change and salinity risk due to reduced water use under agriculture, but agricultural development continued. A second rapid expansion of agriculture occurred post-WWII. By the mid-1980s further clearing of forests and woodlands was restricted in an effort to slow the expansion of salinity. Land and stream salinity has become extensive causing severe natural resource damage. In recent decades strong 'landcare' policy settings have emerged and sponsored development of salinity mitigation treatments, including integrated tree cropping systems. Less extensive salinity problems occur across southern Australia so successful development of salinity management in WA may have wider application.

2. Create new income streams for farms and rural communities through diversifying agricultural enterprises and creating new regional businesses.

   Wheat belt agriculture in Australia has experienced the same adjustments as other Western economies: to fewer and larger farms enabled by technological change; with consequent declines in farm and small town populations. The predominantly mixed enterprise farms (dryland crops, livestock) have trended to a greater proportion of land under wheat, canola and other annual crops, with their wider, year-to-year fluctuations in net farm income. Tree cropping with first-stage, downstream processing in the region offers improved stability of employment and farm income, as demonstrated by economic modelling in this project.

Key enabling factors:
National and state governments resolved to address NRM problems arising from agriculture, and there was a long period (1980-2010) during which favourable policy and funding programs were applied.

This was driven by the recognition of the hydrologic imbalance in dryland agricultural systems by rural communities, agricultural and water resource management professionals, the environmental movement and policy-makers. This directed investment into developing the biophysical understanding of the problem and the technical and practical responses.

The emergence of climate change and the recognition of tree crops as providing both carbon sequestration and renewable energy opportunities, added impetus to resolving NRM problems.

Economic analysis that showed that farm businesses could not finance the remedial salinity treatments and that only economically viable tree crops would be adopted on the necessary scale.

Main challenges encountered:
Policy challenges: Maintaining positive settings for salinity mitigation, renewable energy and carbon sequestration. There have been substantial policy changes at both State and Commonwealth levels since the project commenced, which has made it difficult for both farmers and managers of environmental offset programs to invest in developing new rural industries with certainty.

Technical challenges: Reducing the cost of biomass supply through better system design and management, including identifying species and improving the productivity of species that can deliver both commercial and environmental outcomes.

- Quantifying the competitive impacts of mallee belts on adjacent crop or pasture and building this into the cost of biomass production.
- Developing a farm to factory biomass supply chain, including attracting large-scale start-up operations in biomass processing.

Financial challenges: The ebb and flow of development funds linked to policy settings has been a challenge, in particular the:

- Competitive strength of solar and wind for electricity generation.
- Recent fall in global oil prices has slowed biofuels development.

Potential for scaling-up and replicability:
The environmental challenges facing agriculture across southern Australia are large in scale and cannot be managed by marginal modification of current practice. A range of actions both in engineering works and catchment management through the use of high water use perennial systems (integrated tree crops) will be required. New perennial species and development of systems for their integration into agricultural systems is required for the latter.

The potential scale of woody biomass production required to meet NRM objectives in the WA wheat belt could be up to 10 million dry tonnes per year. This scale of industry would facilitate the utilization of straw residues from existing cereal cropping, adding another several million tonnes to the potential wheat belt biomass resource. Adoption of similar systems across southern Australian cereal cropping regions could increase the scale of the potential resource more than three fold.

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Contact names and affiliation / organisation:
John McGrath and John Bartle, both are Research Associates, with the Science Division, Department of Parks and Wildlife, Western Australia have been major contributors to tree crop development.

Multiple agencies contributed to developing the integrated tree crop systems based on the native Australian mallee eucalypts. The current Department of Parks and Wildlife is nominated as the primary organization due to its continuous involvement in the project since its commencement in 1990.The public research and development investment in tree crop industries exceeds US$ 50 million, including both biomass production and processing. The combined public/private investment in establishing 14,000 ha of integrated plantings is valued at US$ 28 million. No commercial development has yet emerged.

Link with information about the example:
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4.4 Integrating perennial bioenergy crops to enhance agricultural water quality in the north central and northeastern United States

Key lessons learnt

- Biomass energy crops, especially perennial crops and winter grasses, can dramatically improve water quality outcomes without substantial conflicts with food or fibre production.
- Planting and harvesting biomass from these vegetative strips or winter fields reduces nutrient and sediment losses and improves soil and water quality.
- Adding payments for ecosystem services to market prices for biomass can improve the economics of both sustainable energy and achieving water quality goals.

Source: Lynn Betts, USDA Natural Resources Conservation Service

Introduction

Geographic locations: USA north central and northeastern regions, including substantial portions of the Mississippi River and Chesapeake Bay watersheds.

Type of example: Research, education and outreach projects.
"CenUSA Bioenergy" and "Northeast Woody/Warm Season Biomass" (NEWBio) are coordinated agricultural projects (CAP) funded by the USDA – National Institute of Food and Agriculture (NIFA)-Agriculture and Food Research Initiative (AFRI). The competitive grant numbers are 2011-68005-30411 and 2012-68005-19703, respectively.

The CenUSA vision is to create a regional system for producing advanced transportation fuels and other bioproducts derived from perennial grasses grown on land that is either unsuitable or marginal for row crop production. In addition to producing advanced biofuel and bioproducts, the proposed system will improve the sustainability of existing cropping systems by reducing agricultural runoff of nutrients and soil and increasing carbon sequestration. The project is organized around 10 primary systems needed to make this vision a reality: feedstock improvement; feedstock production on marginal land; feedstock logistics; modelling system performance; feedstock conversion into biofuels and other products; marketing; health and safety; education; outreach; and commercialization.

NEWBio is a transdisciplinary regional effort to integrate research and development, education, workforce development, extension, outreach, technology transfer and sustainability analysis (economic, environmental and social) in the northeastern USA where biomass has been a resource for energy and materials for hundreds of years. The region has high agricultural productivity, well-developed transportation and fuel distribution infrastructure, technologically adept human and financial resources as well as substantial demand for advanced biofuels, biopower and bioproducts. Perennial energy crops, especially willow and warm-season grasses grown on abandoned and marginal agricultural and mine lands, in addition to winter grasses harvested as energy double crops, can play a central role in creating a sustainable bioenergy future for the region.

Status: CenUSA is five-year project in its last year of regular funding; NEWBio is a five-year project in its fourth year of regular funding.

Bioenergy and water relationships

Positive impacts on water quality:

Growing perennial biomass crops on environmentally sensitive land could have several potentially beneficial impacts on water quality. Unlike annual crop species, perennial grasses grown for biomass provide continuous soil cover throughout the year. Soil erosion and the subsequent movement of sediment to waterways are markedly reduced. The movement of potential pollutants that are carried by soil, such as phosphorus, are also greatly reduced. Perennials that are strategically placed within the landscape could also slow surface flow reaching waterways and reduce stream flow and streambank erosion. Ultimately, perennial energy crops could be used in strategies to impede and manage surface flow of water and as filters of soil and nutrients moving with it.

Because of their perennial growth habit and extensive root systems, grasses grown for biomass can immobilize and cycle a larger quantity of highly mobile nutrients than annual row crops. Depending on the hydrology of a landscape, perennial bioenergy grasses could be used as buffers to the movement of nutrients, such as nitrate to waterways. Effective strategies for achieving this benefit will require careful placement of the perennial crops so that they might intercept the above and belowground movement of water carrying these nutrients.

A highly spatially refined modelling system has been developed, linking land use decisions made at the field scale in the Upper Mississippi, Ohio and Tennessee Basins through both environmental and hydrological components to downstream water quality effects and hypoxia in the Gulf of Mexico. This modelling system can be used to analyse detailed policy scenarios identifying the costs of the policies and their resulting benefits for improved local and regional water quality.

Numerous field experiments indicate that placing perennial energy crops in a landscape can provide significant water quality improvements by preventing the loss of nitrogen and phosphorus from intensively managed agricultural systems. By applying refined modelling systems to identify the optimal placement of perennial feedstocks within a watershed, the greatest level of water quality improvements while still providing food and fuel production can be identified.

The northeast region of the USA contains many water bodies of significant public interest, including Lake Erie, Lake Ontario and the Finger Lakes in central New York – which are sources of untreated drinking water for many communities – as well as the St. Lawrence, Hudson, Delaware and Susquehanna Rivers and their associated estuaries. All these lake, river and estuary systems have suffered from nutrient and sediment pollution, which has degraded fisheries and impacted the human populations of many cities, including Cleveland, Rochester, New York, Philadelphia, Baltimore and Washington, DC. These last two cities are on the Chesapeake Bay, whose watershed extends into six states in the NEWBio region and has been the target of billions of dollars of investments to improve water quality. The Chesapeake Bay watershed is also a national case study in which new strategies to address non-point source pollution, including from agricultural land, are being piloted.

In 2008, the Chesapeake Bay Commission (an intergovernmental body of state governments and the US Environmental Protection Agency) evaluated the potential of biofuel crops to impact water quality in the Bay. Simulations using the Chesapeake Bay Model indicated that increased production of maize for ethanol would exacerbate water quality problems, but that increased acreages of perennial crops and expanded use of winter cover crops (including as energy crops) could provide major benefits to help meet water quality goals. More recent economic analyses have identified these two strategies as being among the lowest cost mechanisms for reducing nutrient and sediment losses.

For these reasons, the Chesapeake Bay Commission has been strongly engaged with the NEWBio Consortium; its Executive Director, Ann Swanson, served as chair of the NEWBio Stakeholder Advisory Board. NEWBio is currently attempting to better quantify the water quality benefits and their value for the Bay region. Two biofuel cropping systems have been initially analysed: switchgrass as a perennial grass to replace maize and winter rye as an annual grass to be grown as a winter crop on acres that would continue to be used as a summer crop for maize. Preliminary estimates are that switchgrass could reduce nitrogen loading by 24 to 38 kg/ha/year while winter rye could reduce nitrogen losses by 17 to 24 kg/ha/year. NEWBio is currently sampling soil and water impacts of switchgrass, willow, hay and maize crops to document these benefits experimentally while also developing modelling tools to predict impacts over broader regions.

Current estimates of the costs of agricultural nitrogen abatement cover a very wide range. The state of Virginia estimates these costs range from US$ 4 to US$ 227 per kg of nitrogen while Maryland pays up to US$ 148 per ha for cover crops. Pennsylvania has a formal nitrogen-trading marketplace where nitrogen-credit prices average about US$ 6 per kg. At typical yields of 7 to 11 dry Mg/ha, the value of adding nutrient conserving energy crops to the landscape can contribute a significant amount to their market value as biofuel feedstocks. NEWBio will be working intensively over the next two years to document these water quality benefits, including their economic value and the costs of production, with a goal of monetizing this particular ecosystem service to both encourage biomass production and improve water quality.

Positive impacts on water availability:
More often than not, the problem with the watersheds that CenUSA and NEWBio are concerned with is an excess of water rather than a shortage. Growing perennial grasses in watersheds prone to flooding could change the hydrology such that more water could be retained by the landscape and be more slowly released to streams. This impact is likely to be highly localized and limited to some degree by the management of adjacent land. However, there is very high potential for designing landscapes to lessen the impact of moderate flooding on site and further downstream from the landscape in which the perennial bioenergy crop is grown.

Many fields in both the midwest and northeast regions are on shallow soils or are very poorly drained. The drainage systems that carry away water to allow for timely planting of crops in the spring can also subject those soils and crops to drought stress in years with below average rainfall. Strategic placement of perennial crops can help moderate those water availability extremes. NEWBio and CenUSA are investigating the impacts of biofuel crops on water budgets and soil water holding capacity and exploring innovative strategies like the use of energy crops for living snow fences, which could reduce needs for road salt and snowploughing in the winter and attenuate snowmelt and associated flooding in the spring.

Positive impacts on biomass/bioenergy production:
Perennial grasses and winter cover crops have long been used for water quality protection. However, without markets for the harvested biomass, these programs have been limited and often undersubscribed. Coupling financial support for water quality with a market price for this feedstock can increase the margin between the costs of production of biomass and the feedstock price at a biorefinery gate. This increased value proposition can make the difference between the success and failure of a bioenergy project. In the case of the Chesapeake Bay watershed, estimates are that 400,000 ha of perennial energy crops could reduce nitrogen loading to the Bay by 11 million kg per year – a big win for water quality – while providing 3 to 5 million tonnes of biomass feedstock.

Co-benefits:
An important co-benefit of perennial grass as well as winter crops is increased soil organic matter and soil carbon, which can provide both additional GHG mitigation and enhanced soil quality. Soil quality, and its corollary soil heath, are fundamental for maximizing yield and creating more resilient crop production system to cope with weather extremes.

Prospects

Reasons or main drivers for implementing the project/practice/policy:
CenUSA envisions using biomass grown on marginal land to produce biofuels and other bioproducts. The project addresses several dimensions required for such a system to be implemented at a scale large enough to impact water quality on a regional basis. It has already made improvements in the genetics and management of perennial energy crops adapted to marginal land. The enhanced biomass yield realized through these improvements has validated and increased the feasibility of producing biomass on this land. Research on harvesting and transportation logistics has identified promising technologies for improving efficiency and reducing costs associated with these activities. The impacts of these developments are currently being used to inform modelling activities focused on economics and environmental impacts, thus allowing for their assessment at a regional scale. Research is being conducted to evaluate and improve technologies for converting biomass to fuel and other products. The potential for developing markets and commercializing these technologies is also being researched.

NEWBio's core vision is that multiple synergies are possible between supplying large quantities of sustainable bioenergy feedstocks, enhancing ecosystem services, and increasing rural economic development in the Northeast. Explicitly coupling water quality benefits with bioenergy and bioproduct production directly addresses these opportunities, and can help overcome the price differential between sustainable bioenergy and fossil energy feedstocks.

Key enabling factors:
To achieve water quality improvements from the introduction of bioenergy crops it will be necessary for there to be adequate incentives for producers to plant and harvest these crops. This will require the development of private markets that can compete with other uses of land, including traditional row crop production. Policies that support bioenergy crops or penalize the negative environmental impacts of row crop production could provide incentives for producers to adopt these crops.

In many regions of the USA the impacts of agriculture on water quality and availability are foremost in the public's mind. Perennial crops and winter energy crops can help address these quality and supply concerns at lower cost than many alternatives. CenUSA and NEWBio, with their regional research and development activities, have been able to pull together a critical mass of both academic expertise and stakeholder motivation, and targeted a major challenge that previous efforts did not have the resources to address. With feedstock costs a major barrier to moving second-generation cellulosic biorefineries from residue feedstocks (e.g. maize stover) to environmentally beneficial perennials and cover crops, there is tremendous interest in the concept of monetizing ecosystem services to provide additional income to the farmers and effectively reduce feedstock costs.

Main challenges encountered:
With current market conditions as well as energy and agricultural policy, it will be very difficult for bioenergy crops to compete in the market. However, with appropriate policies and incentives, production of bioenergy crops could be economically feasible and yield important ecosystem services.

Potential for scaling-up and replicability:
Watersheds that achieve successful water quality improvement by the widespread adoption of bioenergy crops can provide relevant examples to all watersheds despite the fact that the optimal placement of these crops will differ across locations. We estimate that are nearly 16.2 million ha of marginal land within the midwestern states that could potentially be converted to energy crop production. The Chesapeake Bay watershed, while smaller in size, is widely recognized as a test bed for innovative water quality strategies and solutions. The coupling of water quality benefits with sustainable bioenergy production offers promise anywhere that annual crop production releases agricultural nutrients and sediment and creates negative impacts for water quality, or where water availability is a concern.

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Affiliation / Organisation: Institute of Bioenergy, Climate, and Environment at USDA National Institute of Food and Agriculture

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4.5 Introduction of switchgrass in agriculture landscapes to reduce stream nutrient and sediment concentrations in the southeastern United States

Key lessons learnt

- At a watershed-scale, strategic conversion of some row crops and pastureland to perennial switchgrass has the potential to achieve water quality targets (i.e. reductions in stream nutrient and sediment concentrations) with only minor impacts to overall economic profit (See Figure 1).
- Plantings of switchgrass totalling 2023 ha across a ten-county area of eastern Tennessee, USA have shown improvements in water quality at the field and watershed-scale (See Figure 2) without any observed changes in water availability.

Figure 1: Biomass Location for Optimal Sustainability Model (BLOSM) results

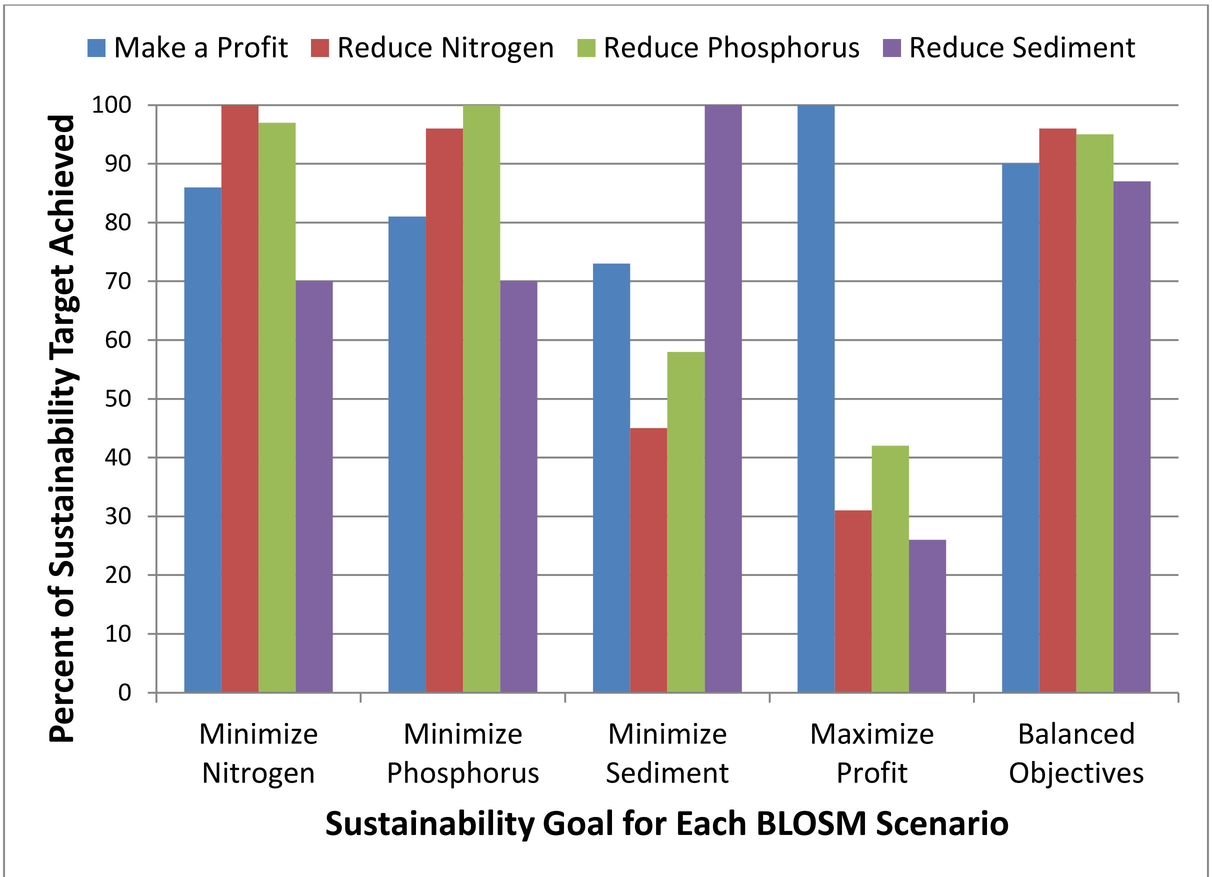


Figure 1 shows the results from five scenarios considered using the Biomass Location for Optimal Sustainability Model (BLOSM), assuming production of about 50,000 MT of switchgrass from the Lower Little Tennessee watershed. The proportion of total watershed area converted under each scenario ranged from 1.2 to 1.8 percent, with overall pasture/hayland area conversions ranging from 107 to 1640 ha and agricultural land conversions ranging from 1477 to 3344 ha. More information about these five BLOSM scenarios may be found in Parish et al. (2012).

Figure 2: Water quality sustainability indicator results

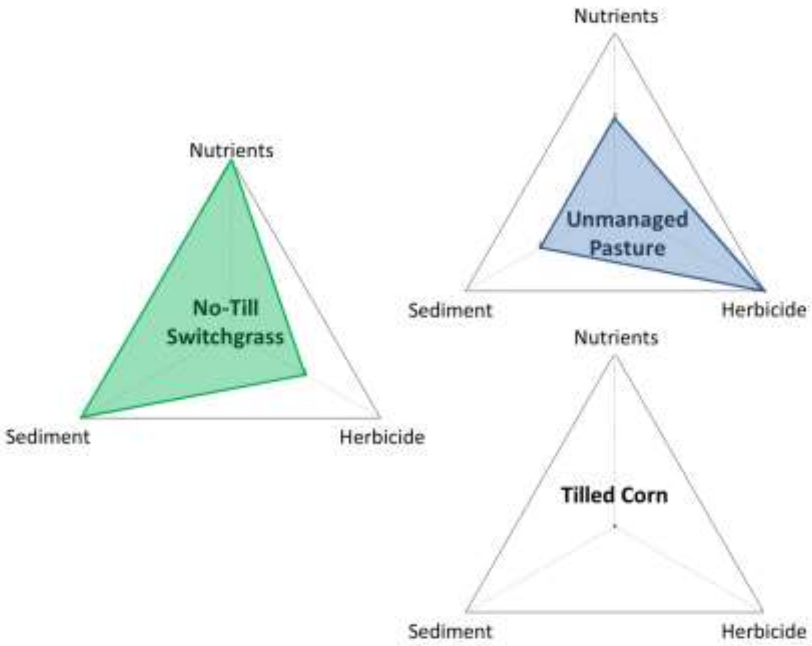
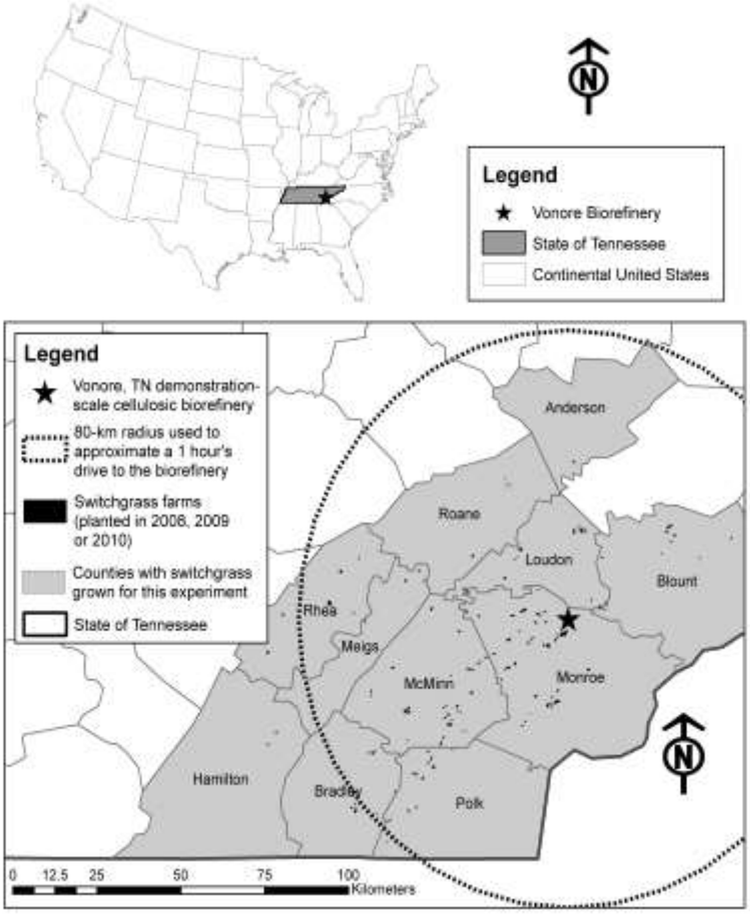


Figure 2 shows the water quality sustainability indicators (i.e. in-stream and runoff concentrations of nutrients, herbicide and sediment) for no-till switchgrass production relative to two local alternative scenarios of unmanaged pasture and tilled corn production. These results come from a Multi-Attribute Decision Support System (MADSS) developed to evaluate trade-offs between 12 categories of environmental and socioeconomic sustainability indicators evaluated for the East Tennessee switchgrass-to-ethanol production system. The larger the shaded area, the more the scenario approaches more water quality sustainability. More information about the synthesis of empirical data, literature review and expert opinion used to develop the qualitative sustainability ratings within the MADSS may be found in Parish et al. (in press).

Introduction

Geographic location: Southeastern United States (See Figure 3).

Figure 3: East Tennessee USA switchgrass-to-ethanol production experiment location



Type of example: Modelling and empirical analysis of a dedicated switchgrass-to-ethanol production system.

Status:

Key lessons are based on five years of observations from a demonstration-scale cellulosic biofuels production experiment (2007 to 2012). Seven recommended sustainability indicators related to water quality and quantity (McBride et al. 2011) were evaluated based on a combination of empirical data collected through a USDA-funded project and modelling analyses conducted by ORNL using the Soil & Water Assessment Tool (SWAT) and a MADSS developed with DEXi software (Parish et al., in press).

Bioenergy and water relationships

Positive impacts on water quality:

Relative to alternative agricultural scenarios of unmanaged pasture and tilled corn, SWAT modelling showed that dedicated switchgrass plantings can reduce in-stream concentrations of nitrate, phosphorus and total suspended sediments (Figure 2). In-field observations by Hayes (2014) showed that switchgrass land cover has extremely low erosive potential.

Positive impacts on water availability:
Switchgrass plantings did not appear to impact water availability within this east Tennessee context.

Positive impacts on biomass/bioenergy production:
Within this east Tennessee context, switchgrass production shows potential for improved environmental and social sustainability trajectories without adverse economic impacts (Parish et al., in press).

Co-benefits:
Modelling analysis (Parish et al., 2012) at a watershed-scale indicated that strategic conversion of some row crops and pastureland to perennial switchgrass has the potential to achieve water quality targets (i.e. reductions in stream nutrient and sediment concentrations) with only minor impacts to overall economic profit (Figure 1). A multimetric analysis of environmental and socioeconomic indicators gathered from the five-year demonstration-scale experiment (Parish et al., in press) concluded that there are several socioeconomic benefits of growing switchgrass in east Tennessee. In particular, annual harvesting of switchgrass can occur at times of the year when farmers are not typically busy preparing or harvesting other crops, thereby allowing them to make use of otherwise inactive equipment and labourers.

Prospects

Driving factors:
The Vonore-area switchgrass plantings were made possible through a US$ 70.5 million demonstration-scale cellulosic ethanol experiment funded by the Tennessee Biofuels Initiative (Tiller 2011). The selected east Tennessee farmers were given incentives to grow switchgrass while the biorefinery was under construction, thereby ensuring full yields and an adequate supply of switchgrass by the time the biorefinery came on line. University of Tennessee Extension Agents worked closely with each switchgrass producer to ensure optimal yields, and each producer was required to collect data throughout the duration of the project.

Funding for bioenergy sustainability analysis and modelling work was provided by the US Department of Energy Bioenergy Technologies Office (BETO) as well as by ORNL, which is managed by UT-Battelle, LLC, for DOE under contract DE-AC05-00OR22725. Water data collection was funded by US Department of Agriculture National Institute of Food and Agriculture (NIFA) Agriculture and Food Research Initiative (AFRI) Competitive Grant no. 2011-68005-30410 via the Southeastern Partnership for Integrated Biomass Supply Systems (IBSS).

Main challenges encountered:
The primary challenge encountered was the lack of a commercial market for switchgrass. The commercial-scale cellulosic biorefinery that had been expected to move into east Tennessee ended up locating in the midwestern USA, and so many of the east Tennessee switchgrass farmers began replacing their fields with other crops after the conclusion of their three-year contracts. This situation created complications for the team gathering water quality data; they had to relocate flumes and sampling equipment to other farms on more than one occasion.

Another primary challenge encountered was the tremendous expense involved in water sampling efforts, particularly over the multi-year timescales needed for true understanding of land use change impacts on the hydrologic cycle. We were therefore forced to rely on models supplemented with limited empirical data.

Potential for scaling-up and replicability:
This project was unique in several respects, including the fact that the selected farmers were given incentives to grow switchgrass over a period of three years. Switchgrass is native to East Tennessee and has greater potential for consistent profit relative to corn production in this region than in other areas of USA. East Tennessee is an area of generally abundant rainfall and surface water, so water consumption by alternative agricultural options is not a problem at present. It is possible that within this eastern Tennessee context, water consumption could be more of a sustainability consideration for biorefinery operations (which were not considered in these analyses) than it is for crop production and logistics. All of these context-specific factors should be considered when comparing the water-related impacts of this pilot-scale switchgrass-to-ethanol experiment with other bioenergy systems in other settings.

References and additional information

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Additional information about these analyses, including publications, may be found on the ORNL CBES website at http://web.ornl.gov/sci/ees/cbes/.

Funding for this research was provided by the US Department of Energy BETO. ORNL is managed by UT-Battelle, LLC, for Department of Energy under contract DE-AC05-00OR22725. Support for this research was also provided by the Southeastern Partnership for Integrated Biomass Supply Systems (IBSS), which is funded through Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-30410 from the USDA National Institute of Food and Agriculture.

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4.6 Extensive bioenergy cropping systems as a means of water body protection and biotope network protection in Germany

Key lessons learnt

- Extensive bioenergy cropping systems can provide substantial ecosystem services such as erosion prevention, water body protection and biotope connectivity.
- Therefore, these multifunctional land-use-systems can contribute to various (political) targets in cultural landscape management (e.g. water framework directive, climate protection, rural development).
- The willingness of the involved stakeholders to cooperate is key for the establishment of such concepts.

Introduction

The joint research project "ELKE" (Development of extensive cropping systems for the production of energy crop as a potential compensation measure, funded by the German Ministry of Nutrition and Agriculture via Fachagentur Nachwachsende Rohstoffe) investigates both ecological effects and economic performance of extensive (low input) land use systems, such as short rotation coppice and mixed biogas cropping, based on four project sites in Germany that account for about 100 ha in total. Public funding for research was combined with private/public investments for the project site implementation. The pilot regions were located in the federal states of Saarland, Lower-Saxony, Hessia and Bavaria, representing different geographical and climatic zones.

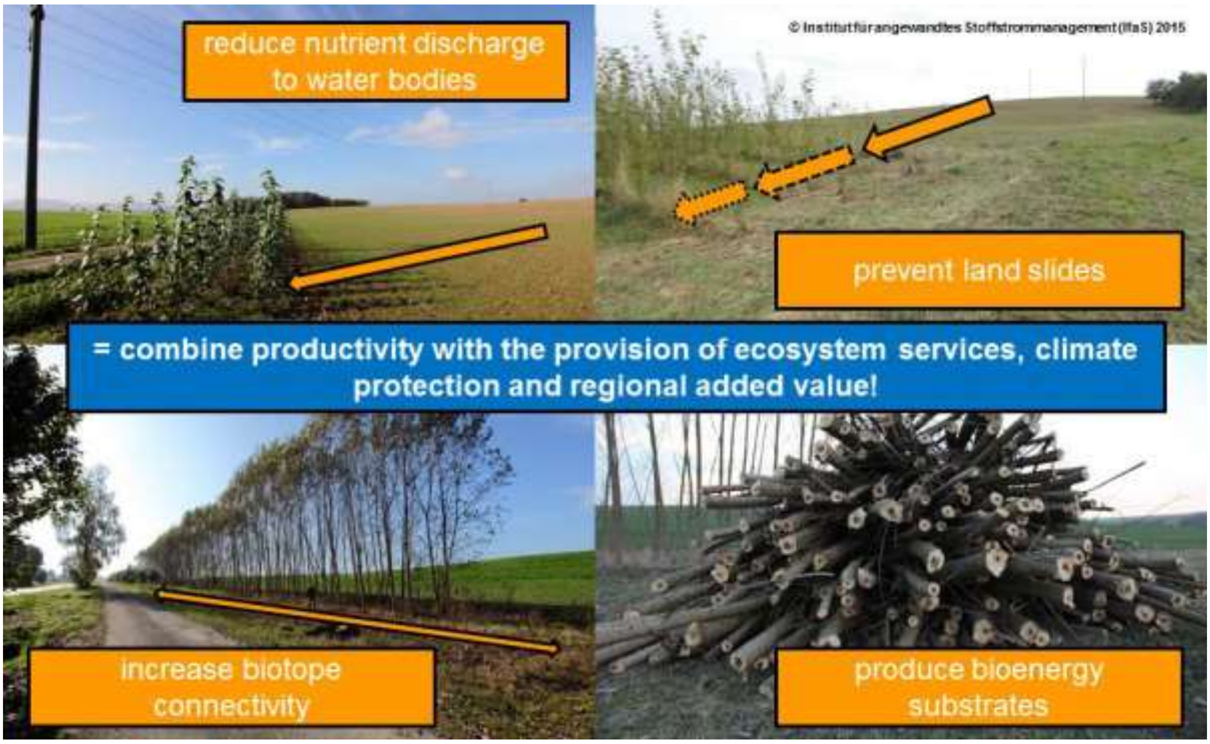
Figure 1: Map of implementation sites

The ELKE concept is a practical approach, which has been developed in cooperation with and in consideration of the demands of agricultural land use. During the project pilot sites of 20 up to 50 ha field trials each on practical scale have been established and constantly monitored with a focus on land use effects on biodiversity, habitat connectivity, soil properties, biomass yield and economic performance.

Bioenergy and water relationships

Buffer strips consisting of fast growing tree species / agroforestry crops or wild and blooming plants next to water bodies are expected to take up the nutrient runoff from the adjacent arable land. The perennial plants form deep roots, which presumably take up diffuse discharge before reaching the surface water bodies. Furthermore, direct driftage of pesticides and contamination during the application is lowered or prevented. Additionally, erosion and therefore the pollution of the water with sediments and the nutrients attached to it are reduced.

Figure 2: Benefits of ELKE project



Source: Frank Wagener, IfaS

Though impacts on water availability were not investigated in detail, the tested land use systems are expected to reduce the amount of water that is available in the landscape as they tend to increase evaporation for growth purposes. On the other hand, they have the function of water retention, which is essential to preventing landslides and erosion.

In spite of “traditional” measures for waterbody protection, such as green buffer strips or hedgerows, the production of renewable resources allows a productive use of water body margins. It is important to take into consideration maintenance of water bodies and keep plantations half-sided, especially when planting short rotation coppice.

In addition to abiotic advantages of these systems removing nutrients and preventing discharge from adjacent arable fields, individual biotopes can be linked and therefore different targets in landscape development can be combined efficiently.

Prospects

Arable land is a scarce resource and needs to serve the purpose of producing food and energy as habitat quality for wildlife. This leads to numerous conflicts, which can be reduced by the implementation of multi-functional land use systems. In Germany, current main drivers for the ELKE systems’ implementation are: the limited availability of land for compensation measures (with regard to the impact-compensation regulation under German nature conservation law); the implementation of the water framework directive; and the obligatory ecological focus area (Greening CAP). Taking into consideration these requirements, stakeholders’ willingness to invest in the establishment of multi-functional land use systems is increasing.

Figure 3: Sample project site

Source: Frank Wagener, IfaS

Crucial for the implementation of the ELKE systems is the consideration of the specific regional agricultural structure, administrative processes and inclusion of measures into an economic context. Therefore, the inclusion of all stakeholders is of great importance. Secondly, a valid economic calculation is the basis for a negotiation between opposing interests. Finally, the willingness of the involved stakeholders (farmers, environmentalists, municipalities etc.) to cooperate is vital for the establishment of such long-term measures.

The main challenges encountered were the political and administrative processes, which turned out to be more time consuming than expected.

In several regions in Germany the energy crop systems have been implemented and monitored with encouraging results in terms of soil erosion and thus reduction in nutrient input to water bodies.

While the pilot project sites within the ELKE-project already accounted for about 100 ha in total until 2009, pilot projects of a larger scale are currently being developed in Kupferzell (Baden-Württemberg), Wittingen (Lower Saxony), Bisterschied (Rhineland-Palatinate) and Ampertal (Amper Valley, Bavaria), where they are meant to serve as an example for a further broad implementation to practice.

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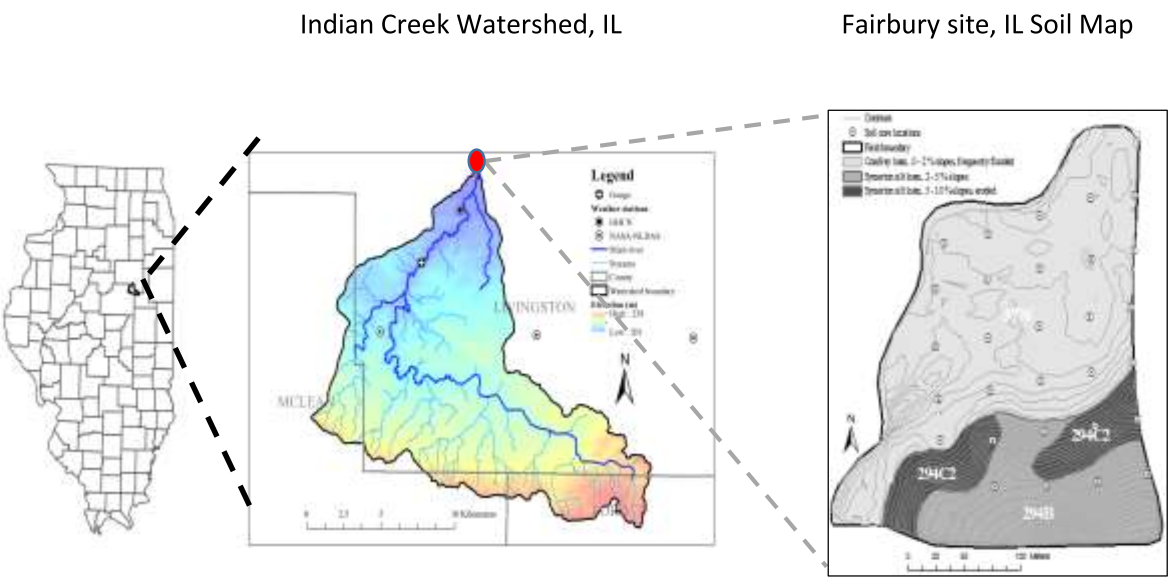
4.7 Lignocellulosic plants as buffer zones in the Indian Creek watershed of the United States

Key lessons learnt

Strategically placed bioenergy plantings in critical field areas can help achieve bioenergy production and the creation of important ecosystem services, such as improving water quality. Riparian buffers, contour buffers and planting in sub-productive areas of a field are possible examples. Our research has shown at the field and watershed scales that considerable benefits could be derived from this practice, including significant reductions in nutrients and sediment loadings to water bodies and reduced GHG emissions. Soils maps and easily available yield maps can be instrumental in positioning the bioenergy crops in locations that target the most vulnerable areas and those that can be cost-effectively converted to bioenergy. Scaling up this approach to the watershed scale is necessary to integrate scientifically sound data with logistic choices and local interests. When deploying bioenergy crops in vulnerable areas, existing management practices developed for business-as-usual cropping may need to be reassessed to minimize impacts to water. Research needs to be conducted in establishing minimum patch size and field geometries that would allow farmers to easily subscribe to landscape-based bioenergy cropping and that would provide optimized logistics and economics. Feedback from farmers and farm operators and consultants is essential in designing landscape solutions that are acceptable and likely to be adopted in farms.

Introduction

Figure 6: Field site location and soils map of applied research project in Livingston County, IL

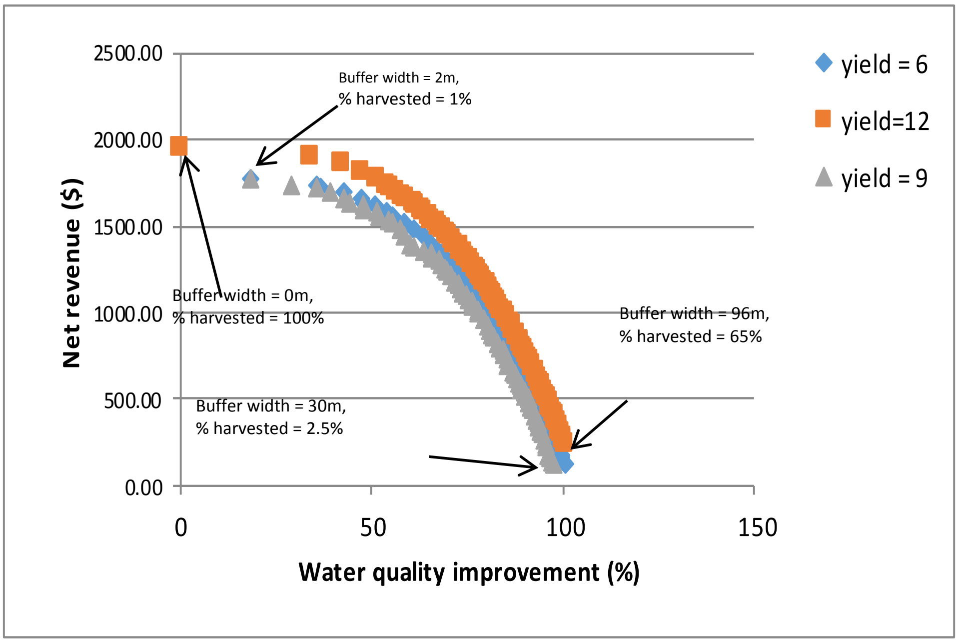


This applied research project at the field and watershed scale is located in the Indian Creek watershed in Livingston County, Illinois, USA. Field site location and soils map are shown. The project is ongoing (2011 – 2017).

Sustainable landscape design, like conservation science, often includes features such as buffers. Conservation buffers are “strips of vegetation placed in the landscape to influence ecological processes and provide a variety of goods and services” (Bentrup 2008). Riparian buffers, buffer contour strips or filter strips and windbreaks are examples of conservation buffers. Government programs in the USA encourage the setting aside of vulnerable or ecologically relevant land from cropping purposes for filtering water runoff and/or providing other ecosystem services. Overall, there is a broad recognition of the crucial role of riparian land and buffer strips in regulating nitrogen flows and more generally water quality. Typically, however, nitrogen saturation in riparian soils tends to slow their effectiveness over time. In government-supported conservation buffers, removal of biomass via harvesting is usually not allowed.

While this ban is considered beneficial to protect the environmental and ecological function of very fragile land, there are other cases where harvesting biomass for energy may provide an attractive income to farmers while at the same time delivering valuable ecological services. Harvesting biomass may also provide a way to remove nitrogen from the buffer via the harvested vegetation, thus maintaining buffer function. Buffers, however, remove some land from the current cropping system, thus creating an economic dilemma for farmers.

Figure 2: Trade-offs between buffer width and harvest percentage and water quality improvements



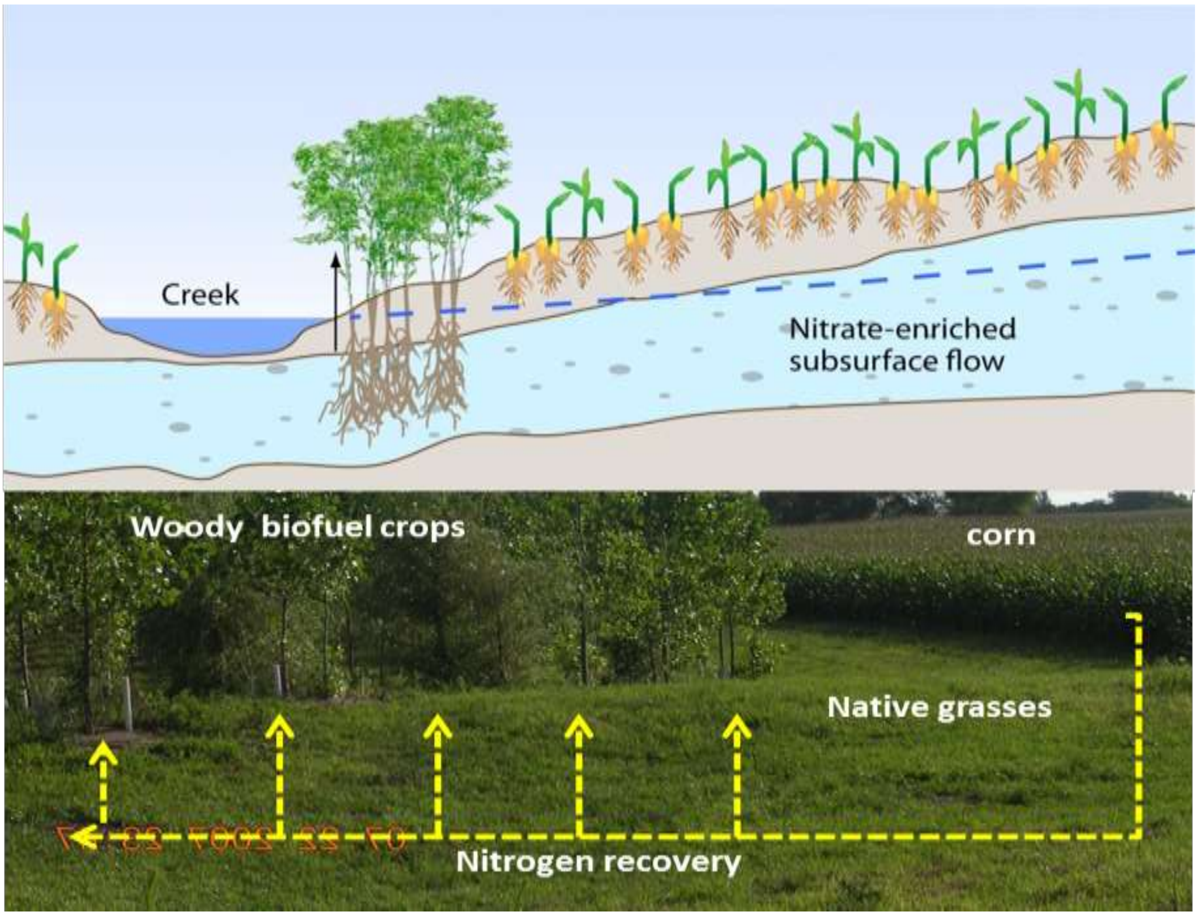
Source: Adapted from Gopalakrishnan et al., 2011

Figure 2 shows the potential trade-offs between buffer width, harvest percentage and water quality benefits at several prices for the bioenergy crop, in this case switchgrass. From this example, it is clear that while many buffer designs are possible and effective, the valuation of the water quality improvement may contribute to the adoption of buffers by providing an economic incentive in case the bioenergy crop does not fully compensate the farmer.

Bioenergy and water relationships

Research has shown the potential benefits of buffer strips or intra-field patches to grow biomass feedstock and simultaneously provide environmental services and has also shown that yields of willows and other bioenergy crops, such as switchgrass, could increase significantly if fertilized. This response to fertilization could allow for a potential yield intensification when biomass crops are grown on landscape positions (buffers) that allow for the reuse of nutrients embedded in subsurface water flowing from agricultural fields. Productive biomass buffers hinge on one important trait that is present but often overlooked in woody crops and to a lesser degree in native grasses: the ability to develop a deep root system, which is the key to intercept nutrient-rich leachate or subsurface flow from cropped land and to increase carbon storage in soil. In this project, our work explores the possibility of developing landscape solutions exploiting the natural deep rooting ability of woody bioenergy crops to reuse nutrients lost from grain agriculture to boost production of bioenergy crops and reduce the loadings that enter surface and groundwater. An illustration of this approach is shown in Figure 3. This approach aims at delivering by-design sustainable agricultural products, including bioenergy, and the concurrent control of non-point source pollution.

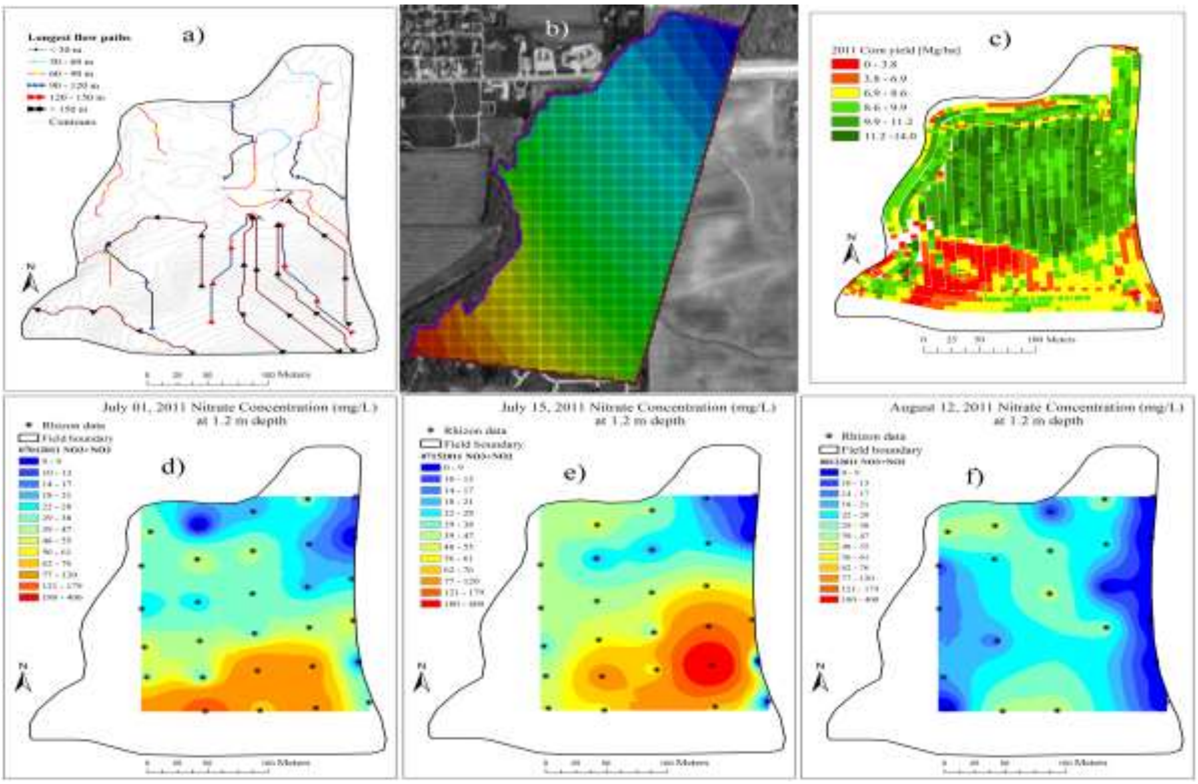
Figure 3: Conceptualization of bioenergy buffer function within a corn field



Our study is composed of several parts. A field scale trial deals with methodologies and lessons learned in designing the buffer system where willows are grown using nutrients scavenged from deeper soil moisture. A second part uses a prevalent biogeochemical model to predict the buffer sustainability, measured as the performance of the designed buffer in terms of yields, nutrient removal and greenhouse gas emissions. A third component develops landscape-level analyses, and a fourth develops a process of farmer involvement to determine the applicability of this approach from a stakeholder’s perspective and build opportunities to collaboratively design a new landscape that is feasible, acceptable and sustainable.

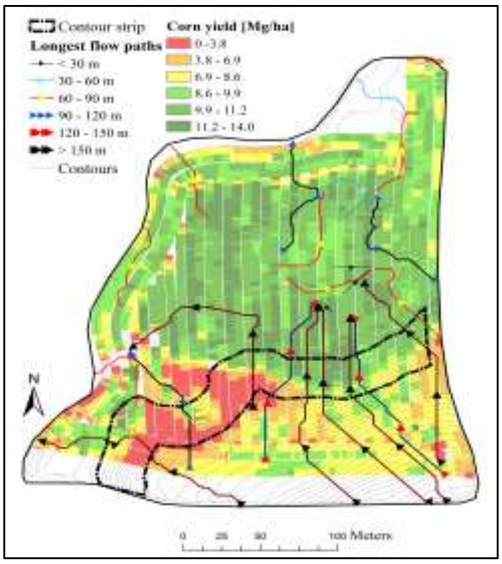
The trial is in a 16-acre field located in the Indian Creek watershed, in the heart of the fertile row crop agricultural belt in the U.S. Midwest. The Indian Creek discharges to the Illinois River and ultimately to the Mississippi River. Results from site characterization are discussed in detail elsewhere (Ssegane, Negri et al. 2015) and are summarized here. Figure 4 shows a synopsis of the various layers of information developed to characterize the site and problem.

Figure 4: Baseline site characterization results: a) terrain analysis; b) groundwater flow direction; c) yield map; and d) – f) nitrate plume at 1.2 m below ground surface at different times over the spring/summer of 2011



In rough coincidence with soil types (Figure 1), productivity (Figure 4c) showed higher yields (≥ 9 Mg ha^{-1}) in the Comfrey loam and lower yields (≤ 3.8 Mg ha^{-1}) in the Symerton silt loams. Terrain analysis showed that the longest and most relevant flow paths convey runoff to the central portion of the field (Figure 4a), while discharge of runoff towards the field edges is somewhat limited, thereby suggesting that direct overland discharges to the Creek (which runs parallel to the left edge of the field) are of secondary relevance to the total nutrient exports from this field. Shallow groundwater flows from the SW to NE roughly parallel to the Indian Creek flow direction (Figure 4b). A 30-m interval grid of small lysimeters revealed the presence at 1.2 – 1.5 m below ground surface of a seasonal, recurring "plume" of very elevated nitrate concentrations centered approximately at the boundary between the Comfrey loam and Symerton silt loam (Figure 4d, e, f). The plume is most concentrated immediately beneath the areas of lowest corn yields suggesting that higher permeability may contribute to poor plant use and higher vertical transport of the mobile nitrate anion. Results from the baselining effort helped us develop a final design for the buffer strip (Figure 5), which was placed above the area of

Figure 7: Final design of the contour buffer



intersection between the two soil types, the area of highest nitrate losses and lowest yields. As this area returns little profit to farmers compared to the rest of the field, its conversion to bioenergy crops may also be of more interest to farmers than high yielding areas.

Willow cuttings (Salix miyabeana clone SX64) were planted in May 2013 in replicated plots along this contour buffer because of their ability to develop deep and dense root systems, their tolerance to drought and flooding conditions, when established, their ability to consume nitrogen beyond their physiological needs (luxury consumption), fast growth, and the long duration of their vegetative season, which covers early days in the spring at the time when the largest nitrate loadings are lost from farm fields. No fertilizer was applied to the willows, with the expectation that they would use the leached nitrogen pool. Herbicide treatment and more frequently mowing was used to control weeds. The willows are currently scheduled for the first biomass harvest in December 2017.

Positive impacts on water quality:
A preliminary analysis shows that the willow buffer could reduce annual leached nitrate by 59 percent (Ssegane, Negri et al. 2015). At the watershed scale, our analysis has shown that growing bioenergy crops in underproductive and vulnerable land has the potential to provide significant benefits in terms of nutrient loadings and sediment reduction while generating sufficient biomass to offset losses in corn production (Fig 6, from Ssegane and Negri (2015)).

Figure 6: Modelled nitrate and sediment loading reductions as well as water yield reductions from the Indian Creek watershed

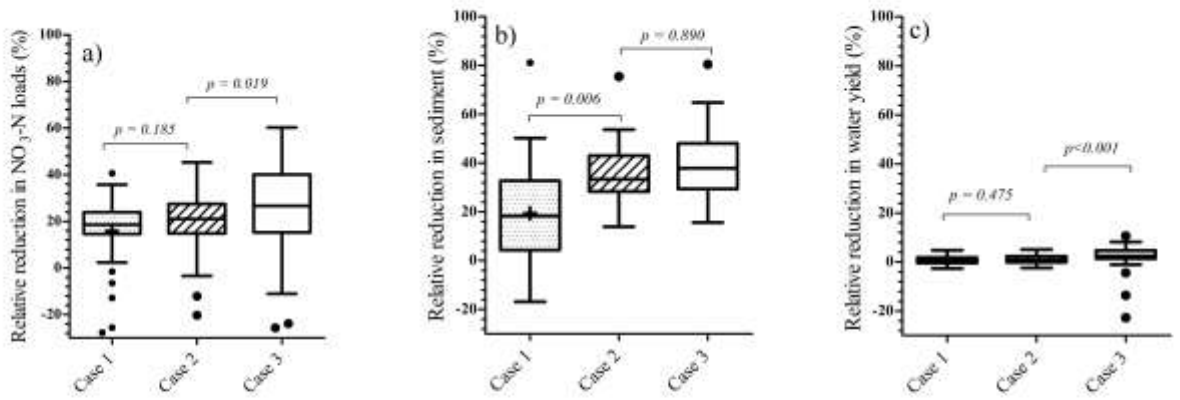


Figure 6 models the nitrate and sediment loading reductions as well as water yield reductions from the Indian Creek watershed when bioenergy crops are grown in different amounts of marginally productive or vulnerable land in alternative to a corn/soybean rotation. Willows are compared to switchgrass and big bluestem. Case 1: 3.2 percent, Case 2: 7.4 percent and Case 3: 14.3 percent of watershed area (Hamada, Ssegane et al. 2015).

Positive impacts on water availability:
In general, switching crops from annual to perennial crops carries the potential for a slight increase in water consumption because of the longer growth season and the robust root system that characterize perennial growth habit. However, our analysis has shown that in this non-water limited region relative reductions in water yields are contained while the water quality benefits are great.

Positive impacts on biomass/bioenergy production:
Modelled results from the field trial have shown that the yield balance would be beneficial, as the buffer would displace 6.7 Mg/ha of corn but replace it with 9.7 Mg/ha of willow biomass.

Co-benefits:
Field modelling showed that the willow buffer could reduce emissions of the greenhouse gas nitrous oxide by 10.8 percent (Ssegane, Negri et al. 2015).

Prospects

Sustainably meeting national targets for production of biofuels will require a new agricultural mind-set that effectively balances concerns about economic viability with an ambitious focus on sustainability. Concerns related to water impacts and other environmental liabilities from agricultural practices call for proactive thinking and the development of a holistic vision for a future where a novel, integrated landscape management optimally produces goods and services to satisfy societal needs for food, feed, energy, fiber, and ecosystem services, ecological health, human well-being and quality of life.

Our work explores one possible approach to develop this vision: to plan at the landscape level the use of land and water resources so that the most fitting crops and agricultural practices are used in the parts of the landscape that are most suited to them and where specific crop traits are used to gain beneficial environmental services. For instance, this approach would encourage the cultivation of main grain crops on the most fertile land while perennial crops are grown where the productivity of main food/feed crops would be lower, or moisture tolerant bioenergy crops would be grown where the land is more vulnerable to flooding or ponding water, or deep rooted perennials would be grown where land is more susceptible to leach nutrients or erode.

Key enabling factors include a clear understanding of expected economic returns and the presence of a market for the generated biomass. The potential for trading ecosystem services to offset production costs is a potentially useful way to encourage practice adoption. To achieve this, there is a need for broader and scaled up data on productivity and environmental performance of this approach, and the development of a certification framework to ensure that ecosystem services payment reflects performance achievements in practice. The main challenges encountered in the experimental work include the need to revisit agronomic practices when operating in environmentally sensitive conditions. Other challenges for broader adoption include enhancing communications between the research and development environment and the real farming communities, and addressing perceptions that the developed landscape may be inefficient, or less productive, or just plainly less acceptable than the current one. The potential for scaling up and replicability is high and relies on finding the right stakeholder combination with the drive, support and will to establish larger demonstration initiatives.

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Additional information:
This project is funded by the U.S. Department of Energy, Energy Efficiency and Renewable Energy, Bioenergy Technologies Office. More information and bibliography can be found at: http://www.anl.gov/energy-systems/project/bioenergy-landscapes .

Appendix 1: AG6 Call for Evidence of Positive Bioenergy and Water Relationships

The Global Bioenergy Partnership brings together public, private and civil society stakeholders in a joint commitment to promote bioenergy for sustainable development. Its purpose is to provide a mechanism for Partners to organize, coordinate and implement targeted international research, development, demonstration and commercial activities related to production, delivery, conversion and use of biomass for energy, with a focus on developing countries. The GBEP Activity Group on Bioenergy and Water aims to identify and disseminate ways of integrating bioenergy systems into agricultural and forested landscapes for improving sustainable management of water resources, including waste water. This includes sharing knowledge and experiences on landscape identification and design, best management practices as well as on policies and instruments supporting bioenergy implementation that contributes positively to the state of water. With the support of the IEA as a GBEP partner, IEA Bioenergy Task 43, assisted by Task 40, is co-chairing the Activity Group and contributing to the work defined in the workplan.

Bioenergy and water are inextricably linked. Water quantity and quality (sometimes their temporal distribution) have been identified as emerging issues of concern in the bioenergy field. Yet, there is evidence that bioenergy systems can be designed and integrated to improve adaptation to water constraints and to optimise overall resource management. For example, effective planting including intercropping for bioenergy feedstock can support water quality improvements by trapping nutrients and sediment, filtering runoff and enhancing infiltration. Also, employment of technical solutions and best management practices in both feedstock cultivation/collection and refining phases can improve both the condition of water resources from both quantity and quality perspectives. Policies and other instruments can prove useful in encouraging the application of these practices among industry actors.

The GBEP Activity Group on Bioenergy and Water has launched an initiative to identify cases of positive outcomes for bioenergy and water interactions. We're writing to seek your participation in this initiative to catalogue and highlight world-wide examples of bioenergy systems, throughout all stages of production, which can produce positive impacts on the status of water. We welcome information on crops and other feedstocks with bioenergy potential, even if not yet used for bioenergy purposes, as well as information about policy initiatives that encourage technical solutions leading to positive outcomes for bioenergy and water.

The goal of this initiative is to showcase innovative examples of how bioenergy systems (in both the feedstock production and conversion phases) can produce positive impacts on the status of water and to serve as a way to inspire and build on this knowledge and experience with other bioenergy producers. Not only technical solutions should be considered, but also policies and other instruments that encourage the adoption of the solutions. Submissions will be reviewed by the Activity Group and those selected will be invited to make a presentation at the Activity Group Workshop on Bioenergy and Water, which will take place during the second half of 2015 (date and location to be confirmed). Selected submissions will be also compiled and published through the GBEP.

The Call for Evidence

A call for evidence and examples of good natural resource management to produce bioenergy that has positive impacts on the status of water. Note that the spirit behind the call for evidence is not the mitigation of impacts caused by existing crops used for bioenergy e.g., by improving water quality treatment etc., but on using innovative approaches in integrating bioenergy into landscapes and existing systems that can demonstrate an improvement in natural resource management to benefit the state of water.

Case Studies/Examples could be relevant to soil stabilisation and productivity, flood control, infiltration rates, water filtration, hydrologic stability, reduction in nutrient and sediment export, vapour shift (non-beneficial evaporation to transpiration), water productivity, and other issues. Possible case studies might include (but are not limited to):

I. Integration of specific crops in key regions or landscapes and/or siting of crops, examples including, for example:
   a. Developing upstream degraded lands in rainfed watersheds to enhance green water use efficiency and minimize erosive runoff;
   b. Plantation of forest and bioenergy trees alongside roads and highways to reduce runoff and siltation load;
II. Modifying existing practices – cultivation and harvest:
   a. Mixed crop and livestock (agriculture-based);
   b. Alley cropping, rotation cropping and buffer plantations providing soil and water protection along with biomass for energy";
   c. Harvesting in Streamside Management Zones; and
   d. Bioenergy crop interplanted with existing managed forests.
III. Using 'waste' resources for bioenergy where such materials would pose a water quality risk in business as usual case (e.g., process wastewater discharge from industrial use used to produce biofuel or biofuel feedstock.).
IV. Implementing bioenergy systems that enable solutions to problems concerning water quality or access to water resources, examples include the use of local bioenergy sources to support water extraction for irrigation, hygiene, drinking, etc. in situations where energy access is scarce or non-existing.
V. Introducing innovative policies and other instruments that have been shown to encourage the adoption of best management practices for improving water resource utilization through bioenergy systems.

Submission Guidelines

All information should clearly identify how the bioenergy system (or part thereof) can improve the state of water while also supporting the production of food and materials. If you have any questions, please send an e-mail to: jessica.chalmers@winrock.org

Kindly use the template below to make electronic submissions to mailto:andrea.rossi@fao.org mailto:by May 8th, 2015.

Template for Submissions	
General	
Contact name	*Please identify whether you are submitting as an individual or on behalf of an organisation*
Affiliation / Organisation	
Location of project/policy/practice	*Please identify the country and specific location within the country*
Other details	*Please provide any further relevant details e.g., organization description, size and type of investment (i.e. public, private or public/private), etc.* [max. 100 words]
Publications	*Please include the list of publications (if any) on the specific project/policy/practice described*
Link	*Please include the link to the project web-site (if any)*
Details	
Type of Example	*Please identify whether you are providing an example that is* *i) A policy* *ii) A practice or approach* *iii) A specific project/activity*
Status	*Please specify whether the Example is currently being implemented and indicate start and end dates as appropriate*
Positive impacts for water quality	*Please provide a description of how the Example you are providing has produced or is expected to produce positive impacts for water quality* [max. 500 words]
Positive impacts for water availability	*Please provide a description of how the Example you are providing has produced or is expected to produce positive impacts for water availability* [max. 500 words]
Reasons or main drivers for implementing the project/practice/policy	[max. 250 words]
Key enabling factors	*Please describe the main environmental, social, economic and/or policy-related factors (if any) that enabled the implementation of the Example and contributed to its success* [max. 250 words]
Achieved outcomes	*Please provide information on the outcomes achieved for water quality and/or water availability* [max. 500 words]
Main challenges encountered	*Please describe some of the main challenges e.g., Policy , technical, financial, other* [max. 250 words]
Potential for scaling-up and replicability	Please discuss whether and under which conditions the Example could be scaled-up and replicated elsewhere [max. 250 words]

Appendix 2: AG6 August 2015 Workshop Agenda

<u>25 August 2015, Tuesday</u>

09.00 – 09.30	**Participant's registration**
09.30 – 09.45	**Opening and Introduction** *Andrea Rossi, GBEP Secretariat* *Göran Berndes, IEA Bioenergy*
09.45 – 10.15	**Overview of the examples received and selected** *Göran Berndes, IEA Bioenergy*
10.15 – 10.30	**Coffee break**
10.30 – 11.30	**Session I: Bioremediation and Riparian Buffer Zones** Moderator: *Shabbir Gheewala, King Mongkut's University of Technology, Thailand* • Bioremediation of industrial drainage water with Sesbania aegyptiaca *Ahmed Abdelati, Desert Research Center, Egypt* • Bioenergy crop buffer zone in Central Illinois *Cristina Negri, Argonne National Laboratory, USA*
11.30 – 13.30	**Session II: 'Waste' to Energy and Water-Smart Processes** Moderator: *Uwe Fritsche, IEA Bioenergy* • Livestock waste to biogas: the Italian BiogasDoneRight® model *Guido Bezzi, Consorzio Italiano Biogas e Gassificazione, Italy* • Biogas from livestock waste to reduce pollution in Lake Tai, China *Takashi Hayashi, Ministry of Agriculture, Forestry and Fisheries, Japan* • Waste-to-bioenergy in Argentina *María Rosa Murmis, Ministry of Agriculture, Livestock and Fisheries, Argentina* • Transforming the sugarcane ethanol industry to address water challenges in Brazil *Andre Elia, UNICA, Brazil*
13.30 – 14.30	**Lunch break**
14.30 – 15.30	**Session III: Agroforestry, Intercropping and Rotational Cropping** Moderator: *Göran Berndes, IEA Bioenergy* • Impacts of switchgrass intercropping in traditional pine forests on hydrology and water quality

	Devendra Amatya, Center for Forested Wetlands Research, USA • Short rotation coppice strips integrated with site-typical crop rotation *Manuela Baerwolff, Thuringian State Institute for Agriculture, Germany*
15.30 – 15.45	**Coffee break**
15.45 – 16.45	**Session III (continued)** • Integrated woody biomass cropping for salinity control in dryland agriculture in Australia *John Mc Grath, Department of Parks and Wildlife, Western Australia* • Perennial biomass crops on environmentally sensitive land in the US *Kenneth Moore, CenUSA Bioenergy, Iowa State University, USA*
19.00	**Dinner**

26 August 2015, Wednesday

09.30 – 10.30	**Session IV: Controlling Growth of Invasive Species** Moderator: *Andrea Rossi, GBEP Secretariat* • Producing electricity from biomass from terrestrial invasive alien plants *Helen Watson, University of KwaZulu-Natal, South Africa* • AquaMak: Improving water quality by harvesting water plants for biomass utilization. *Vasco Brummer, Institute for International Research on Sustainable Management and Renewable Energy, Germany*
10.30 – 10.45	**Coffee break**
10.45 – 11.30	**Lessons learnt and recommendations for dissemination, scaling-up and capacity building** *Uwe Fritsche, IEA Bioenergy*
11.30 – 12.30	**Q&A and Discussion**
12.30 – 13.00	**Conclusions** *Göran Berndes, IEA Bioenergy*
13.00 – 14.30	**Lunch**

Appendix 3: AG6 August 2015 Workshop Participant List

First Name	Last Name	Affiliation
Ahmed	Abdelati	Desert Research Center, Egypt
Márcia Ma. G	Alcoforado de Moraes	Federal University of Pernambuco, Brazil
Devendra	Amatya	US Department of Agriculture - Forest Service, USA
Nita	Apriliano	Ministry of Energy and Mineral Resources, Indonesia
Alma Delia	Baez –Gonzalez	INIFAP, Mexico
Göran	Berndes	IEA Bioenergy and Chalmers University of Technology, Sweden
Guido	Bezzi	Italian Biogas Consortium, Italy
Vasco	Brummer	ISR, Germany
Manuela	Bärwolff	Thuringian State Institute for Agriculture, Germany
Emmanuel	Chinyamakobvu	UNCCD, Germany
Jean Francois	Dallemand	EC-JRC, Italy
Ioannis	Dimitriou	Swedish University of Agricultural Sciences, Sweden
Andre	Elia	UNICA, Brazil

First Name	Last Name	Affiliation
Uwe	Fritsche	IEA Bioenergy and IINAS, Germany
Shabbir H.	Gheewala	King Mongkut's University of Technology, Thailand
Takashi	Hayashi	Ministry of Agriculture, Forests and Fisheries, Japan
Graham	Jewitt	University KwaZulu-Natal, South Africa
Luís Carlos	Job	Ministry of Agriculture, Brazil
Louise	Karlberg	Stockholm Environment Institute, Sweden
John	McGrath	Department of Parks and Wildlife, Western Australia
Kenneth J.	Moore	Iowa State University, USA
María Rosa	Murmis	Ministry of Agriculture, Livestock and Fisheries, Argentina
M. Cristina	Negri	Argonne National Laboratory, USA
Dotor	Panjaitan	Ministry of Energy and Mineral Resources, Indonesia
Guillermo	Parra Romero	DICAPAR, Paraguay
Benedito	Riberio	Embassy of Brazil to Sweden, Brazil

First Name	Last Name	Affiliation
Andrea	Rossi	GBEP Secretariat
Ibnu	Syahrudin	Ministry of Energy and Mineral Resources, Indonesia
Magnus	Stark	The Royal Swedish Academy of Agriculture and Forestry, Sweden
Suhas	Wani	ICRISAT, India
Helen K.	Watson	University of KwaZulu-Natal, South Africa
Arthur	Wellinger	IEA Bioenergy and Triple E&M, Switzerland