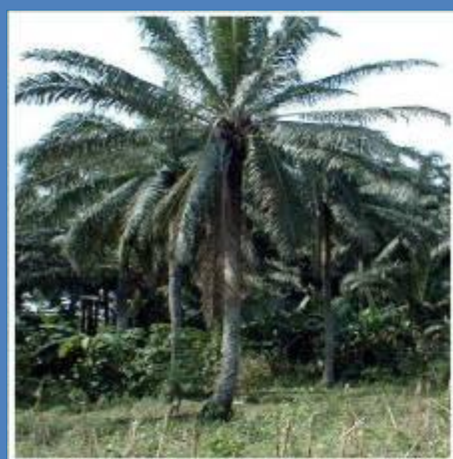
July 2009

Building capacity to monitor compliance with biofuel sustainability standards

White paper #2: Existing and emerging tools and approaches




Winrock International aims to support the efficient development of sustainable biofuels standards by assisting in providing access to relevant data on the technical, social, economic and environmental characteristics of biofuels.

Winrock International will develop three technical White Papers on GHG emissions, the role of water and building capacity to monitor standards. Three country impact evaluations of applying standards in national settings will be undertaken for the US, Brazil and Indonesia.

This White Paper focuses on capacity for monitoring compliance with biofuel sustainability standards.

For questions or comments contact:

Jessica Chalmers or,
David Walden

Winrock International

1621 North Kent Street, Suite 1200

Arlington VA 22209

+44 (0) 7985 499 061

Email: jchalmers@winrock.org

+1 (703) 525 9430

Email: dwalden@winrock.org

ACKNOWLEDGEMENTS

This work has been funded by The David & Lucile Packard Foundation. Winrock wishes to thank numerous organizations and individuals for discussions on this topic including ProForest, Dr Valerie Kapos (UNEP-WCMC), Bob Saunders & Allan Rankine (BP), Michelle Morton (Shell), Aaron Berry (Renewable Fuels Agency), Bart Dehue (Ecofys), Scott Loarie (Stanford University), Lucas Joppa (Duke University), Bob Norman (Greenpalm), Suzanne Hunt (Hunt Green LLC), Christine Ake (ED&F Man), Sonia Yeh (UC Davis), Stephen Delgrosso (USDA), Maryline Guiramand (Roundtable on Sustainable Biofuels), Christine Ake (ED&F Man).

CONTENTS

I. INTRODUCTION

The substantial and growing interest in biofuels as a potential contribution to improving energy security, reducing greenhouse gas emissions and in delivering rural economic development benefits has been challenged in recent years by non-governmental organizations and some scientists. In some cases these intended benefits have not been delivered, and instead, negative consequences such as land grabbing and increased GHG emissions have been reported.

In recognition of the need to ensure intended benefits are delivered there are numerous organizations, alliances and policy-makers involved in developing standards for biofuels and biofuel feedstock production. Some of these standards serve as tools for guiding public policy decisions at the national level (such as taskforces under the Global Bioenergy Partnership), while others are intended for application at the field or project level (i.e. voluntary standards such as the Roundtable on Sustainable Palm Oil – RSPO or mandatory criteria in the EU Renewable Energy Sources Directive). These standards are currently at different stages in their development, some are being implemented and other organizations are just beginning the process of developing criteria.

Terminology.

Standard – A set of principles & criteria

Monitoring - a set of activities conducted to gather and analyze data

Methodology – specification for data collection, analysis and reporting

Verification- the activity of checking the validity of the claims of a project.

Certification – the formalization of compliance through certificate issuance

This white paper is focused on building capacity for monitoring compliance with biofuel sustainability standards. Within this framework, building capacity encompasses a host of issues that include financial, technological, educational and social requirements. This paper is primarily intended to assist organizations developing standards for biofuels in accessing existing and emerging information on tools, approaches and mechanisms for monitoring compliance and outcomes.

Technologies that provide the necessary information for monitoring can be broken into two categories—those that collect and convey the data, and those that aid in interpreting the data. Although there are no universally adopted sustainable biofuel standards at this time, there are datasets, tools and best practice techniques from monitoring programs across other sectors (such as agriculture and forestry) that may be applicable for developing monitoring approaches[1]. Not all data will be easily measurable and different data sources and collection tools will be more appropriate depending upon circumstance. Tool choice will depend on the intended data use, destination, urgency and cost of collection. A combination of tools is often the most appropriate approach (Rusillo, 2009).

[1] For example the Forest Stewardship Council (FSC) program.

II. BACKGROUND

There are organizations, alliances and policy-makers involved in developing standards for biofuels and biofuel feedstock production. Delivering the sustainable outcomes for biofuels intended by these standards depends upon monitoring performance. Given the relative infancy of most of the biofuel and feedstock standards, few monitoring programs have been established thus far. Although assessments have taken place, for example on potential land use change and biodiversity issues, the frameworks for sustained data collection and analysis have yet to be developed.

Table 1: Illustration of sustainability standard / guideline development for biofuels and/or feedstocks (This list is not exhaustive)

	Type (Voluntary / Mandatory)	Consensus based?	Membership	Scope: Biofuel (B) or Feedstock (F)
International/Regional				
Global Bioenergy Partnership (GBEP) (GHG and sustainability taskforces)	Voluntary	Y	International policy-makers (policy-makers)	B
Roundtable on Sustainable Biofuels (RSB):	Voluntary	Y	Multistakeholder	B
Better Sugarcane Initiative (BSI):	Voluntary	Y	Multistakeholder	F
Roundtable on Sustainable Palm Oil (RSPO):	Voluntary	Y	Multistakeholder	F
Roundtable on Responsible Soy (RTRS):	Voluntary	Y	Multistakeholder	F
Sustainable Agriculture Network / Rainforest Alliance	Voluntary	Y	Multistakeholder	F
European Committee for Standardization (CEN)	Voluntary	Y	Multistakeholder - European	B
International Organization for Standardization	Voluntary	Y	Multistakeholder - International	n/a
Asia-Pacific Partnership Clean Development & Climate	-	-	Multistakeholder - Limited International	n/a
IADB 'Biofuel Sustainability Scorecard'	Voluntary	N	n/a	B
World Bank biofuel sustainability scorecard	Voluntary	-	n/a	B
Brazil INMETRO	-	-	n/a	B
UK Renewable Transport Fuel Obligation	Mandatory reporting	N	Regulatory	B
German Government	Voluntary reporting	N	Regulatory	B
U.S.				
CA Low Carbon Fuel Standard (LCFS):	Mandatory	N	Regulatory	B
Sustainable Biodiesel Alliance	Voluntary	Y	Multistakeholder - national	B

	Type (Voluntary / Mandatory)	Consensus based?	Membership	Scope: Biofuel (B) or Feedstock (F)
American National Standards Institute (ANSI), Sustainable Agriculture Standard	Voluntary	Y	Multistakeholder - national	B
Southern Bioenergy Roadmap: SAFER	Voluntary	n/a	Multistakeholder - regional	B
Council on Sustainable Biomass Production:	Voluntary	Y	Multistakeholder - regional	B
Keystone Alliance for Sustainable Agriculture	Voluntary	Y	Multistakeholder –national	F
Sustainable Food Lab (biofuel – responsible commodities team)	Voluntary	Y	Multistakeholder	F

The UK has developed the first sustainability program specifically for biofuels within a policy framework at the national scale. The volume of biofuel sold in the UK is monitored to track progress against mandated volumes and in addition, the GHG savings and sustainability characteristics of the biofuel are reported by obligated parties[2]. The program predominantly relies on identifying sustainable biofuels by requiring biofuel feedstocks to be grown and certified to an existing standard (e.g. the Roundtable on Sustainable Palm Oil) which has been benchmarked against the UK principles and has been judged to meet the required performance. This 'meta-standard' approach (creating an overarching standard upon which others are benchmarked) is also being developed by the Roundtable on Sustainable Biofuels.

At a regional level, the EU has agreed upon several sustainability criteria that biofuels sold in EU Member States *must* meet from 2010 in order to count towards targets[3]. A 35% minimum GHG saving and avoiding land cultivation on areas of high biodiversity and high carbon stocks are required. The mechanism to monitor compliance with this standard is to *'… encourage the development of multilateral and bilateral agreements and voluntary international or national schemes that cover key environmental and social considerations, in order to promote the production of biofuels and other bioliquids worldwide in a sustainable manner. In the absence of such agreements or schemes, Member States shall require economic operators to report on these issues*.' (European Commission, 2008)

National and regional monitoring schemes may rely at least partly on voluntary certification standards to meet project-scale sustainability objectives; however there are a number of challenges for monitoring programs:

A. Most standards relevant for biofuel are in their infancy. Voluntary certification standards such as Proterra (for GMO-free soy), organic agriculture standards (e.g. IFOAM) and standards have certified hectares but were primarily developed for health and safety (Assured Food Standards and GLOBALGAP) (see Annex 2). The Roundtable on Sustainable Palm Oil is now scaling up its certified area and others such as the Roundtable on Responsible Soy and Better Sugarcane Initiative are under development. Rainforest Alliance/ Sustainable Agriculture Network are developing a biofuels addendum for specific

[2] Obligated parties include biofuel distributors and refiners (See Annex 8)
[3] Biofuels should make-up 10% (by energy content) of transport fuels sold by 2020.

feedstocks based on the well-established certification standards for other crops such as coffee and the Council for Sustainable Biomass Production will focus specifically on lignocellulosic feedstocks. The volume of certified product available in the short-term (2010-2012) will not be sufficient to meet biofuel volumes expected to be required by US and EU policy decisions in that time period.

B. The standards developed to date for biofuel feedstocks do not cover all issues that have been identified as a requirement for biofuels. For national monitoring schemes such as the EU and UK approaches, some of the feedstock sustainability standards do not cover key principles such as carbon stock conservation (See Annex 1).

C. ‘Best’ management practices (BMPs) are often used as indicators of a positive outcome owing to ease of verification (Clay, 2008) but not all practices identified as ‘best’ have the same outcomes when applied in different site-specific locations. The collective impact of a suite of actions or BMPs may have trade-offs or no beneficial impact at all. A lack of geo-referenced data is a key limitation to understanding site-specific drivers and appropriate responses for example:

1. Increasing the use of urea as a fertilizer for example will reduce calculated GHG emissions[4] but could substantially increase the risk of acidification of water sources.
2. Improving water use efficiency in areas of water scarcity may not be sufficient to deliver a sustainable outcome if net abstractions are greater than water availability.
3. In addressing the issue of GHG emissions in agriculture ‘best practice’ guidelines such as reducing tillage or undertaking no-till may be specified. While this has been proven to reduce emissions owing to lower machinery use and increased soil carbon sequestration if practised over the long term, in specific cases[5] (such as when applied to waterlogged soils), there are instances in which promoting this ‘best’ practice could actually increase GHG emissions.
4. Developing biofuels on degraded or marginal lands is promoted to avoid competition for resources with food crops but little is known of the potential hydrological (and climatological) impacts of the large scale conversion of to crops when crop transpiration, infiltration and shading will increase (Berndes, 2002). Higher inputs on marginal lands e.g. of fertilizers to obtain economic yields may also negatively affect local water quality and GHG emissions.

D. Qualitative indicators such as practicing no-till or establishing buffer zones record activities, are descriptive and do not identify why a particular outcome has occurred or failed to occur. *Causal links between actions and outcomes are not necessarily well-understood* and

[4] Ammonium nitrate production has higher lifecycle GHG emissions than urea owing to higher energy requirements in the production of nitric acid.
[5] Environmental factors (climate, soil organic C content, soil texture, drainage and soil pH) all play a significant role in determining the nitrous oxide emissions from soil. Nitrous oxide emissions are one of the largest and most uncertain areas of GHG emissions for biofuels and have a global warming potential almost 300 times that of carbon dioxide. Nitrous oxide emissions from soil depend on (amongst other things), the oxygen and moisture status and gas diffusion in agricultural soils which in turn depend on soil texture and drainage. Fine textured soils have more capillary pores and hold water more tightly than sandy soils and waterlogged soils or those at risk of holding water through no-till practices, anaerobic conditions may be more easily reached and maintained for longer periods which increases GHG emissions (Stehfest & Bouwman, 2006).

therefore indicators designed to represent these links may require modification over time (based on further scientific research & evidence). A structure for effective feedback is essential for continuous improvement towards delivering sustainable outcomes.

Monitoring performance to determine (a) whether the indicators are suitable for monitoring purposes, and (b) what the outcomes of specific actions or combinations of actions are and how they contribute to sustainability goals is the essential feedback loop that enables the standard to remain meaningful and adapt where necessary to changing circumstances and includes evaluation and impact assessment activities. 'Better' management practices than imply continual improvement are a more suitable term than 'best' (Clay, 2008) but even better management practices may not deliver sustainable outcomes (see example C2 above).

E. Baseline data may not be gathered before a program begins (i.e.- GHG emissions of the biofuel, land cover and carbon stocks, etc.), Without an established baseline it is impossible to monitor sustainability outcomes over time;

F. An inconsistent application or lack of standardised data collection procedures, measurement parameters and reporting mechanisms is problematic from a monitoring perspective;

G. The market structure for biofuels providing challenges for monitoring and lifecycle traceability e.g. spot market trading makes capturing and passing relevant information through the supply chain difficult;

H. Political or cultural issues: Country risks e.g. corruption, can compromise monitoring programs;

I. Obtaining relevant and robust data, establishing and maintaining information management systems, and the technical skills and abilities demanded within a monitoring program are serious challenges for time & budget constraints;

Aim and scope of the paper

Biofuels standards can help avoid investment in biofuel production systems with net negative impacts if there are effective and cost-efficient ways to monitor compliance. There is increasing pressure on all agricultural production systems to monitor performance against a range of criteria.

This paper identifies existing and emerging technical approaches for monitoring sustainability criteria identified in Table 2 that attempt to overcome some of the challenges identified above. The current paper is not a comprehensive list of all issues and tools but serves to illustrate potential techniques and methods. Further work and collaboration is required to build sufficient capacity to enable the use of such developing biofuels compliance monitoring tools in a cost-effective and transparent manner.

The first section of the paper (Chapter III) focuses on tools and techniques for monitoring purposes. The second section (Chapter IV) focuses on the requirements for capacity building to support monitoring programs as a concluding chapter on building capacity.

III. TOOLS & TECHNIQUES FOR MONITORING

The following section describes several tools and techniques for accessing and interpreting data for biofuel sustainability monitoring purposes.

Sampling for cost effective monitoring

Measuring and monitoring large volumes of data to obtain robust results can be costly and unnecessary. Sampling approaches study a subset of a larger system in order to allow generalisations to be made about the area of interest. Monitoring can be conducted at an international, national, regional or local level and the most cost effective approach at regional and national levels could benefit from a sampling approach. The samples chosen would represent a key characteristic for example carbon stocks or water use and the regional data (such as satellite data) would be combined with field data for ground-truthing.

To facilitate the accuracy and precision of monitoring and assist in choosing the representative samples, large scale areas can be stratified to form relatively homogenous units which diminish the sampling efforts necessary, while maintaining the same level of confidence. Useful tools for defining strata from which to chose local level samples include ground-truthed maps from satellite imagery, aerial photographs and maps of vegetation, soils or topography (Pearson et al, 2005a).

Table 2 illustrates the indicators and tools associated with monitoring compliance with indicators that could apply at various scales. Based on the principle that practice does not equal performance, the indicators are performance based. However, the list is not exhaustive - it illustrates a selection of approaches and tools that could be used to monitor compliance.

Table 2: An illustration of performance-based indicators and monitoring tools for biofuel sustainability standards. This list is not exhaustive.

Criteria	Indicator	Tools / techniques	See section
Reduced GHG emissions	Reduced GHG emissions compared to baseline (gCO2eq / MJ biofuel)	• EIA with GIS to identify & avoid N_2O hotspots in field e.g. soil type, slope, and precipitation. • LCA (or well-to-wheel) assessment	A D
Soil quality	Soil erosion (ton/ha.yr)	• EIA with GIS to identify soil erosion risks. • High Conservation Value assessment	A
Water quality	Nutrient run off avoided	• EIA with GIS to identify risk of run-off & appropriate practice with data on slope, elevation, soil type. • Use existing water quality monitoring programs	A
Water use	Water scarcity No water rights conflict	• Remote sensing to determine availability on a regional level	B

Criteria	Indicator	Tools / techniques	See section
	Reduced water use per unit of product (m3/ unit)[1]	• Remote sensing for local water consumption & High Conservation Value assessment • LCA for consumptive water use	A E
Conservation of carbon stocks	Carbon payback time[2] (years) Soil carbon sequestration (tC/ha.yr)	• Remote sensing to identify land cover changes and above ground carbon stocks • Modeling (with calibration) for soil carbon e.g. COMET-VR[3]	B C
Land rights respected	No violation of legal boundaries & free prior, informed consent.	• GPS mapping to define GIS map of land title, tenure, customary rights. • Guidance book on 'Free Prior Informed consent'[4]	G (Box 5)
No contribution to food insecurity	Increased crop yield (t/ha) Production on 'idle/degraded' land Increased income ($/ha or $/family/yr)	• Leverage existing monitoring programs e.g. GEOSS[3] • Remote sensing for yield and land cover changes • Social LCA (impact assessment)	B G
Contributes to rural & general economic development	Increased crop yield (t/ha) Increased income ($/ha or $/family/yr) Number of jobs	• Remote sensing • Income data with GIS for spatial links • Social LCA (impact assessment)	B G
Conservation of biodiversity	Number of & spatial extent of species or critical species	• High Conservation Value assessment	Box 2 Annex 6

Acronyms: EIA = Environmental Impact Assessment; GIS = Geographical Information systems; GPS = Global Positioning System; LCA = Life-cycle assessment; COMET-VR = Voluntary Reporting of Greenhouse Gases-CarbOn Management Evaluation Tool; GEOSS = Group on Earth Observation System of Systems.

[1] Measuring water use per unit of biofuel is possible but of significance is whether a) the water is rainfed (and potentially not in water scare area) or b) irrigated. In addition, measuring water productivity of biofuel only rather than the energy produced from a bioenergy system comprising biofuel (e.g.. biofuel + electricity from sugarcane bagasse) could alter conclusions. See Winrock international, (2009b) for further discussion.

[2] Carbon payback time is a measure of the length of time taken to 'payback' GHG emissions associated with changing land use to produce biofuels. See Gibbs et al (2008) and Winrock International (2009a) for further details.

[3] These tools or programs are discussed further in the report.

[4] See http://www.forestpeoples.org/documents/law_hr/fpic_and_rspo_companies_guide_oct08_eng.pdf

A. Environmental Impact Assessments

An environmental impact assessment (EIA) consists of a set of activities that are undertaken to ensure that the likely effects of new development on the environment are fully understood and taken into account before the project goes ahead.

The biofuel supply chain, from cultivation to final distribution, includes activities that risk delivering negative outcomes. For many biofuel crops, the application of fertilizers (such as nitrogen and phosphorus) during cultivation as well as herbicides and pesticides can result in negative water quality impacts (such as increased nitrate and sediment loading in water courses). These impacts can contaminate drinking water supplies and reduce oxygen content in the water which affects the local ecosystem. Elevation, slope, rainfall and land management practices can influence transport of these nutrients into waterways and soil erosion risks.

Also within the cultivation stage, current tools for measuring & monitoring GHG emissions from biofuels indicate that N_2O emissions from soil are one of the largest and most uncertain emissions for many biofuels and can account for up to 80% of some fuel chain life-cycle emissions. Managing & mitigating N_2O emissions effectively could provide substantial GHG benefits (Smeets, et al 2009).

The following tools and techniques provide an illustration of how sustainability criteria may be assessed and monitored.

Using Geographical Information Systems (GIS) for risk assessments: water, soil and GHGs.

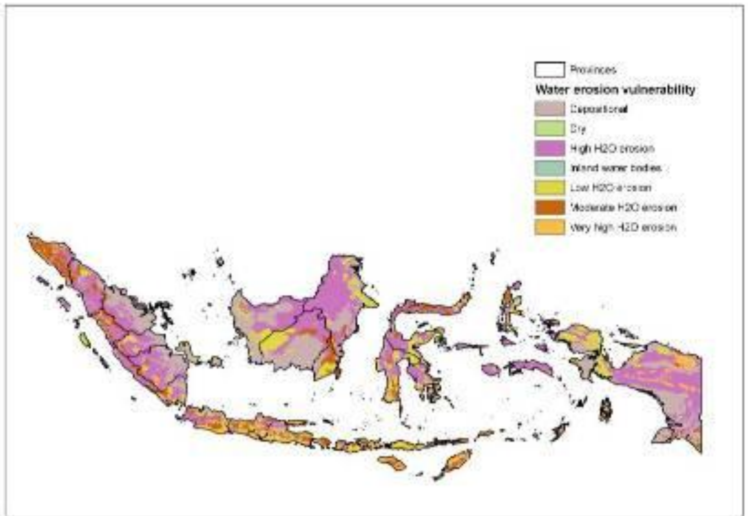
A geographical information system captures, stores, analyzes, manages, and presents data that is linked to spatial location. GIS applications are tools that allow users to create interactive queries, analyze spatial information, edit data, create maps and present the results of all of these operations.

GIS tools are being used on a regional level to define agro-ecological zones for crop suitability and tools and methodologies are publicly available[6]. Data sets of geophysical parameters such as rainfall, soil type, slope etc. can be used to generate maps of crop suitability which can developed further by adding data into these maps associated with protected areas. The Brazilian Government is undertaking this approach to agro-ecological zoning for sugarcane to plan and restrict the establishment of new plantations according to climatic and ecological conditions (Empraba, 2008).

GIS techniques can also be used on a more detailed level to develop baselines and understand potential implications of crop choices and land management techniques as part of a risk assessment in an EIA. By combining data layers on soil type, elevation, slope and rainfall, areas at risk of water and soil erosion can be defined at a local or regional scale (Figures 1 and 2).

[6] http://www.fao.org/ag/agL/agll/aez.stm

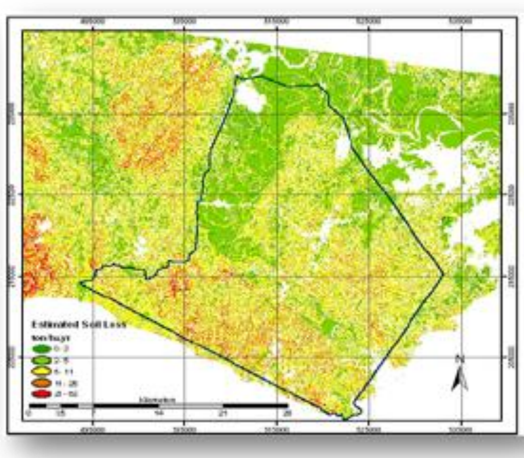
Figure 1: A GIS analysis of water erosion vulnerability on a national scale in Indonesia.



Source: Reich *et al*, 2001.

These techniques can identify the performance of water quality and soil erosion improvements. The cost effectiveness of actions promoted to improve water quality and soil erosion for example is highly variable depending on the local context. In the US, planting winter cover crops, for example, can range from US$800/ lb of phosphorus to US$29/ lb depending on site specific contexts (Winrock International *et al*, 2009) Adopting no-till techniques on specific farms can also reduce non-point source water pollution and reduce soil erosion. A pilot project on identifying avoided soil loss based on better management practices (Winrock International *et al*, 2009) estimates an average soil loss avoidance of 1.01tons/acre.yr in Vermont and 1.58tons/acre.yr in Iowa.

Figure 2: A GIS analysis illustrating areas of soil erosion risk (>11t/ha.yr).



Source: Sulistioadi *et al*, 2004.

Establishing N_2O emissions from soil are also critical from a monitoring perspective but creating a baseline and monitoring N_2O emissions from soil (and stimulating voluntary market interest in N_2O emission reduction projects) is challenging. IPCC Guidelines developed for reporting N_2O emissions under national greenhouse gas inventories are not intended to measure project-scale emissions. Indeed studies (Roelandt *et al*, 2005 & Stehfest & Bouwman, 2006) have demonstrated the unreliability of the IPCC Tier 1 approach for project scale assessment.

Geospatial techniques can be employed to identify 'hotspots' of risk for GHG emissions such as areas with specific soil types and at risk of waterlogging. By combining data layers on soil types, slope and elevation and rainfall with qualitative data on the types of fertilizer used and application approaches, these 'hotspot' maps could be generated and used to target appropriate management practices to minimize these risks. Avoiding such hotspots is likely to positively influence the GHG balance for a biofuel without requiring detailed site-scale measurements.

Box 1: Combining GIS techniques – A Practical Example for an EIA

GIS techniques can also be used to assess transport routes for efficiency and improve economic and environmental costs of transportation. This network of transport routes can be used within a spatial analysis framework to determine likely feedstock production areas & implications. For example, sugarcane and palm oil have time-related limitations from harvest to conversion. Data on transport distance and timing can be combined with data layers on land cover, rainfall, protected areas for biodiversity, above ground carbon stocks and soil carbon stocks (provided sufficient data exists) to illustrate whether the locations of feedstock production are within 'hotspot' risk areas.

The use of a Geographic Information System (GIS) can also facilitate site selection and risk assessment for the development of predictive modelling that could provide a powerful tool in monitoring the spread of potential invasive species, and designing control strategies. Warm-season grasses that are promoted for biofuel use could be classed as potentially invasive species as they may outcompete other species across a wide range of environments, including those with prolonged hot, dry periods. Giant reed grass is highly flammable and could increase wildfire risks. Switchgrass is considered invasive by Southern Weed Science Society but is often recommended for use as a buffer zone for water quality and planting it along streambanks may pose risk of long distance dispersal and invasion (Davis, 2008). Risk assessments using GIS for compliance monitoring should be conducted.

Box 2

A High Conservation Value approach for managing local impacts

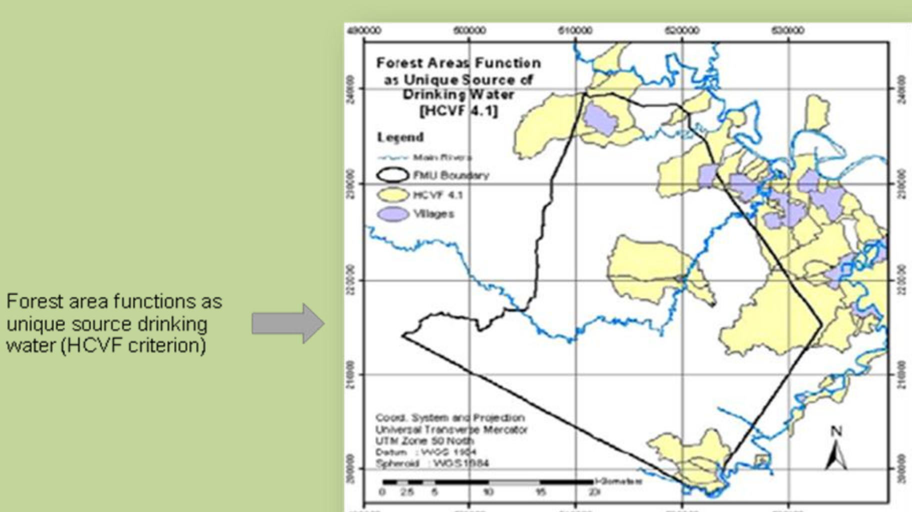
The designation of 'High Conservation Value' was originally devised in the context of forest certification (HCVF) and used within the Forest Stewardship Council, although it is applicable to all kinds of ecosystems and habitats. The Global Toolkit lists the following six 'High Conservation Values' ('HCVs') which cover the range of conservation priorities including social priorities.

- *HCV1.* Forest areas containing globally, regionally or nationally significant concentrations of biodiversity values (e.g. endemism, endangered species, refugia).
- *HCV2.* Forest areas containing globally, regionally or nationally significant large landscape level forests, contained within, or containing the management unit, where viable populations of most if not all naturally occurring species exist in natural patterns of distribution and abundance.
- *HCV3*. Forest areas that are in or contain rare, threatened or endangered ecosystems.
- *HCV4*. Forest areas that provide basic services of nature in critical situations (e.g. watershed protection, erosion control).
- *HCV5*. Forest areas fundamental to meeting basic needs of local communities (e.g. subsistence, health).
- *HCV6*. Forest areas critical to local communities' traditional cultural identity (areas of cultural, ecological, economic or religious significance identified in cooperation with such local communities).

The HCV designation has developed into a valuable and flexible toolkit for a variety of uses, including land-use planning, conservation advocacy, and designing responsible purchasing and investment policies. The concept is used in some of the commodity roundtables (such as the Roundtable on Sustainable Palm Oil) and is also identified in the UK national biofuel standard (the RTFO meta-standard).

National interpretations are key to implementation of the HCV toolkit and some, including for Indonesia and Malaysia, have been developed. GIS techniques and tools have been used as part of an HCV assessment within local and site-specific contexts and develop management plants (Sulistioadi *et al*, 2004). Figure 3 illustrates a local assessment of spatial estimation of forest areas and watersheds, identifying both unique sources of drinking water. These techniques enable better choices and practices to be identified within a specific context.

Figure 3: Using GIS techniques to illustrate ecosystem services (Source: Sulistioadi *et al* (2004)



B. Remote sensing

Water, land cover and carbon stocks

The conversion of natural vegetation to crops can lead to significant GHG emissions through the release of stored carbon. This can be sufficient to negate any GHG savings that could be generated by displacing fossil fuel[7]. Recent studies also indicate that changing land use could impact GHG emissions through increased emissions of volatile organic compounds from some land cover types.[8]

For land cover change monitoring, land identification (classification) is required to establish a baseline (this baseline or 'reference date'[9]) will vary depending upon the standard (see Annex V). This land cover can be used to quantify carbon above and below ground through associating land cover with existing estimates of the carbon stocks of such land cover. Future advances in remote sensing technologies could estimate carbon stocks directly

Site observations and measurement may work for small areas but can be costly over large areas. Ensuring the credibility of data is essential and remote sensing technologies are available that can facilitate monitoring activities.

Most sustainability standards also consider water consumption. The cultivation of crops requires may require substantial volumes of water and in areas of water scarcity, even better management practices that reduce the volume of water required in processing may be insufficient to mitigate this problem. Measuring and monitoring water availability and consumptive water use remotely could represent a cost-effective compliance tool.

Remote sensing: overview

Remote sensing data can identify consumptive water use, land cover and vegetation types which can enable a baseline to be determined and monitor these changes over time cost effectively[10]. New technological developments could increase the applications and robustness of remote sensing data.

Remote sensing techniques obtain information through the use of two different types of sensors: passive or active. Passive sensors (e.g. The Thematic Mapper (TM) sensor system on the Landsat satellite) record radiation reflected from the Earth's surface and use solar energy as the

---

[7] The concept 'carbon payback time' has been used in site specific analyses as a sustainability metric for biofuels (RFA, 2008a & 2008b, Gibbs *et al* 2008, Kim & Dale, 2009, Searchinger *et al* 2008). Carbon payback time is defined by calculating the emissions associated with changing a reference land use to biofuel cropland and dividing by the emissions saved by that biofuel displacing fossil fuel.

[8] Recent studies (Nemitz, 2008) indicate that monitoring of specific land use changes will be significant as biogenic volatile organic compounds such as isoprene, emitted from some plants as a key component of biosphere-atmosphere interaction, have been found to be significantly greater over oil palm plantations than rainforest in South East Asia. As precursors to ozone formation (a greenhouse gas), the risk of climatalogical implications of large scale land conversions has been identified.

[9] Standards often refer to this date as the reference date rather than a baseline.

[10] The reference years are also used to ensure no negative changes occur in areas high conservation value – remote sensing is not able to detect some of these criteria e.g. biological diversity.

source of radiation (therefore the passive sensors capture data only during the day). Active sensors provide the source of the energy (rather than relying on the sun)[11].

Because different spectral responses can be interpreted as different land types, satellites that collect this data can clearly distinguish surface properties. Remote sensing can be used at a global, national or field scale to address the following questions:

- What is the land cover type in a particular area and how has it changed over time?
- What are the different vegetation types in a specific area and how have they changed over time? (level of detail depends on the sensor used)
- What are the above and below ground biomass carbon estimates and how have they changed over time? (Based on vegetation type, density, etc.)
- Where are the areas of potentially low above and below ground carbon stocks that could be explored further for biofuel production?
- What is the evapotranspiration from this area over the growing season (consumptive water use) and how does that relate to the rainfall – will water scarcity be an issue? How is this relationship changing over time?

Satellites that collect remote sensing data use different spatial and temporal scales (Table 3). For accurate monitoring, the most important factors to consider when choosing a remote sensing tool are the size of the project to be monitored (national vs local), the pixel size of the chosen medium of remote sensing (ranging between 5km and <1m), the frequency of observation (i.e. daily / hourly), and of course, available budget. To ensure the validity of data collected through remote sensing, it is also recommended that ground based data be used for comparison purposes. The extent of the remote sensing data collected will depend on the criterion monitored, the quality and resolution of the remote-sensing data gathered (e.g. cloud cover can cause significant problems), and the detail of the result sought. Table 3 provides examples of remote sensing sources and applications by both spatial and temporal scales of resolution.

Table 3: An illustration of remote sensing sources and applications

Scale	Global	Regional/National	Sub-national	Local
Spatial resolution	5km – 1km / 1km – 250m	250m – 60m	60m – 10m	<10m
Temporal resolution	Hourly / daily	2-3hrs / every 10 days	1-2hrs / every 10days	1-2hrs / every 10days
Source	Modis* (1km-250km)	Envisat (250m) Landsat* (30m)	Ikonos** (3m/1m) QuickBird** (2.4m/0.6m)	

[1] Measure of smallest angular or linear separation between two objects that can be resolved
[2] Time interval between data acquisitions
* Freely available
** Commercial satellites
Source: Justice & Becker-Reshef (2007)

[11] The LIDAR data is example of data collected by active sensor. The laser beam system sends out a beam of light with, the beam of light reaches the surface and is reflected back to the sensor. The sensor records the time needed for the beam of light come back to the sensor.

Recommended spatial resolutions required to verify reference land cover in particular areas has not yet been defined within sustainability standards. In countries where large scale agriculture is common (e.g. USA, Argentina, Australia, Russia, and Brazil), most requirements can be met using sensors with a spatial resolution of 30 – 80m. In other countries (for example in Africa and Europe where farm sizes are small and the agricultural landscape complex), mapping crop types and estimating agricultural area requires sensors with a spatial resolution of less than 20m (Justice & Becker-Reshef, 2007).

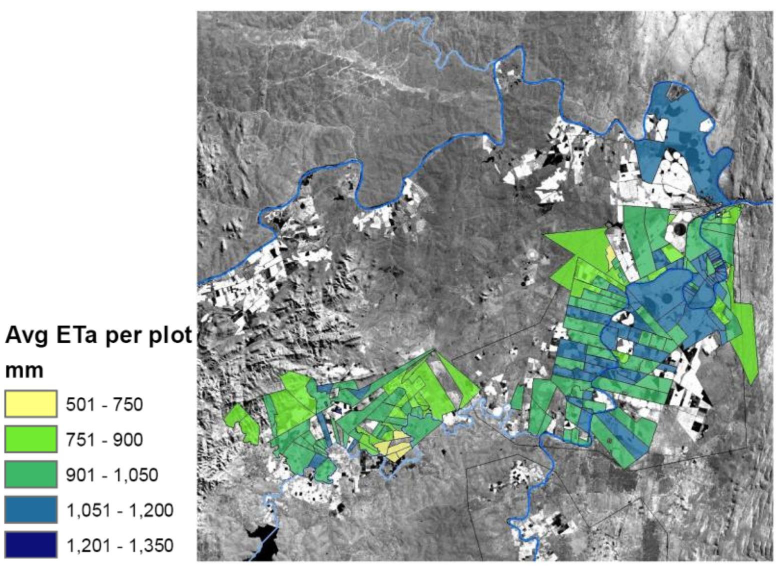
Remote sensing for water use & availability

Remote sensing technologies can be used within specific regions to assess consumptive water use significance in relation to water availability. Differences in crop types, for example, will influence evapotranspiration and assessments can be used to understand the water use implications of changing crops in specific areas. An algorithm (SEBAL) has been developed to calculate consumptive water use (evapotranspiration). This algorithm relates surface temperature to the incoming solar radiation and the surface albedo, which together define what the “natural” temperature of the surface would be in the absence of evapotranspiration. The difference between the calculated “natural” temperature and the actual temperature allow for an estimation of the actual evapotranspiration independently of the actual land use. Further combining the evapotranspiration estimates with information about the vegetative state of the land, or the Leaf Area Index, provides an indicator of yield for crops (Perry, 2007).

Site scale

This remote sensing tool can be used on a site-scale to assist in monitoring water use and enforcing water rights such that impacts on streamflows are kept to agreed levels (Perry, 2007).

Figure 4: Average evapotranspiration per plot for 2 catchment areas in South Africa.



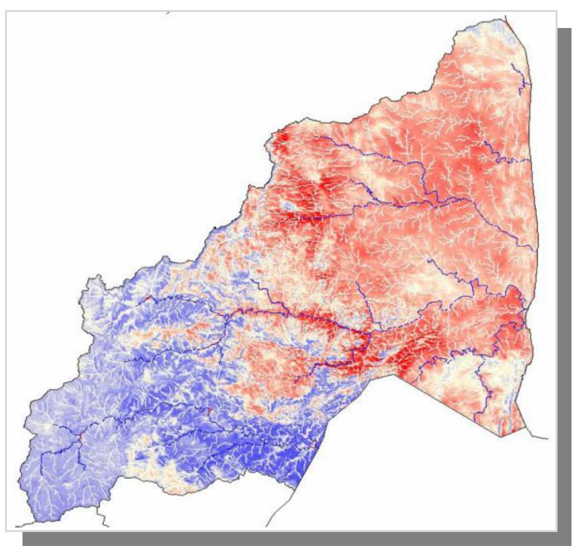
Source: Perry (2007).

Regional or national scale

Remote sensing data from satellite imagery (e.g. MODIS or Landsat) can be overlain with rainfall data within meaningful boundaries such as a river basin, to assess of the implications of a project on net water availability (Perry, 2007). Figure 5 illustrates an analysis of the Inkomati basin in South Africa, combining annual evapotranspiration with satellite-based information about annual rainfall[12]. The area in blue indicates a region where there is excess moisture, i.e. the rainfall amount is greater than the evapotranspiration rate, which suggests that there is enough water via rainfall to support increased agricultural growth. The red area indicates that there is too little water available to support increased agricultural growth that relies primarily on rainfall.

However, such results must be viewed with care and assessed in the context of basin management. Without land cover details it is not possible to understand why there is excess production (blue). This area could be an upland forest with high rainfall and may represent the water catchment above the area in red. While the area in red appears to be in net-water deficit, the water in the blue area may in fact flow into the red area and provide the necessary requirements. Changing land use in the blue area based on the outcome of this model alone could disrupt the hydrology of the area and reduce the water available for users downstream in the red area.

Figure 5: Net water production (blue) and consumption (red) for the Inkomati catchment, South Africa.



Source: Perry (2007).

When deriving evapotranspiration estimates from different satellites, different results are produced, and therefore researchers must consider the reliability of each imagery source and scale. A study in China found that Landsat images estimated greater evapotranspiration over forest, wetland and cropland than MODIS data (Zeng et al, 2009). These tools could hold

[12] Derived from the Tropical Rainfall Measurement Mission but such geo-referenced data is also available from the International Water Management Institute Climate and Water Atlas.
http://trmm.gsfc.nasa.gov/images_dir/images.html or http://www.iwmi.cgiar.org/WAtlas/Default.aspx

considerable potential for cost effective monitoring and further research to ensure robust results are delivered is required.

Some sustainability standards identify ‘conserving groundwater supplies’ as a criterion for sustainable production of biofuels. Understanding and observing groundwater supplies will be as important as monitoring surface water. Groundwater is estimated to provide about 50 percent of the world’s drinking water, 40 percent of the water used for industry, and 20 percent of water used in irrigated agriculture. While technologies do exist, capabilities lag behind those for surface water monitoring and large-scale, comprehensive, integrated implementation projects are required (CSIS, 2005).

Remote sensing for land cover, carbon stocks & fire

Coarse resolution remote sensing for land cover identification

The MODIS (Moderate Resolution Imaging Spectroradiometer) data are available and published using global land cover categories identified by the International Geosphere Biosphere Program (IGBP). IGBP categories consist of 17 cover classes; eleven classes of natural vegetation, three classes of developed and mosaic lands, and three classes of non-vegetated lands[13].

The IGBP land cover categories were not designed specifically for use with MODIS and therefore some of the emerging sustainability standards will likely require modification of some of the original MODIS land cover categories to meet their own land cover categories. Unfortunately, with coarse resolution (1-km, equivalent to a pixel area of 100 ha) and broad land cover categorization, the spectral characteristics of the finer classes may be similar to each other in many cases (e.g. woody savannah and shrubland) and thus land cover changes may not be sufficiently well defined for detailed monitoring.

Medium resolution remote sensing for land cover identification

Analysis of land cover can be undertaken at medium resolutions. *Landsat*TM[14] data is now freely available and can be used for regional scales. However due to possible economic constraints given the volume of data required to be captured, stored and processed, medium resolution is difficult to use for national and global scale purposes (Lu, 2006).

The Canasat Project in Brazil is coordinated by the National Institute for Space Research (INPE)[15] and provides information about the spatial distribution of cultivated sugarcane area in Central-South States of Brazil. The Project has used remote sensing satellite images since 2003 in São Paulo State, and since 2005 for the remaining sugarcane producing States in the

[13] The natural vegetation units distinguish evergreen and deciduous, broadleaf and needle-leaf forests; mixed forests, where mixtures occur; closed shrublands and open shrublands; savannas and woody savannas; grasslands; and permanent wetlands of large areal extent. The three classes of developed and mosaic lands distinguish among croplands, urban and built-up lands, and cropland/natural vegetation mosaics.

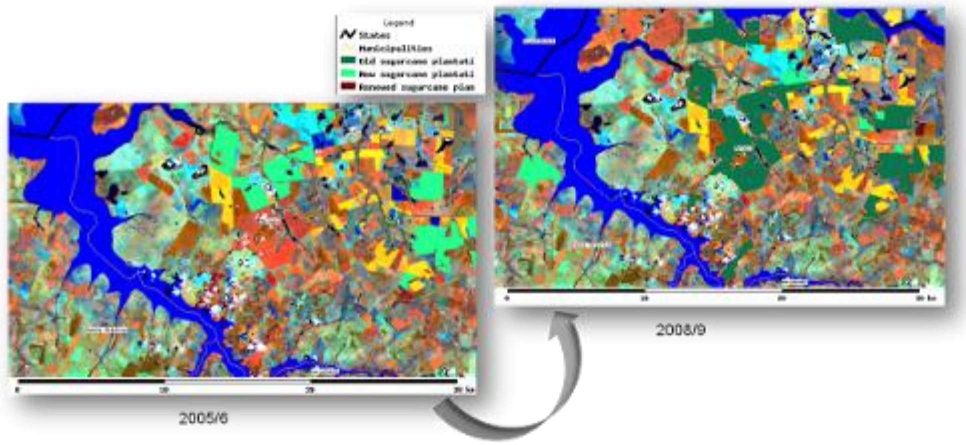
[14] LANDSAT http://landsat.gsfc.nasa.gov/

[15] INPE has also developed TerraAmazon, open-source software for large-scale land change monitoring. INPE´s new Regional Centre for Amazonia in Belem is under construction and will establish local and international capacity building for monitoring tropical forests.

Central-South of Brazil. Figure 6 provides an example of land cover change maps from this project.

There are two methods for developing land use *change* maps for monitoring purposes. The first uses satellite images from two separate time periods with the remote sensing analyst classifying the land cover changes based on the change of the reflectance values. The second method uses pre-classified images from two time periods and after comparison defines the changes. There is currently no standardized methodology or biofuels sustainability compliance standards guidelines for interpreting remotely sensed data for land cover and land use change information. Very few countries have such land use and land cover datasets that have been prepared using change detection techniques for all classifications.

Figure 6: Screenshots from the CANASAT Project, Brazil, illustrating changes in cane distribution from crop year 2005/6 to 2008/9.



Source: CANASAT Project (2009).

This coarse and medium scale remote sensing data establishing land cover data can be used to calculate above ground carbon stocks. Traditional techniques for collecting information on carbon stocks rely heavily on field-based measurements. In regions with heterogeneous biomass stocks over large land areas, substantial resources are often required to ensure a high degree of accuracy and precision in reported estimates. The use of remote sensing data provides an alternative method for reducing costs of measuring the carbon stocks of forests and savannas.

Remote sensing approaches rely on calibrating the satellite measurements to *in situ* estimates of above ground biomass at field study plots which is often determined using a combination of relationships between simple plot-level measurements (e.g. stem diameter, density and sometimes canopy height and/or depth) (Goetz *et al*, 2008). Though this approach is well used the uncertainty of accuracy is high (Gibbs, *et al* 2007). New technologies on satellite systems could improve this uncertainty. LiDAR uses laser light to estimate forest height/vertical structure (see Figure 7) but is not yet used on a satellite system but is planned. The NASA DESDynI program will include a LIDAR sensor and could be used in the future to map 3D vertical structure of vegetation which could be used to improve accuracy of measurements. Annex 3 provides an overview of different approaches for measuring above ground carbon stocks.

Remote sensing techniques can also be used to detect burning of vegetation (such as may be practices in land preparation) for up to several years following the fire through detection of ‘burn scars’. Avoidance of burning practices is intended to mitigate air quality issues associated biofuel feedstock production and as fire is associated with methane emissions; remote sensing techniques can monitor methane emissions from burning.

Innovative tools for above ground carbon stock data

While the capacity for monitoring changes in land cover is improving rapidly with advances in remote sensing technology, in many developing countries reliable data on carbon stocks are scarce and allocating significant resources for monitoring may be difficult. Programs to acquire remote sensing data as part of monitoring systems would be beneficial (Angelsen *et al*, 2009).

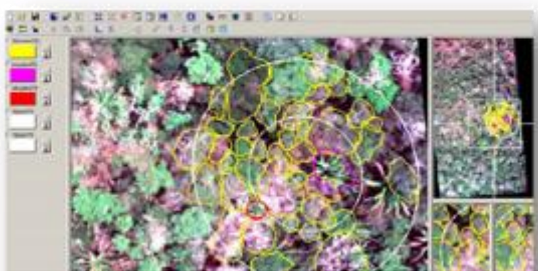


Figure 7: An illustration of the use of M3DADI to measure carbon stocks.

High resolution images, such as IKONOS, are usually used on a site rather than regional scale for several reasons: because of the storage capacity needed for a large volume of data; the expense to purchase the images; and the huge amount of time and labour needed to process the images (Lu, 2006). Thenkabail et al (2004) used IKONOS imagery to determine the above ground carbon stocks of oil palm in West Africa and monitor changes over time. The plantation locations were mapped with an overall accuracy of 88%-92% (although the differentiation of various age groups of oil palms was limited, influencing the accuracy of the carbon stock results).

A multispectral, three-dimensional aerial digital imagery system (M3DADI) has been designed and used to collect high-resolution overlapping stereo imagery (≤10 cm pixels) which can distinguish individual trees and shrubs (Pearson *et al,* 2005b). This system has been successfully tested in a pine savanna in Belize and tropical forests in Puerto Rico, Peru and the Republic of Congo. In Belize, (Brown et al. 2004) 77 aerial-imagery plots across transects were measured and assessed with a variety of vegetation cover: trees, shrubs, palmettos and grasses. The study estimated that a conventional field approach would take around three times more person-hours than the aerial approach. High resolution optical imagery such as this can discriminate savanna land cover types and densities, data which can be used to substantially improve carbon stock inventories.

The selection of suitable variables from remotely sensed and ancillary data and the selection of suitable algorithms for land cover, carbon stocks, water availability, etc., are complex procedures, requiring a good understanding of the relationships and interactions among tested variables and land cover attributes. Analyzing such data requires advanced skills in mathematics, modeling, computer programming, and remote sensing (Lu, 2006).

A high-quality data source is a prerequisite for developing above ground carbon estimation models. Significant uncertainties in collected data may be due to inconsistency of data collection dates, and complex vegetation composition and density. Calibration or validation of the calculated above ground carbon is necessary (Lu, 2006). Guidance on ensuring accurate measurement is identified in *Sourcebook for Land Use, Land-Use Change and Forestry Projects* (Pearson *et al*, 2005a).

Other reasons for monitoring land cover changes

Remote sensing techniques for understanding land use change can also lead to improved monitoring of the actual changes in GHG emissions over time compared with those calculated based on assumptions. For example, emissions associated with direct land use change are attributed to biofuel in some LCA methodologies. In order to do this, the emissions from land use change are annualized over 20 years and added to the biofuel. The calculation assumes that the land remains as cropland for 20 years. However, in most cases that land will change between crop types and different uses over a 20-year period, or may remain as planted cropland for a longer period and therefore the actual fluxes will differ. Significantly, the estimated GHG emission changes resulting from land use change are generally only carbon stock changes (and therefore only carbon dioxide calculations or methane where burning takes place). However, changes in N_2O emissions are often not accounted for. N_2O emissions from natural vegetation are not generally taken into account when changing land use, but should be considered (Stehfest and Bouwman, 2008) and monitoring these outcomes could be possible using a combination of tools such as remote sensing and modeling.

Monitoring indirect land use change.

There are discussions about the consequences of expanding biofuels production and implications for GHG emissions (Searchinger *et al,* 2008, Fargione et al, 2008). The principle of indirect land use change, for example, is that diverting existing crops to biofuel production induces a corresponding land use change somewhere else in the world to ‘fill the gap’ in demand for the crop. The GHG emissions from this indirect land use change are generally attributed to the biofuel, emissions which are so large they often negate any fossil displacement benefit. Models are being developed to predict such outcomes and in California (through the California Air Resources Board) the quantified results may eventually inform public policy decisions. Again, specific outcomes should be monitored against forecasts to inform the validity of results. Setting the parameters of such models to predict outcomes in the present day (or several years past) and monitoring the validity of those forecasts through using aerial imagery to identify actual land use changes could assist this monitoring framework should such modeling approaches be adopted.

Remote sensing for monitoring yield

Currently, crop yields can be forecast using climatological data combined with data on soil type etc to model yield and serve as a monitoring tool. However, there is a move towards integrating near real-time rainfall data and satellite observations of vegetation condition to improve yield monitoring (Justice & Becker-Reshef, 2007) by comparing time-series data. The data may indicate increased yield or reduced production due to drought, floods, insect infestation. Monitoring of crop condition and phenology is undertaken using various vegetation indices, formed from coarse and moderate resolution time-series data (Justice & Becker-Reshef, 2007). This approach necessitates a consistent and well-calibrated data record.

Targeted imaging of local crop condition as part of a sampling approach can be undertaken using very fine spatial resolution data. Airborne sensors (such as that identified in Figure 7) can have a spatial resolution from 10 cm to 1 m. Interpreting different infrared bands illustrate the density of vegetation and can be used to determine the yield of a crop. Anomalies in infrared bands indicate crop health and can be used to forecast yields as well as monitor over time. In some cases they are now routinely used for monitoring of crop productivity and health. Novel sensor approaches could be developed in the future which could enable farmers to genetically "tag" their crops to enhance the signature that can be detected through remote sensing to better detect crop distress or optimal harvesting[16].

C. Modeling soil emissions & carbon sequestration

Some draft standards include requirements for either conserving soil carbon or monitoring soil carbon trends. The availability of key pieces of data to inform these criteria are unreliable[17]. Even where substantial resources are available e.g. at the European level, there is a lack of geo-referenced, measured and harmonised data on soil organic carbon generated from systematic sampling programmes. At coarse resolutions a standardised map, (*i.e.- FAO digital soil map of the world*[18]*)* is available but often these data stem from high-level calculations based on land cover, climate and topography. Accuracy levels of this data, when applied to a sub-national or regional scale are often low.

Modeling approaches could play a key role in monitoring compliance with soil carbon[19]. Currently, the most common method for measuring soil carbon involves taking a soil sample from the field and processing it in the lab. Unfortunately, field data collection is expensive and time consuming. Emerging, portable site-specific tools such as *laser-induced breakdown spectroscopy (LIBS)*[20], *near-infrared spectroscopy (NIR)* and *inelastic neutron scattering* could eventually provide soil carbon and fertility measurements and monitoring. In the meantime these tools could be used to verify current models discussed below.

The Century model is a generalized biogeochemical[21] ecosystem model originally developed to simulate soil organic matter dynamics and plant production in grazed grasslands and agro-ecosystems. The model simulates carbon (i.e., biomass), nitrogen and other nutrient dynamics and simulates cropland, grassland, forest and savannah ecosystems and land use changes

[16] http://spie.org/x15006.xml?ArticleID=x15006

[17] To obtain an accurate inventory of organic carbon stocks in mineral or organic soil, three types of variables must be measured: (1) depth, (2) bulk density (calculated from the oven-dried weight of soil from a known volume of sampled material), and (3) the concentrations of organic carbon within the sample.

[18] http://www.fao.org/ag/agl/agll/dsmw.stm

[19] For convenience and cost-efficiency, it is advised to sample to a constant depth, maintaining a constant sample volume rather than mass. A 30cm probe is an effective measurement tool (Pearson et al, 2005) given this is the depth to which land use changes or management practices largely affect soil carbon.

[20] Based on splitting soil elements with energy from a laser and can assist in determining overall soil fertility. However, reported accuracy at present is 3-14 percent. (CASMGS, 2007)

[21] Chemical, physical and biological interactions.

between these different systems in the US[22]. Other soil carbon models exist, such as RothC[23], and have been applied to international contexts in Kenya, Jordan and Brazil (Milne *et al,* 2005)

The Century model has been combined with a decision support tool and web-friendly interface (COMET-VR) in the US to value carbon sequestration for crop cultivation. The Voluntary Reporting of Greenhouse Gases-CarbOn Management Evaluation Tool (COMET-VR)[24] allows landowners and others to get a rapid estimate of the carbon sequestration rate on land in the U.S[25] and to explore how changes in management of the land might affect carbon sequestration rates. Users input a history of agricultural management practices on one or more parcels of land. The results are presented as ten-year averages of soil carbon sequestration or emissions with associated statistical uncertainty values. This information can then be used to report into the USDA's voluntary greenhouse gas reporting system (The 1605b program).

Dynamic interactions between soil biochemical components and the atmosphere are complex. N_2O emissions are influenced by the environment and management practices (Stehfest & Bouwman, 2006) and should be accounted for. At present some LCA methodologies rely on high level default data for N_2O emissions that are based only on the level of fertilizer application. A methodology created by Stehfest & Bouwman (2006), originally designed for tropical and sub-tropical climates, could be used to test and validate the feasibility of using alternative values they present.

Modeling approaches are also used for N_2O emissions. Although there is no international model that facilitates the assessment of N_2O emissions from soil, the DAYCENT biogeochemical model in the US does have the ability to simulate the impacts of land use options not only on nitrogen gas emissions from soil, but also NO_3 leaching, crop yields, and soil carbon levels. In the EU the DNDC model is used for simulating nitrogen gas emissions from soil.

Models that integrate these inter-relationships should be used to move away from national-level default values for project-scale monitoring. Similar to the VR-COMET modeling tool for monitoring soil carbon described above, a modeling approach that generates a greater level of precision using climatic data and management approaches for N_2O emissions, combined with the geospatial data would provide an alternative to relying on national-level IPCC assumptions. Efforts in the US are underway to combine Century and DAYCENT models to improve the accuracy of estimating real outcomes (Delgrosso, *pers comm*.) and could be a substantial move towards improving capacity for monitoring sustainable biofuel production in the US.

One of the key issues for wider application of such models outside the US is the lack of relevant datasets in a standardized format. For some countries and regions the data will be easier to collate given existing in-country capacity for data collection of this type. For international settings, long-term commitments to establishing the framework for this model type are required to ensure the sustainability and credibility of such a program.

---

[22] Century is widely used in the U.S. and in several other countries for estimating national soil carbon inventories. It has been used to estimate impacts of the Conservation Reserve Program (CRP) on soil carbon sequestration and to conduct county level soil carbon estimates.

[23] RothC – The Rothamsted Carbon Model http://www.aglearn.net/resources/isfm/THE%20ROTHAMSTED%20CARBON%20MODEL.pdf

[24] http://www.cometvr.colostate.edu/

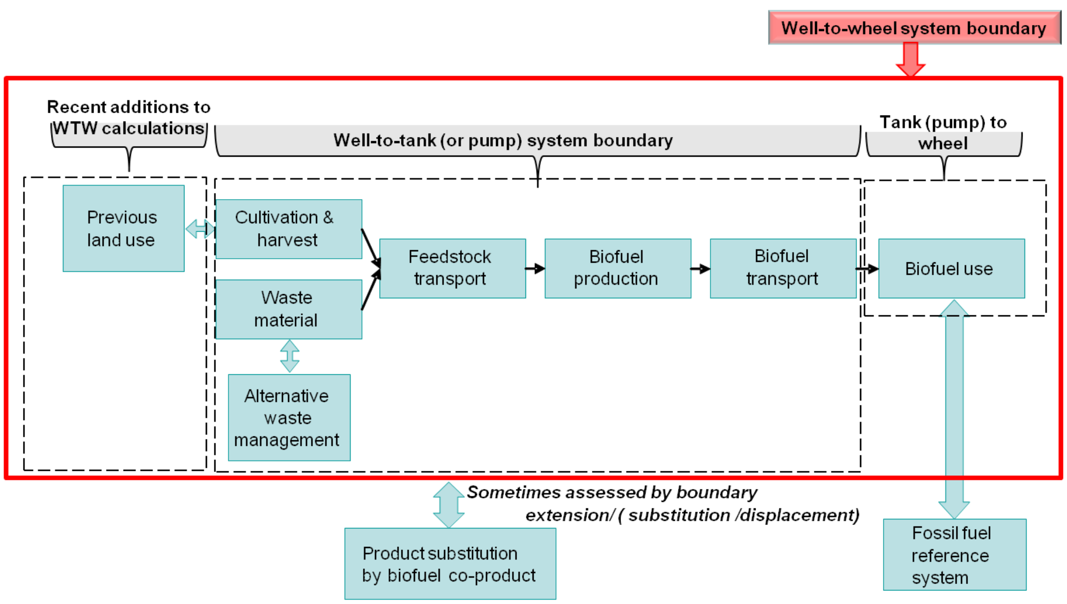
[25] Except Hawaii

D. Lifecycle Assessment for GHG emissions

All emerging biofuel sustainability standards (though not necessarily feedstock standards) reference GHG emissions within their principles. Fuel chain GHG emissions can be monitored using a Life Cycle Assessment (LCA) measurement approach. The LCA is used to measure all of the inputs, such as the raw materials and energy required in cultivation, processing and transport, and the outputs (greenhouse gases) associated with the entire supply chain of the product from cradle to grave.

Considerable work has gone into developing LCA approaches for measuring and monitoring GHG emissions for biofuels. For biofuels, the term well-to-wheels (or well-to-pump) is often used and have focused predominantly on GHG emissions rather than the energy balance only because even a 'good' energy balance could represent 'bad' GHG emissions (for example if even small amounts of coal are used for processing). These well-to-wheel approaches allocated emissions to specific activities throughout the supply chain but do not include market induced feedback loops (such as high prices of fertilizer) that influence the trajectory of emissions; they provide the tool to monitor how the lifecycle energy or emissions are changing over time.

Figure 8: An illustration of the units included in a well-to-wheel GHG analysis for biofuel. Energy use and emissions at each stage in the supply chain are included.



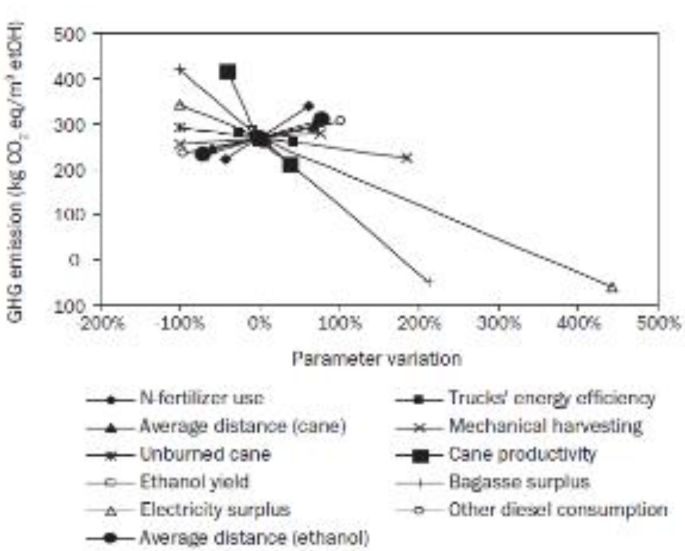
Source: Redrawn from E4Tech (2008)

Using and LCA (or well-to-wheel) approach can indicate the relative drivers within a supply chain on GHG emissions and highlight where efforts might best be focused to reduce emissions. Data on cultivation, transport and processing steps indicate relative magnitudes of importance, all of which vary within and between different feedstocks and processing techniques.

In many cases reducing transport miles, for example, is considered a key 'best practice'. This could be significant in some fuel chains but in others the LCA approach illustrates that this is not the primary driver and the significance depends on the product and the efficiency of transport. According to European LCA calculations (JEC, 2008), transporting sugarcane ethanol 5,500 miles to the EU is 110 times greater in distance than the rapeseed is transported but only 24 times greater in emissions (or 17 times greater compared to palm oil over 5,500 miles). In addition, transporting rapeseed for 50km in a truck has only half the GHG emissions per MJ transported than transporting wood chips for the same distance.

Sensitivity analyses indicate the parameters that would provide the most substantial reductions. In Figure 9 for Brazilian sugarcane, cane productivity influences the GHG balance but of greater significance is the move to more efficient energy production and increasing electricity export.

Figure 9: Sensitivity analysis in life-cycle GHG emissions for Brazilian sugarcane **(Macedo, 2008)**



Existing studies and tools for quantifying GHG emissions

Table 4: An overview of key parameters in existing models and methodologies

	UK Renewable Transport Fuel Obligation (UK RTFO)	EU Renewable Energy Directive (EU RED)*	JRC, EUCar, Concawe (JRC)	Greenhouse Gases Regulated Emissions & Energy Use in Transportation (GREET)	ERG Biofuel Analysis Meta-Model (EBAMM)	California Low Carbon Fuel Standard (CA-GREET)[1]
Location	www.dft.gov.uk/rfa	http://ies.jrc.ec.europa.eu/WTW	http://ies.jrc.ec.europa.eu/WTW	http://www.transportation.anl.gov/modeling_simulation/GREET/index.html	http://rael.berkeley.edu/ebamm/	http://www.arb.ca.gov/fuels/lcfs/lcfs.htm
Fuel chain coverage	International Large number fuel chain pathways Liquid biofuels	International Focus on liquid biofuels	International Substantial number fuel chains	USA focus Liquid biofuels, fossil fuels and solid biomass.	USA focus Corn ethanol and switchgrass	USA focus Liquid biofuels but includes Brazilian cane
Metric	gCO_2eq/MJ	gCO_2eq/MJ	gCO_2eq/MJ	gCO_2eq/MJ	gCO_2eq/MJ	gCO_2eq/MJ
System boundaries	Well-to-wheel (excl transport from refinery).	Well-to-wheel	Well-to-wheel	Well-to-pump *and* well-to-wheel Includes variety of end use scenarios.	Well-to-pump	Well-to-wheel
Co-product treatment[2]	System expansion & allocation by market value	Allocation by energy	System expansion	All methods available in the tool	System expansion	System expansion for some and allocation by energy
Direct land use change emissions	Included only if a change reported	Not included by default	Not included	Limited	Not included	Under development
Annualised land use emissions	20 years	20 years	n/a	-	n/a	30 years
Indirect LU emissions	Not included	Not yet included	Not included	Not included	Not included	Will be included in final version
Global Warming Potentials[3]	3rd report Some emission factors based on earlier reports	3rd report Some emission factors based on earlier reports	3rd report Some emission factors based on earlier reports	3rd report	3rd report Some emission factors based on earlier reports	4th report

[1] Methodologies and results are draft and under discussion/consultation

[2] Refers to how the co-products produced in the cultivation and manufacture of biofuels are treated with respect to GHG emissions

[3] Global Warming Potentials are defined in the IPCC Assessment reports (#4 is the most recent report)

LCA Monitoring Challenges

Lack of harmonization & data accuracy: As Table 4 illustrates, there is no single harmonized methodology for measuring and monitoring well-to-wheel emissions for biofuels. Therefore direct comparison of results from different studies is not yet possible. The database of emissions may also be incomplete e.g. a fertilizer lifecycle emission for China may be different for that in Indonesia. In addition, many emission factors themselves are based on LCAs that could use different global warming potentials or methodologies.

Double counting: Challenges for monitoring GHG emissions also arise because of the boundaries drawn to calculate lifecycle GHG emissions. LCA calculations include input data from a wide range of sources, including those from other sectors whose GHG emissions that are recorded for biofuels may already be monitored (e.g. the petrochemical industry for fertilizer production emissions). Reporting and calculating emissions data within biofuel chains that show variability in emissions, if aggregated to the national or international scale, may lead to risks of double counting emissions or benefits.

Traceability refers to the ability to identify and verify information at each step in a process chain. Traceability systems within biofuel supply chains can be complex with hundreds of steps within the chain, and include the mixing and blending of feedstock and biofuel therefore a *lack of available and accurate data for collection is a key issue*.

Section F discusses traceability in more detail as a tool for monitoring compliance with sustainability standards.

Box 3: Data collection obstacles for biofuel well-to wheel calculations

Input data such as fertilizer application, energy use in conversion etc. Are key requirements for an LCA. They also vary substantially between farms or processing units, regions and countries.

To facilitate data availability, databases with typical default factors for key inputs have been developed for existing tools (see Table 4) but there is no single database based on a harmonized methodology.

Lifecycle emissions depend on cultivation approach, processing techniques etc and in order to improve the accuracy of emissions from one stage, actual data from specific fuel chains could be used. Available data on land management practices generally comes from associations for conservation agriculture (or agricultural agencies) and estimates from experts (EEA, 2005). National statistical data sets such as the Farm Structure Survey in the EU are carried every 2 to 3 years on a sample basis. Key information on farm management, land use etc are obtained from such surveys but other critical information such as storage approaches for manure to manage ammonia emissions may not be collected through broad and sampled surveys.

Many existing certification standards or voluntary schemes with regular audits do not collect data on GHG emissions or the practices that would assist in obtaining information. One project has piloted two years of farm audits as a ‘bolt-on’ approach to a required certification audit (HGCA, 2008). The audit used questionnaires to collect information on cultivation technique, soil type, fertilizer usage & type; pesticide usage and harvesting, drying and transport data. It was estimated that to conduct the piloted GHG audit at the same time as the existing audit would cost around £50 (Calver, *pers comm*.).

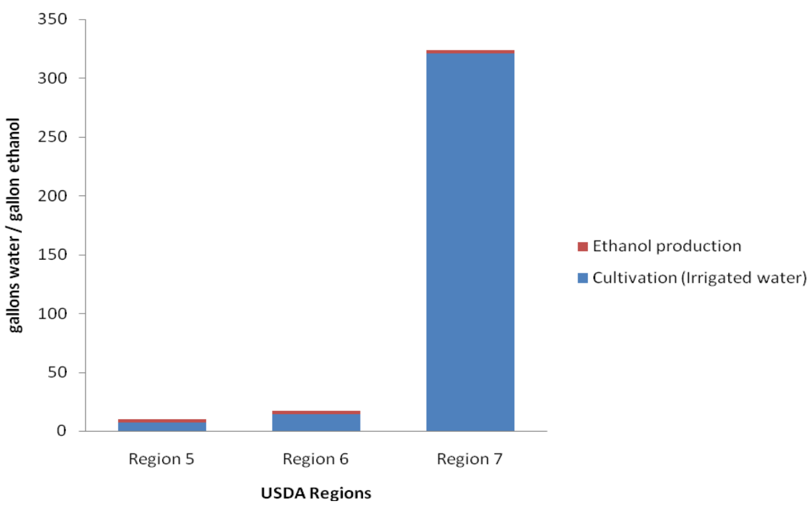
E. Lifecycle assessment for water use

Lifecycle assessments to date for biofuels and water have illustrated that crop production rather than conversion has the most substantial impact on water consumption by far (98-99% in the cultivation stage). This is due to the truly 'consumptive' nature of crops during the process of evapotranspiration, resulting in water loss throughout the feedstock production process. By looking more closely at all unit processes, the LCA methodology demonstrates that although water use for biofuel processing (i.e. in an ethanol factory) can be relatively large in abstraction terms, that water is either recycled or discharged and, therefore, does not represent a true consumptive use (Seckler *et al,* 2009).

Understanding the context for water consumption is key for delivering sustainable outcomes. If the consumption takes place in an area of water scarcity, there are key issues compared to production in an area of good water availability. Organisations such as the International Water Management Institute provide the geospatial information for potential evapotranspiration that is critical to assessing whether consumptive water use is a problem from a water scarcity perspective in regional contexts.

A recent study (Argonne, 2009) illustrates the concept of an LCA assessment for consumptive water use. The LCA uses irrigation water as the key input in order to introduce the concept or rainfed vs irrigated crops that a focus on water requirements alone would not deliver. The results illustrate the significance of water in the cultivation stage, but also that these requirements vary by region. Such a tool could be used to address regional suitability for biofuels and to monitor changes over time in consumptive water use.

Figure 10: A water footprint analysis of corn ethanol in 3 US regions based on irrigated water use.



Source: Argonne (2009).

F. Traceability: a tool for monitoring entire supply chains

Monitoring biofuel sustainability is not limited to feedstock production or conversion. In many cases, parties required to submit information or wishing to make claims about sustainable biofuels (such as the lifecycle GHG emissions) are often the parties supplying or distributing the biofuel to end-users (sometimes mandated by government policy to supply biofuel).

In order to make claims about the characteristics of the biofuel being supplied, data from the field (for example on land use, biodiversity and cultivation practices) is required. In addition, lifecycle assessments encompass the entire supply chain, from cultivation to distribution. Reporting information at the point of use requires data collection capacity throughout the chain (for example on the processing and transport activities).

The Chain of Custody (CoC) is the process through which the source of a product and claim, in this case biofuel, is verified. The CoC is essential for the functioning of a scheme which aims to assure the use of sustainable produced biomass for energy purposes (Dehue *et al*, 2007). The forestry sector has substantial experience with the development and implementation of a chain of custody through certification schemes such as that developed by the Forest Stewardship Council. There is very little experience within the biofuels industry, however. One commodity standard, the Roundtable on Sustainable Palm Oil, is linked to biofuel production as well as the food sector, and has developed supply chain guidelines that are linked to the final claims made about the product.

Options for establishing a chain of custody

There are several ways to set up a Chain of Custody:

- An *identity preservation (IP) system* allows each item to be tagged to an individual farm.
- A *segregation*, or bulk commodity, system doesn't allow this level of traceability but does segregate certified material from non-certified material throughout the supply chain.
    - For some biofuels the supply chain is very complex and high costs would be incurred for segregation on a widespread basis. This approach is similar to that of supplying green electricity to the grid i.e. the 'green' electrons are supplied and somebody claims them and we have to be sure nobody else claims them too – but this creates a market demand relatively quickly compared to the substantial capacity building required throughout supply chains for biofuels (often also those for food).
- A *mass balance* approach accounts for product on a unit basis i.e. units or percentage of certified material in = units or percentage of certified material out. In the case of the FSC, this approach allows labels on products such as 'contains 65% certified material'.
    - In this system, every party in the supply chain is required to account for and allocate certified and non-certified material. The requirement to modify software systems in trading houses and throughout the biofuel supply chain for this approach would be significant and with one 'break' in the chain the system cannot operate (Morton, *pers comm*.).
- Finally, a *book and claim* system can be used where the commodity is traded completely separately from the 'green' certificates. This is akin to trading "green" electrons i.e. they are not physically tracked.

Biofuel traceability & monitoring systems

Existing national monitoring systems in the US (such as the Renewable Fuel Standard (RFS)) and UK (such as the Renewable Transport Fuel Obligation (RTFO)) have been developed for compliance with volume blending mandates, but approaches taken regarding data transfer differ. The RFS requires physical traceability from the obligated party back to the renewable fuel producer (or importer) while the UK requirements for carbon and sustainability reporting are based on a mass-balance approach (where other systems are not in operation). The proposed Low Carbon Fuel Standard in California also requires proof of a physical pathway in reporting. Annex 8 provides a comparative overview of these approaches.

The objective for establishing a specific chain of custody for biofuels relates to the objective. Is the objective to generate demand for sustainable product so that benefits are delivered by creating a drive for further certification (*promoting sustainable production*)? Or, is the requirement to identify each movement of fuel from its source to consumption of that specific product (*promoting sustainable consumption*)?

Table 5: An illustration of the status of the chain of custody within existing certification standards

Standard name	Bulk commodity	Mass balance	Book and claim
Assured Combinable Crops Scheme (ACCS)	-	-	-
Forest Stewardship Council (FSC)	Yes	Yes	-
Genesis Quality Assurance (Genesis QA)	-	-	-
Linking Environment And Farming (LEAF)	-	-	-
Roundtable on Sustainable Palm Oil (RSPO)	Under development	Yes	Yes
Round Table on Responsible Soy (RTRS)	Options under development	Options under development	Options under development
Sustainable Agriculture Network/ Rainforest Alliance (SAN/RA)	Yes	-	-

Source: RFA, 2009

The current structure of the biofuel supply chain can be incredibly complex. In some cases, a biofuel shipment could change ownership 15 times (Saunders, *per comm*.) and the data transfer requirements in these cases would be substantial. Spot trading is common place for some biofuels and therefore establishing information transfer between parties is a substantial undertaking. Guidance documentation, awareness raising and training is required and common approaches and templates for data transfer would ease administrative costs for parties within the supply chain.

G. Social impact assessments

Social Life Cycle Assessment (sLCA)

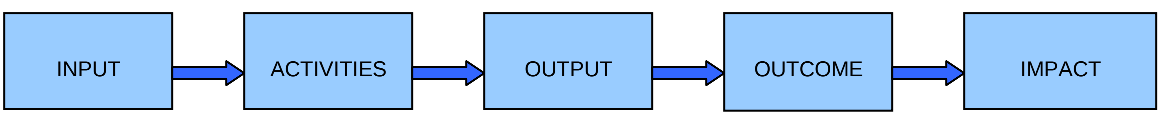
Measuring social impact is a challenging process given the difficulties in proving a causal relationship between an object or event and human behavior. Determining social impact is often an exercise in best-guessing based upon evidence found through personal interviews and statistical correlation between events and behavior. Although there is no universally accepted set of social metrics used by businesses to measure social impact (i.e. are interventions actually affecting people's lives in the ways intended) there are similar methods of outlining an organization's theory of change, a theory which can serve as a guide for program design and monitoring and assist in guiding further research.

Box 4: Understanding social impacts

Initially, planned interventions may appear to have beneficial impacts in developing communities. Internet access is highly correlated with household income, for example, leading some to believe that improving internet access and thereby reducing the digital divide will cause an increase in the income of women in developing countries. However, Bimber (2000) reported that among individuals with internet access, men use the internet more often than women, regardless of differences in income. In this case, information & communication technologies can serve to perpetuate gender inequalities when gender roles remain stagnant (DiMaggio and Hargittai 2001). In addition, it is unclear at this point whether those using the internet in developing countries are deriving income from that use, or whether that use is draining family income.

Figure 11 illustrates the process of identifying the inputs, activities, outputs, outcomes and impacts for a project implemented in Nepal:

Figure 11: An example of indicators according to relationship between output, outcome and impact value chain: Biogas Project



Financial and material support; Technical Support.	Construct Factories Educate Users	Number of Biogas Factories Installed; Number of educational sessions given .	Reduction in use of Fertilizer and kerosene; Reduction in time used to gather firewood	Improved health - 5 fewer visits to Dr.; Increased income - $100 / family / yr

Organizations use qualitative and quantitative methods to establish baselines of social indicators and conduct social surveys to indicate social change. Examples of social surveys include the Progress out of Poverty Index[26], which encompasses a tested set of 10 culture-specific questions whose answers correlate highly with poverty levels in a given country.

[26] http://www.progressoutofpoverty.org/

Box 5: Using georeferenced data assists in monitoring outcomes

Personal digital assistants (PDAs) are handheld computers useful for remote data collection (see Figure 12 below). PDAs can now be integrated with GPS which will significantly improve monitoring capacity by allowing georeferencing of collected data. The data collection software can be developed or modified to ensure a user-friendly interface that allows the results to be analysed and displayed in a spatial manner through maps. Icons and pictures can also be used to overcome the potential barriers of low literacy levels. Geographical Information Systems (GIS) are a key tool in integrating and modeling this spatial information.

These GPS systems can be utilized to map boundaries for legal land titles and/or customary rights to assist monitoring compliance with these criteria.

Figure 12: PDA unit being used to collect data for an empowerment project women's participation in government

While this approach is more expensive than using a standard GPS unit to record locations and taking hand written notes (costs can range from $250-700 per unit (t4cd),the benefits can include: a larger volume of data collected in a given period of time; a greater potential for accuracy of data collected; and easier data interpretation. Annex 6 highlights new mobile phone technology that could provide cost-effective data capture and transfer in remote areas.

H. Dynamic geospatial monitoring tools

The basic inputs to a monitoring system at key points in the biofuel supply chain include satellite observations, in-situ observations, ground surveys and model outputs. The availability of these data in a timely fashion is critical for effective monitoring. In addition to the inputs, the monitoring systems include data processing, synthesis, analysis and information reporting and dissemination components (Justice & Becker-Reshef, 2007).

Dynamic approaches to monitoring are illustrated by the USGS National Water Information System. Real-time data typically are recorded at 15-60 minute intervals, stored onsite, and then transmitted to USGS offices every 1 to 4 hours. Data from real-time sites are relayed to USGS offices via satellite, telephone, and/or radio and are available for viewing within minutes of arrival[27].

In developing a dynamic monitoring approach for biofuels, data available from satellite imagery can be used to define numerous sustainability parameters as set out in the previous chapter. The rules and instructions for software to interpret this data automatically have been and continue to be developed in many academic research programs. These rules (algorithms) to translate regularly available data from satellite data (such as MODIS and Landsat™) into visual representations of land cover, for example, are already available and could be used within a 'real-time' framework as opposed to the time-lagging involved in the creation of static maps (Loarie, *pers comm.*). A web-based system akin to GoogleEarth™ could integrate climatic datasets with land cover data. One such tool is in the early stages of development – EarthAudit[28]. This approach could be further developed to include population and socio-economic data including an ability to upload results of national, regional or local surveys for biodiversity assessments, invasive species, land tenure etc. through a web-based interface to provide a cost effective monitoring and verification tool. In addition, the use of video tutorials within a web-based framework (Loarie *pers comm*.) in partnership with academic institutes could reduce the time lag between scientific findings and practical implementation in regional contexts for sustainable outcomes.

CAPACITY BUILDING REQUIREMENTS - FINDINGS

Building capacity for monitoring biofuel sustainability standards at any scale encompasses delivering the financial, technological, educational and social requirements that will allow all parties concerned to deliver their objectives. The objectives and therefore the requirements often differ between standards, and will certainly differ between actors and within different national settings. Objectives and economic situations will ultimately determine capacity building activities; however support to enhance technical and institutional capacities would no doubt be helpful in some countries.

The tools described in the previous section illustrate the potential to overcome various challenges. For example:

a) Using environmental impact assessments combined with GIS techniques will assist in providing an understanding of the context for delivering sustainable outcomes and facilitate the implementation of appropriate better management practices.

b) Remote sensing tools can obtain information on land cover changes and carbon stock changes as well as water consumption and availability, including changes occurring over time. This tool can provide data where datasets currently are not available within national institutions, cut down substantially on the time required for data analysis and interpretation, provide confidence in the reliability of information and avoid the potential for corruption if independently generated and interpreted.

[27] http://water.usgs.gov/waterwatch/
[28] http://www.earthaudit.org/

c) Life cycle assessments can provide a tool to monitor changes in water use or GHG emissions compared to a baseline.

The availability of tools alone however is not sufficient to enable successful monitoring of outcomes. There are limitations that remain and need to be addressed.

Develop a theory of change & feedback loop for monitoring

In addition to establishing a baseline, effective monitoring systems often begin with the methodology of articulating an organization's "theory of change", i.e. by drawing out, or mapping, the underlying assumptions about how proposed actions lead to change[29]. Assumptions explain both the connections between early, intermediate and long term outcomes and the expectations about how and why actions will bring them about[30]. Rusillo (2009) recommends that organizations build a robust structure for monitoring and evaluating their theories of change in order to asses overall *outcomes*. This monitoring and evaluation system provides an evaluation of progress towards high-level goals as well. This is a significantly useful approach for better understanding biofuel sustainability. Establishing a feedback loop within a monitoring system enables this theory of change to be tested with data collected and interpreted as part of the program.

Establish context & baselines

Access to baseline data is critical and not always readily available. There is a particular lack of comprehensive GIS data especially in developing countries.

Sub-national scale maps are required, initially for regions of current and future biofuel development. They are key to cost effective monitoring and are not readily available. Land cover assessments, carbon inventory data for above and below ground carbon, soil carbon and consumptive water use will be important parameters for establishing a baseline for sustainability monitoring.

These mapping activities are also critical in order to understand the role of better management practices and their limitations in local contexts. Local and regional maps assist in understanding and avoiding risk and can include: risk maps of water-logging or drought from soil type, elevation and precipitation (which can increase GHG emissions and reduce yields), areas of high carbon stock (above and below ground) and areas providing key ecosystem services. Generating GIS maps is an essential part of sustainability assessment & monitoring within different locations and time periods. Using these geospatial tools to assess impact can also save significant time and financial investment by reducing the amount of time needed for assessing impact on the ground.

The development and integration of socio-economic data sets with environmental data should be pursued in order to improve understanding of causal linkages.

---

[29] For more information see "Theory of Change: A Practical Tool for Action, Results and Learning." Prepared for the Annie E. Casey Foundation. 2004. http://www.aecf.org/upload/PublicationFiles/CC2977K440.pdf
[30] http://www.theoryofchange.org/background/basics.html

Leverage existing monitoring programs & approaches

Some biofuel sustainability goals and objectives share potential indicators with other established monitoring programs.

A number of global crop programs are aimed at understanding and addressing food security, and as such, monitor land cover changes and climatological aspects and interpret results with respect to food security. These programs include the USDA Foreign Agricultural Service (FAS) Global Agriculture Monitoring program (GLAM), the UNFAO Food Security Global Information and Early Warning System (GIEWS), the USAID Famine Early Warning System (FEWS)[31], the EU DG-JRC Monitoring Agriculture with Remote Sensing (MARS) and the EU Global Monitoring of Food Security program (GMFS). They utilize satellite observations in their procedures for regional to global scale agricultural monitoring (Justice & Becker-Reshef, 2007)[32] and where this data exists they could be used to monitor sustainability outcomes on a national and international scale.

International co-ordination and commitment is needed to maintain the availability and improve data available from remote sensing sources. In-situ observations in data sparse regions could be integrated to provide more robust data (Justice & Becker-Reshef, 2007) and an assessment of the most appropriate in-situ observations should be based on an effective sampling approach.

Equitable and consistent data and pricing policies would enable the broadest possible use for agricultural monitoring, particularly in developing countries. Data should be provided in standardized formats and routine provision would greatly facilitate interchangeable use of moderate resolution data from different systems (Justice & Becker-Reshef, 2007).

Data from national water monitoring programs (such as those established by the US Environmental Protection Agency or US Geological Survey in the US) could be used for national biofuel monitoring purposes (see FAO, 2006) but in many cases collaboration for water monitoring is key given that water flows across national boundaries. CSIS (2005) report that innovative trans-boundary programmes for water monitoring exist in four Central Asian nations in the Aral Sea Basin[33], and among three nations in the South Caucasus[34] which allow whole-basin water quantity and quality analyses that were never before possible.

In preparation for the establishment of REDD (Reducing Emissions from Deforestation and forest Degradation) – a collaborative effort between UNEP, FAO and UNDP (FAO, 2008) will support national initiatives including monitoring and reporting systems. REDD capacity building programs will be significant and include training on remote sensing techniques and GIS, collation of existing methodologies and toolkits, developing a data repository for key country databases and providing long-term secure storage for these data. Further understanding of how

[31] http://www.fews.net/Pages/default.aspx

[32] The Global Earth Observation System of Systems (GEOSS) is a large national and international cooperative effort to bring together existing and new hardware and software, making it all compatible in order to supply data and information at no cost. The system is intended to deliver outcomes and benefits of a global informational system that are of direct benefit to biofuel sustainability standards including integrated water resource management, biodiversity conservation and sustainable land use and management.

[33] http://ironside.sandia.gov/Central/centralasia.html

[34] http://www.kura-araks natosfp.org

these datasets could be used for a biofuel sustainability monitoring program to reduce costs of compliance would be beneficial. Initially it appears that there may be definitional differences within land cover categories that may limit the ability to leverage datasets. Table 6 illustrates how different approaches are used to classify forest.

A better understanding of the datasets of existing monitoring schemes - i.e. those that could be used within biofuel monitoring - would assist in developing more cost-effective monitoring schemes. Guidance on appropriate definitions and scale for mapping would also be required.

Table 6: A comparison of the definition of a forest under different rules or guidance documents

EU Renewable Energy Sources Directive (for biofuels)	FAO definition (potentially for REDD)	UNFCCC (2001): COP-7: The Marrakech Accords (potentially for REDD)	UK Renewable Transport Fuels Obligation (for biofuels)
Land spanning - more than 1 hectare with trees higher than 5 metres and a canopy cover of more than 30%, or trees able to reach these thresholds *in situ*; OR - more than 1 hectare with trees higher than 5 metres and a canopy cover of between 10% and 30%, or trees able to reach these thresholds *in situ*	Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in situ*	includes: minimum forest area: 0.05 to 1 ha, potential to reach a minimum height at maturity in situ of 2 to 5 meters, minimum tree crown cover (or equivalent stocking level) of 10 to 30 percent. This definition does not exclude any particular woody land use as long as it meets the thresholds decided on by a country.	Land spanning more than 0.5 hectare with trees higher than 5 metres and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural (or urban) land use.

A similar problem with definitional issues is encountered when focusing on so-called 'marginal, 'idle' or 'degraded' land for biofuel production. This will require the development of national interpretations which could be based on a number of tools including the Global Assessment of Land Degradation and Improvement (GLADA), Global Assessment of Soil Degradation (GLASOD) and South and Southeast Asian Soil Degradation Status Assessment (ASSOD). These lands may require greater inputs to maintain yields, be susceptible to erosion, or be part of local inhabitants' livelihoods. Some work in specific countries is underway to explore potential approaches to identification of appropriate land (Ardiansyah, 2009) that could utilize remote sensing and GIS technologies combined with ground-based data.

Support traceability efforts

Experience to date highlights the significant administrative challenges in data transfer, both with respect to lack of data availability because of spot-trading, and to the administrative resources (and internal software development) required for record keeping. Proof of physical pathways either through mass-balance or track and trace systems fundamentally change international fuel markets by requiring supply chains to be identified rather than using spot trading approaches.

Commitment from supply chain parties to these approaches require software systems to be built for data tracking. Training for parties handling data on the required parameters for collection and provision guidance is key and may be required in numerous languages. Training includes documentation guidelines and workshops for practical training.

A harmonized approach to traceability rules and requirements for biofuels is ambitious given the number of standards in development but would limit the administrative burden for parties within the supply chain and supplying to different markets.

Awareness-raising, education & training.

Delivering sustainable outcomes requires an understanding of the local context and in geospatial analysis in particular. Capacity building programs are required that raise awareness and knowledge levels on relevant and common data collection and transfers technical skills in geospatial analysis. An established route through such structured programs in partnership with academic institutes to promote better management practices as scientific developments progress would reduce the time lag between scientific discovery and practical implementation.

The RSPO has endorsed a training series for oil palm producers (ProForest-Wild Asia Stepwise support programme) on interpretation and implementation of the RSPO principles and criteria specifically for Malaysia and Indonesia, and will allow producers to work toward implementation and certification. However, such programs require commitment and financial resources from producers[35]. Smallholders would be unlikely to be able to meet these costs and standards development risks reducing markets access and economic opportunity.

For sustainability schemes that require independent third party certification, enabling auditors and verifiers to understand, access & collect & interpret relevant information is key. Engagement of auditors early in the process is critical to the success of a scheme (Proforest, *pers comm*.) and the development and delivery of training courses to assist the move from standard development to the implementation phase is required. For parties downstream that wish to make sustainability claims e.g. biofuel distributors, engaging auditors early in the process enables parties to have a greater understanding of what constitutes appropriate evidence, while allowing flexibility for different tools to be used (Morton, Berry & Rankine, *pers comm*.).

Ensure key particpants are not exluded from markets

The integration of smallholders into the process of monitoring for biofuel sustainability standards is a crucial and as yet unresolved issue. The incorporation of third party certification for verification purposes finds that costs are prohibitive for smallholders, potentially restricting market access and opportunities for income generation and diversification. Group certification is proposed within the RSPO in order to overcome the issues of costs but to

[35] The cost for the 4 day course is US$1288 with a discount available for NGOs http://www.rspo.org/resource_centre/SSP%20Training%20Course.pdf. Other training programs have been sponsored by donors e.g. the Indonesia Oil palm commission and WWF conducted training module / awareness raising in August 2004 before RSPO criteria agreed. Costs (Rps 398,107,356 or approx US$400,000) were met by Stichting Doen and Netherlands Embassy (IPOC & WWF, 2004).

date the system is not operational. Lessons from the horticulture sector in Kenya and Ghana (Ouma, 2008) found that smallholder farmers can achieve certification but continuous maintenance is a problem due to the high costs of compliance, technical barriers to entry and the need for a steady cash flow in a sector that is vulnerable to problems such as seasonality, water shortages or pest infestations. The economic viability of certification for very small farms may lead to the conclusion that certification is not always an option (Ouma, 2008). In addition, the move towards establishing better management practices and delivering this within local contexts will require resources. Significant external assistance support to maintain certification is required (Ouma, 2008) and given the potential risk that outcomes will not be delivered if performance is not monitored, these resources should be focused on understanding the context for delivering better management practices for improved outcomes and not simply on certifying that management practices are being undertaken.

A recent conference (UNCTAD, 20008) concluded that integration of small scale farmers into sustainability standards requires:

- Adequate bridge funding and credit facilities to provide working capital;
- Support for efforts to disseminate new technologies and management methods (eg. creating centers of excellence);
- Improve research, education, physical infrastructure, quality-management institutions and extension services for sustainable agriculture, in particular by enhancing budgetary allocations in sustainable agriculture research, support and extension;
- Support the creation of more competitive farmer organizations that can effectively participate in market development; this support should also be extended to traders and small and medium enterprises that work with small scale farmers on meeting sustainability standards;
- Create awareness about sustainability issues and support small scale farmers in meeting the standards;
- Provision of independent information in a suitable form on existing sustainability, benefits and key challenges;
- Creation of information portals on sustainability standards and share best practice in sustainability standard adaptation and compliance.

Develop a dynamic approach to collecting and interpreting data

Reliance on static maps can be problematic in that they become outdated for monitoring purposes as soon as they are created. Although in the early stages of development, web-based tools such as EarthAudit[36] that create dynamic maps through the use of software programs designed to automatically interpret data (such as remote sensing data) could be used to develop independent monitoring capabilities.

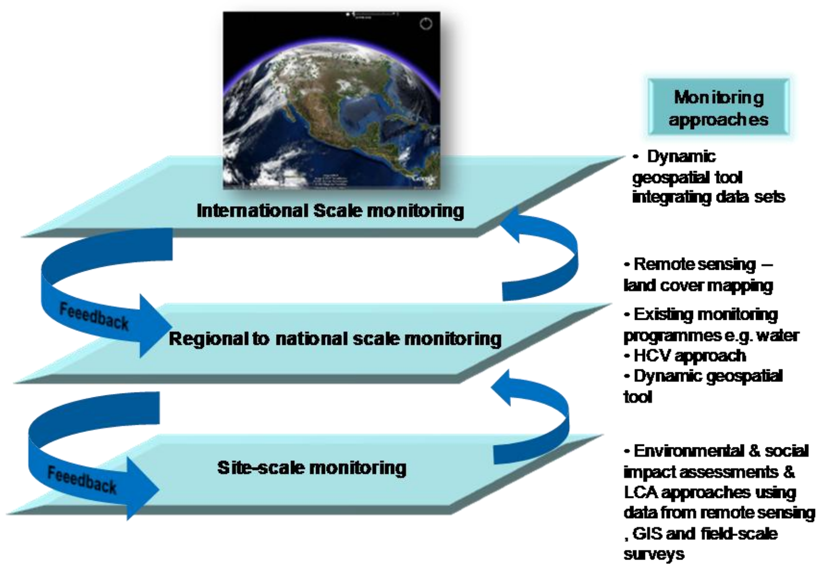
A structured framework that uses innovative technologies and combines geospatial datasets from local scale, regional and international datasets (including socio-economic & environmental) would not only improve our understanding of the outcomes of biofuel production, it would

[36] www.earthaudit.org

facilitate the understanding of the 'feedback loop' that can ensure effectiveness of indicators and activities. Data sharing agreements for public use of private data sources would also significantly advance our ability to understand of causal linkages.

Currently, no structured framework exists for data transfer between voluntary certification schemes, governments and international agencies and therefore an approach is needed to: facilitate more effective transfer of information to various stakeholders; enable wider access to monitoring results and the associated research; and facilitate combining logistical and financial resources, common analyses and data sets. Developing this framework and its associated procedures and systems for monitoring outcomes and impacts of different aspects of biofuel sustainability will be key to long-term strategic and cost effective monitoring.

Figure 13: An illustration of an integrated framework and dynamic monitoring approach for biofuel sustainability that combines the use of tools at various scales of assessment.



ANNEX 1: SUMMARY OF CRITERIA IN SELECTED BIOFUEL SUSTAINABILITY STANDARDS (ILLUSTRATIVE AND NOT EXHAUSTIVE)

	European Directive (REsD)	UK	Roundtable Sustainable Biofuels	Better Sugarcane Initiative[1]	Roundtable on Sustainable Palm Oil	Roundtable on Responsible Soy	Sustainable Biodiesel Alliance	Sustainable Agriculture Network (biofuels addendum)
Biofuel (B) or Feedstock (F)	B	B	B	F	F	F	F	F
Legality: Follow all applicable laws of the country		✓	✓	✓	✓	✓		
Consultation, planning & monitoring								
Design & operated participatory processes that involve all relevant stakeholders			✓	✓	✓	✓	✓	✓
Land rights								
Shall not violate land rights (Free, prior informed consent)		✓	✓	✓	✓	✓		
Climate Change / Conservation of carbon								
Reduce GHG emissions as compared to fossil fuels	✓	✓	✓		✓	✓	✓	✓
Conserve above and below ground carbon stocks	✓	✓				✓		
Human & labour rights								
No violation of human rights or labour rights, ensure decent work and & well-being of workers		✓	✓	✓	✓	✓	✓	✓
Rural & social development								
Contribute to the social and economic development of local, rural and indigenous peoples and communities			✓		✓	✓	✓	
Food security								
Biofuel shall not impair food security			✓					
Conservation & biodiversity								
Avoid negative impacts on biodiversity & ecosystems	✓		✓	✓	✓	✓	✓	✓
Soil: Promote practices that seek to improve soil health and minimize degradation		✓	✓	✓	✓	✓	✓	
Water								
Optimize surface and groundwater use, Minimizing contamination or depletion		✓	✓	✓	✓	✓	✓	✓
No violation of existing formal and customary water rights			✓					
Air: Air pollution from shall be minimized		✓	✓				✓	
Economics								
Cost-effectiveness & production efficiency			✓	✓	✓		✓	-

[1]Note: Better Sugarcane Initiative is a performance based standard rather than qualitative criteria.

ANNEX 2: VOLUNTARY CERTIFICATION SCHEMES (EXISTING AND UNDER DEVELOPMENT)

	RSB	RSPO	RTRS	GLOBAL GAP	SAN / RA	IFOAM	FSC	SA8000	AFS[37] (ACCS)	Proterra	BSI	LEAF
Sugarcane	Yes	-	-	-	In development		-	-	-	-	Yes	-
Corn	Yes	-	-	Sweet Corn only	-	Yes	-	-	-	-	-	-
Palm oil	Yes	Yes	-	Yes	In development		-	-	-	-	-	-
Rapeseed	Yes	-	-	-	-		-	-	Yes	-	-	Yes
Soy	Yes	-	Yes	-	In development		-	-	-	Yes	-	-
Energy crops (switchgrass)	Yes	-	-	-	-		-	-	-	-	-	-
Forest residue	?	-	-	-	-		Yes	-	-	-	-	-
Other		-	-	-	Coffee, tea etc		-		Wheat	-	-	Yes
Country coverage	Global	Palm producing regions**	Soy producing regions	100 cert. bodies in >80 countries	Global*	750 member organizations in 108 countries	Global	Global	UK	Soy producing regions	Sugar producing regions	Europe
Area certified	0	350,000 hectares by end 2008	0	n/a	527,090 hectares (1,302,467 acres) Jan 09	32,000,000 hectares end of 2007	112m ha	Not by area (worker's rights)	UK	n/a	0	n/a
# farms certified	0	n/a	0	n/a	31,158	n/a		0		n/a	0	n/a

* Belize, Brazil, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Ethiopia, Guatemala, Honduras, Indonesia, Ivory Coast, Kenya, Mexico, Nicaragua, Panama, Peru, Philippines and Tanzania ** National interpretations for Indonesia, Malaysia, Columbia and under development for Papua New Guinea

Acronyms: RSB: Roundtable on Sustainable Biofuels; RSPO: Roundtable on Sustainable Palm Oil; RTFS: Roundtable on Responsible Soy; GLOBAL GAP: Partnership for Good Agricultural Practice; SAN: Sustainable Agriculture Network; IFOAM: International Federation of Organic Agriculture Movements; FSC: Forest Stewardship Council; SA8000 / SA International Global Social Accountability Standard; AFS (ACCS): Assured Food Standards (Assured Combinable Crops Scheme); BSI: Better Sugarcane Initiative; LEAF: Linking Environment & Farming

[37] http://www.redtractor.org.uk/site/REDT/Templates/GeneralWho.aspx?pageid=14&cc=GB

ANNEX 3: BENEFITS & LIMITATIONS OF AVAILABLE METHODS TO ESTIMATE CARBON STOCKS

Method	Description	Benefits	Limitations	Uncertainty
Biome averages	Estimates of average forest carbon stocks for broad forest categories based on a variety of input data sources	- Immediately available at no cost - Data refinements could increase accuracy - Globally consistent	- Fairly generalized - Data sources not properly sampled to describe large areas	High
Forest inventory	Relates ground-based measurements of tree diameters or volume to forest carbon stocks using allometric relationships	- Generic relationships readily available - Low-tech method widely understood - Can be relatively inexpensive as field-labor is largest cost	- Generic relationships not appropriate for all regions - Can be expensive and slow - Challenging to produce globally consistent results	Low
Optical remote sensors	Uses visible and infrared wavelengths to measure spectral indices and correlate to ground- based forest carbon measurements E.g: Landsat, MODIS	- Satellite data routinely collected and freely available at global scale - Globally consistent	- Limited ability to develop good models for tropical forests - Spectral indices saturate at relatively low C stocks - Can be technically demanding	High
Very high-res. airborne optical remote sensors	Uses very high-resolution (~ 10–20 cm) images to measure tree height and crown area and allometry to estimate carbon stocks E.g: Aerial photos, 3D digital aerial imagery	- Reduces time and cost of collecting forest inventory data - Reasonable accuracy - Excellent ground verification for deforestation baseline	- Only covers small areas (10 000s ha) - Can be expensive and technically demanding - No allometric relations based on crown area are available	Low to medium
Radar remote sensors	Uses microwave or radar signal to measure forest vertical structure E.g: ALOS PALSAR, ERS-1, JERS-1, Envisat)	- Satellite data are generally free New systems launched in 2005 expected to provide improved data - Can be accurate for young or sparse forest	- Less accurate in complex canopies of mature forests because signal saturates - Mountainous terrain also increases errors - Can be expensive and technically demanding	Medium
Laser remote sensors	LiDAR uses laser light to estimates forest height/vertical structure E.g: Carbon 3-D satellite system combines Vegetation canopy LiDAR (VCL) with horizontal imager	- Accurately estimates full spatial variability of forest carbon stocks - Potential for satellite-based system to estimate global forest carbon stocks	- Airplane-mounted sensors only option - Satellite system not yet funded - Requires extensive field data for calibration - Can be expensive and technically demanding	Low to medium

Source: Gibbs et al, 2007

ANNEX 5: AN OVERVIEW OF REFERENCE DATES AS CUT-OFF POINTS FOR SUSTAINABILITY CRITERIA

	Reference date	Application
EU Renewable Energy Sources Directive (RED) and Fuel Quality Directive (FQD	January 2008	Applied to land use change for carbon stock and biodiversity criteria
EISA - US Renewable Fuel Standard (RFS)	19 December 2007	Applied to GHG reduction requirements for facilities under construction by this date & to land status to qualify as 'renewable fuel'
California Low Carbon Fuel Standard (LCFS)	To be determined	
UK Renewable Transport Fuel Obligation (RTFO)	30 Nov 2005	Applied to land use change for carbon stock and biodiversity criteria
Roundtable on Sustainable Biofuel	To be determined	
Roundtable on Sustainable Palm Oil	30 Nov 2005	Applied to assess high conservation value criterion
Roundtable on Responsible Soy	To be determined	
Better Sugarcane Initiative	To be determined	

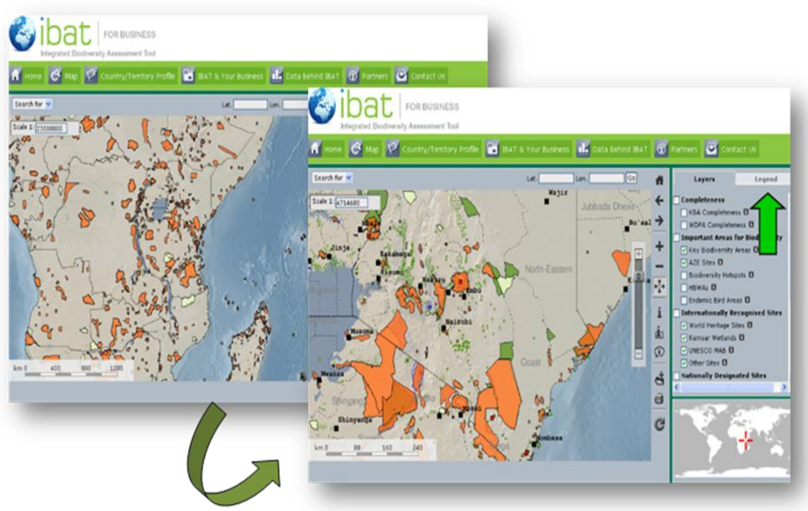
ANNEX 6: ADDITIONAL TOOLS

Integrated Biodiversity Assessment Tool (IBAT)

Initiated by BirdLife International and Conservation International, the Integrated Biodiversity Assessment Tool (IBAT) for Business, provides site-scale biodiversity information. It contains the World Database on Protected Areas (WDPA) and the World Biodiversity Database and is intended to allow decision-makers to incorporate important biodiversity priorities into their risk assessment procedures for existing and potential operations.

Core site-scale data available through IBAT are i) Protected Areas: National legally protected areas categorized by IUCN, together with sites recognized under international agreements such as the UNESCO World Heritage, UNESCO Man-and-Biosphere and Ramsar conventions. These datasets originate from the WDPA and ii) Key Biodiversity Areas: Critically important sites holding globally threatened, restricted range and/or biome-representative communities of species, as well as globally significant congregations of any species. These sites, including Important Bird Areas, Important Plant Areas and sites identified by the Alliance for Zero Extinction, have been identified in 173 countries and territories by a global network of international and local partners using global standards and criteria. These datasets originate from the World Biodiversity Database (WBDB).

Figure 14: Illustrative screenshots from IBAT for Tanzania & Kenya



Source: www.ibat.org

New phone technology for data collection & processing

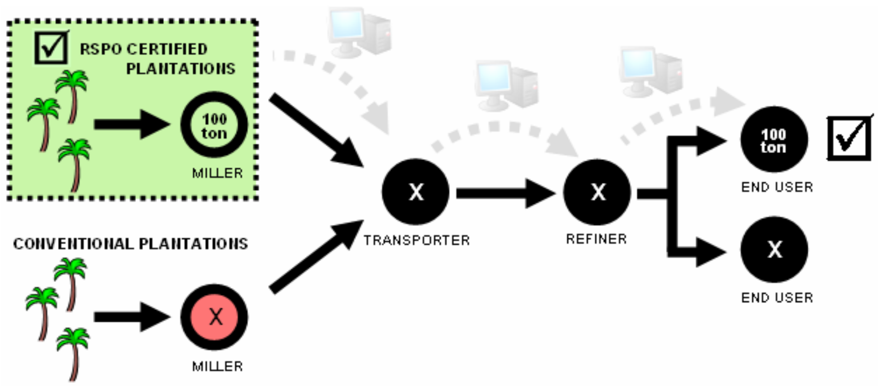
Mobile phones have been used to deliver the market prices of feedstocks to the cell phones of farmers to allow efficient and optimized sales opportunities with the highest profit maximization. Opportunity alert services enable information to be transferred directly to a mobile phone without the need for internet access which is a key requirement in many remote areas. Information that could assist with delivering capacity in meeting sustainability standards could include, opportunities to connect sellers of sustainable product with buyers, training days or programs, guidance on compliance activities or reminders of key requirements and prices for biofuels or feedstocks in markets of interest.

The increased availability of cell phones in remote areas and the advancement of mobile software and its growing compatibility with web interfaces have revolutionized data collection. A new mobile technology 'Rapid Android' has been developed that enables a mobile/cell phone to be used as a data entry tool <u>and</u> data aggregation platform. The Rapid Android software works as an operating platform (like Windows XP or Vista is for computers) and expected to make deploying field based short messaging service (SMS) data collections systems both easier and more affordable (Dimagi, 2009).

Key data for biofuel sustainability could be collected cost-effectively and rapidly from the field as part of a monitoring program. The software is open-source, or free, which means that copyright does not exist and the software can be modified and distributed for specific uses. The application is available on any android phone and is currently around $400. Rapid Android has the ability to send and receive bulk SMS and collect data through forms which are editable on the phone. The data can be viewed, aggregated, plotted and exported to a main computer via Excel over an internet link (Dimagi, 2009).

ANNEX 7: TRACEABILITY: THE CASE OF PALM OIL

Figure 15: A mass-balance system: This has been specified by the EU Renewable Energy Sources Directive as the required method for verifying claims.



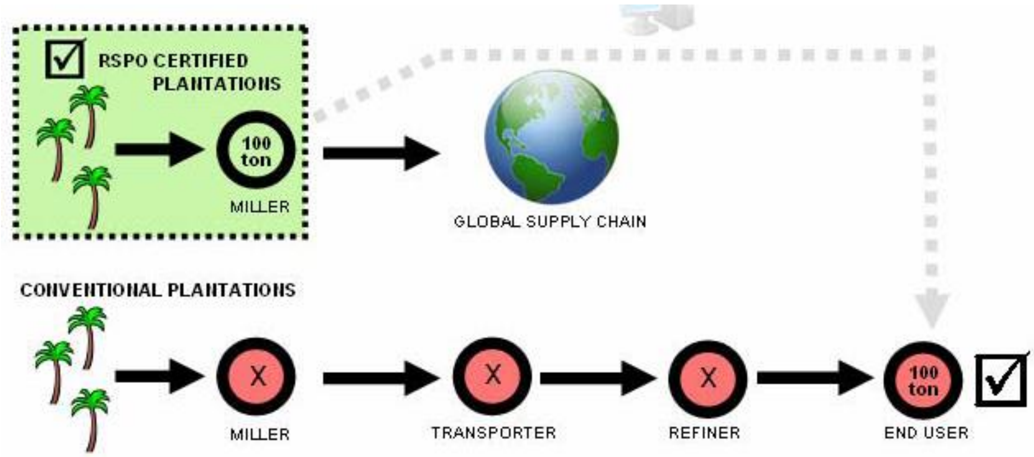
Source: RSPO (2008).

The objective for establishing a specific chain of custody for biofuels relates to the objective. Is the objective to generate demand for product certified as sustainable that outstrips supply and therefore drives further certification to meet demand (*sustainable production*)? Or is the requirement to identify each movement of fuel from its source and consume that specific product (*sustainable consumption*)?

Book and claim (certificate trading).

A market-based trading system has been established for the RSPO in addition to the other approaches. Users of palm oil can buy certificates from a trading platform without having to have followed the product throughout the supply chain. The GreenPalm Programme identified below is the only chain of custody currently in operation for the RSPO (though others have been agreed and are under development).

Figure 16: A book and claim system that allows product and certificate to be decoupled. The product enters the global supply chain without any traceability but the certificates are registered on a trading platform. End-users can buy certificates to match the products bought from the global supply chain.



Source: RSPO (2008).

Each certificate is valid for 1 tonne of palm oil. Initial bids for the CPO certificates were in the region of \$50. Market prices for CPO in the region of \$780 for 2007 compared to \$478 in 2006, therefore a certificate at \$50 would represent between 6% and 8% of the average international prices for 2006 and 2007. At the time of writing March 2009, the bids for CPO are currently at \$40 and there are no offers for PKO certificates. CPO Futures are approximately \$556 representing a premium of 7% for certified crude palm oil.

Assuming 1 hectare produces 3.5tonnes of crude palm oil (excluding palm kernel oil) and the certificates are \$40 respectively, the CPO certificate would provide a \$140/hectare return which represents approximately 6% of net returns per hectare at \$2,200/ha, excluding certification costs. Illustrative data used to quantify soil carbon sequestration benefits and reduced nitrous oxide emissions from soil for palm oil at \$10/tCO_2eq are significantly lower than the premiums available for certified sustainable palm oil (Winrock International, 2009). The high price of palm oil in recent times has meant that the premium represents very little of the net return. Should net returns per hectare be in the region of \$1000/ha, such a premium would represent 14%.

There are around 40m tonnes of palm oil produced annually (FAOstats, 2007). Approximately 4.5million tonnes of palm oil are destined for Europe and 1million tonnes to the US (for a variety of end uses mainly in the food sector). The volume of certificates available based on the assumption that all those registered pass the planned audits would be 1.5-2 million tonnes (Norman, *pers comm*.)

however the potential CPO equivalent of EU biodiesel imports in 2020 could be 3.32million tonnes based on an EU calculations[38].

There are no such certificate systems in place for other currently commercial biofuel feedstocks e.g. sugarcane, rapeseed, corn or soy, but they could develop in this direction. One of the most significant costs associated with the development of such a trading platform is the legal framework and documentation (Norman, *pers comm*.). As this has now been developed, the marginal costs associated with including other commodities would not be significant.

The disadvantage of the book and claim system illustrated with respect to the monitoring of biofuel sustainability is that it skips several important steps in the supply chain that are key to monitoring GHG performance i.e. only the farm and the fuel supplier are part of the system in No information on transport distances, energy use and type at feedstock and biofuel processing facilities is collected.

Dehue et al, (2007) suggest it would be possible to have a book-and-claim system which includes the major steps in the supply chain. The registration and issuance of certificates at different stages that include key data and account for conversion factors would have to be undertaken by an independent Issuing Body but at present no such body is active and operating in this manner. This approach could also be difficult given that some of the sustainability standards (including the EU mandatory sustainability criteria) may not allow a 'book and claim' approach (Dehue et al 2007).

[38] See Figure 3-1 in http://www.renewablefuelsagency.org/_db/_documents/Ecofys_Review_of_EUIA_on_biofuel_targets.pdf Assumes all imports met by palm biodiesel. 0.95tonnes biodiesel per tonne palm olein and 0.8tonnes palm olein per tonne CPO.

Box 6: Greenpalm - Certified palm oil certificate trading scheme

The GreenPalm programme is a commercial trading platform for certificates from the RSPO. It is the 'book and claim' approach described above.

A web-based trading platform facilitates the sale and purchase of certificates. The certificates and the actual oil are traded separately so the only parties that participate are the farmer (registering certificates) and the buyer.

End-users can claim that they are promoting the production of RSPO verified sustainable palm oil to the extent that they have redeemed certificates for the year of the claim. This is in comparison to the claim through a segregated supply chain which allows end-users to claim they are supplying certified product.

GreenPalm brokerage fees, payable by the buyer (to GreenPalm) are $3 per certificate and an additional $1 per certificate is paid/ donated by the buyer to RSPO. Current (March 2009) contribution to RSPO total $12,964.

Avoiding double-counting: Utz Certified will maintain a central database of all certified producer volumes on behalf of the RSPO. If a producer registers volume in the GreenPalm trading system their balance will be reduced in the central database. The producers' physical movements of oil will also reduce the balance in the database. Other chain of custody approaches have not yet been operationalised and therefore the extent to which the system is robust has not yet been tested.

There are currently 160 redeemed PKO certificates and 35,185 certificates registered for PKO, whereas there are 2,575 CPO certificates redeemed and 130,662 certificates registered.

ANNEX 8: TRACEABILITY: A COMPARISON OF EXISTING AND EMERGING NATIONAL MONITORING MECHANISMS

	US Renewable Fuels Standard Tracking and compliance system	UK Renewable Transport Fuel Obligation Tracking & compliance system	CA Low Carbon Fuel Standard
Obligated (or regulated) parties for liquid fuels	Includes oil refiners, importers and blenders	Includes oil refiners, importers and blenders	Includes oil refiners and importers but the proposal generally allows the regulated party for a fuel to transfer its compliance obligations by written instrument to another party under specified conditions
The 'tracking' tool	The Renewable Identification Number (RIN) is a 38-character code (alpha and numeric) that is generated at the point of biofuel production by the manufacturer	Renewable Transport Fuel Certificate (virtual) issues on submission of carbon and sustainability report.	Credits and deficits (virtual). LCFS Reporting Tool (LRT) and Credit Tracking System (CTS). For biofuels that are covered under the RFS, RIN number will be generated.
Control point for mechanism	RIN must be assigned: At point of renewable fuel production or at point of import in the case of imported fuels	At the excise duty point	Differs between fuels and is based on regulated party
Why is the tool needed?	Used to track compliance with the Renewable Fuels Standard (RFS) that requires obligated parties to blend a proportion of renewable fuel (and in consideration of its equivalence value).	The certificate is used to track compliance with the RTFO that requires obligated parties to blend a proportion of renewable fuel. The C&S reports are used to collect information on the biofuel characteristics & scheme encourages parties to engage & improve performance.	Used to track compliance with the requirement of regulated parties to reduce carbon intensity of all transportation fuels sold in California by 10 percent by 2020
What info is collected?	Includes: Year of production, producer ID, facility ID, batch number, cellulosic/non-cellulosic, equivalence value (i.e. how much the fuel counts for: corn ethanol has an equivalence of 1.0 and includes others such as biodiesel (FAME) with a value 1.5 and cellulosic ethanol 2.5.)	Type of biofuel; feedstock; country of feedstock origin; volume; environmental and/or social standard to which the feedstock was grown; carbon intensity of the fuel (to calculate GHG savings) and the level of detail (tier) of the carbon calculation.	Includes: type of fuel; RIN numbers; blendstock feedstock; feedstock origin; production process; carbon intensity of blendstock and reference fuel; amount of each blendstock (MJ); amount of each fuel used as fossil replacement (MJ); credits/deficits of CO2eq generated per quarter (MT).
How often?	Quarterly (and annually)	Monthly (and annually)	Quarterly (and annually)
How does the tracking / monitoring system work?	Track and trace mechanism up to point of blending. The RIN is sold with the renewable fuel as it enters the supply chain and stays with the fuel until an obligated party purchases the fuel and blends it. A Product Transfer Documents (PTD) e.g. invoice, containing transaction details is required when ownership of a renewable fuel is transferred to	Sustainability information transferred through the chain through mass-balance approach where other systems not in place. Each party in the supply chain must keep records of the carbon and sustainability information required for reporting. RSPO book and claim approach has been approved for reporting on palm oil-based biodiesel.	Regulated parties will be required under the proposal to establish physical pathway evidence for transportation fuels subject to the LCFS. Physical Pathway can either be the applicable combination of actual fuel delivery methods, such as truck routes, rail lines, gas/liquid pipelines, electricity transmission lines, others.

	US Renewable Fuels Standard Tracking and compliance system	UK Renewable Transport Fuel Obligation Tracking & compliance system	CA Low Carbon Fuel Standard
	another party. An obligated party can purchase RINs instead of blending the renewable fuel into its petroleum-based product. The RIN has a lifespan of 2 years. Reporting of RIN credits by obligated parties is done at the end of every quarter. Before reporting to the EPA, obligated parties must ensure the RINs have not been used before or are not duplicates of others. The RINs seller is responsible for making the RIN good if EPA deems the RIN unacceptable.	An online system generates a virtual Renewable Transport Fuel certificate for each liter of fuel that is reported with carbon and sustainability information. RTFCs are tradable and obligated parties may purchase certificates to meet their obligation. A buy-out price is also set to buy-out of this obligation.	An online, interactive LCFS Compliance and Reporting Tool (CRT) will be used for reporting, credit banking, and credit transactions. 3rd party entities are proposed not to be allowed to purchase, sell, and retire LCFS credits at the onset of the LCFS Proposed regulation allows for the exporting of credits to other GHG trading programs (subject to the requirements) but prohibits the imports of credits from other programs outside the LCFS
Trading systems	Commercial registries. No regulator facilitated tool (see latest developments)	Regulator hosts the facility (web-based registry) but does not facilitate trades	Regulator hosts the facility.
Challenges	Many renewable fuel producers are small business and do not necessarily have the resources required to maintain the RIN program. The commercial registries for RINs are not able to catch all duplicates. To date, the system has not been automated which has resulted in substantial numbers of administrative errors (one commercial registry has identified nearly 16,000 invalid RINs since September 2007)	The traceability (or chain of custody systems) for transferring carbon and sustainability systems are not established and any break in this complex fuel supply chain means carbon and sustainability information cannot be reported. The mass-balance approach changes the nature of the fuel market that is (in many cases) based on spot-trading. The ability to purchase GreenPalm certificates for palm oil has recently been approved.	Traceability system not tested as system hasn't yet begun operation.
Latest developments	A new EPA system will screen and register RINs after they are generated by the producer and before they enter the supply chain.	Intention to issue certificates based on the GHG performance of fuels. Two EU Directives influence outcome: Renewable Energy Sources Directive is a mandate for energy from renewable fuels and the Fuel Quality Directive contains a requirement to reduce fuel chain carbon intensity (similar to LCFS) Implementation options are under consideration in some EU Member States.	Now adopted (April 2009)

REFERENCES

Angelsen, A., Brown, S., Loisel, C,. Peskett, L., Streck, C., Zarin, D (2009) Reducing Emissions from Deforestation and Forest Degradation (REDD): An Options Assessment Report prepared for the Government of Norway. The Meridian Institute.

Ardiansyah, F. (2009) Identification of Responsible Cultivation Areas for Biofuel Crops in Indonesia. Presentation at Research Workshop on Sustainable Biofuel Development in Indonesia, Jakarta, Indonesia. Available from: http://www.iges.or.jp/en/bf/activity20090204.html

Argonne National Laboratory (2009) Consumptive Water Use in the Production of Ethanol and Petroleum Gasoline. Report No. ANL/ESD/09-1. Energy Systems Division.

Berndes, G. (2002). *Bioenergy and Water – the Implications of Large-Scale Bioenergy Production for Water Use and Supply.* Global Environmental Change vol 12, issue 4: 253-271.

Bimber, Bruce (2000) *Measuring the Gender Gap on the Internet*. Social Science Quarterly. Vol. 81, no 3. Pp 868-876.

Brown, S., T. Pearson, D. Slaymaker, S. Ambagis, N. Moore, D. Novelo, and W. Sabido. (2004) *Application of Multispectral 3-Dimensional Aerial Digital Imagery for Estimating Carbon Stocks in a Tropical Pine Savanna*. Report to The Nature Conservancy Conservation Partnership Agreement. Pp 22.

CANASAT http://www.dsr.inpe.br/mapdsr/eng/intro.jsp Accessed 23 March 2009.

CASMGS (2007) *LIBS: A new rapid method for measuring soil carbon*. Available from http://soilcarboncenter.k-state.edu/originals/LIBS_article.html

Center for Strategic and International Studies - CSIS (2005) *Global Water Futures: Addressing our global water future*. Center for Strategic and International Studies with Sandia National Laboratories, USA.

Clay, J. (2008) *The role of better management practices in environmental management.* In Tucker , C. Hargreaves, J. (Eds) Environmental Best Management Practices for Aquaculture. Wiley Blackwell.

Davis, A. (2008) *Risk Analysis and Management of Biofuel Feedstock Invasive Potential*. USDA-ARS. Presentation at the Biofuels and Sustainability Conference 2008, Champaign, Illinois, USA.

Dehue, Bart, Sebastian Meyer and Carlo Hamelinck. (2007) *Towards a Harmonised Sustainable Biomass Certification Scheme.* Ecofys Netherlands BV. Commissioned by WWF International, FSC, the Dutch and the UK Governments. Paper can be found at http://assets.panda.org/downloads/harmonised_sustainable_biomass_scheme.pdf

Digital Opportunity Initiative (2001) *Creating a Development Dynamic: Final Report of the Digital Opportunity Initiative.* Accenture, Markle Foundation, UNDP Report can be found at: http://www.markle.org/downloadable_assets/doifinalreport.pdf

Dimagi (2009) *Rapid Android*. Presentation to Web4Dev conference. Available from http://www.web4dev.org/images/4/4a/8_jackson_Unicef_Rapid_Android_web4dev.pdf

DiMaggio and Hargittai (2001) *Social Implications of the Internet.* Annual Review of Sociology. 27:307-36.

EMPRAPA (2008) *Produto inédito reduz fertilizantes na produção de cana-de-açúcar*. Available from http://www.embrapa.br/embrapa/imprensa/noticias/2008/maio/1a-semana/produto-inedito-reduz-e-fertilizantes-na-producao-de-cana-de-acucar

European Commission (2008). *European Parliament legislative resolution of 17 December 2008 on the proposal for a directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources* (COM(2008)0019 – C6-0046/2008 – 2008/0016(COD))

EEA (2005) European Environment Agency (2005) *Agriculture and the Environment in EU-15 – the IRENA indicator report.* EEA report No 6/2005. European Environment Agency, Denmark.

FAO (2006) *Water monitoring: mapping existing global systems & initiatives*. Background document prepared by FAO on behalf of the UN-Water task force on monitoring. UN Water, Stockholm. Available from http://www.unwater.org/downloads/UNW_MONITORING_REPORT.pdf

FAO Statistics. Available online www.faostat.fao.org

FAO, UNDP & UNEP (2008) *UN Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD): Framework Document*. Published 20 June 2008 Can Available from: http://www.undp.org/mdtf/un-redd/docs/Annex-A-Framework-Document.pdf

Fargione, J., Hill, Tilman, J.D. Polasky, S. & Hawthorne, P. (2008). *Land Clearing and the Biofuel Carbon Debt.* Science 319 No. 5867, 1235-1238. DOI: 10.1126/science.1152747

Gibbs, H., Brown, S., O'Niles, J., & Foley, J. (2007) *Monitoring and estimating tropical forest carbon stocks: making REDD a reality*. Environmental Research Letters, 2, doi:10.1088/1748-9326/2/4/045023

Goetz, S., Baccini, A., Laporte, N., Johns, T., Walker, W., Kellndorfer, J, & Houghton, R.A. (2008). Mapping *and Monitoring Carbon Stocks with Satellite Observations: An Update*. Paper presented to United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP), Fourteenth session. Poznan, Poland.

HGCA (2008) *Understanding and managing uncertainties to improve biofuel GHG emissions calculations.* Project report 435 Part Two. HGCA, UK.

IPCC (2006), *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published IGES, Japan.

IPOC & WWF Indonesia (2004) *Report on Training on Sustainable Palm Oil/High Conservation Value Forest (HCVF).* Available from http://www.rspo.org/PDF/RT3/Proceedings/Session%203A%20IPOC%20WWF.pdf

JEC (2008) *Well-to-Wheels analysis of future automotive fuels and powertrains in the European context: version 3.* CONCAWE, EUCAR, ECJRC http://ies.jrc.ec.europa.eu/WTW

Justice, C. & Becker-Reshef, I. Eds. (2007) Report from the Workshop on Developing a Strategy for Global Agricultural Monitoring in the framework of Group on Earth Observations (GEO). FAO, Rome.

Kim, H., Kim, S. and Dale, B. (2009) *Biofuels, Land Use Change, and Greenhouse Gas Emissions: Some Unexplored Variables*. Environ. Sci. Technol., 43 (3), pp 961–967

Lu, D. (2006) *The potential and challenge of remote sensing-based biomass estimation*. International Journal of Remote Sensing, 27 (7), pp 1297–1328

Macedo et al (2008) *GHG Emissions in the Production and Use of Ethanol from Sugarcane in Brazil: The 2005/2006 Averages and a Prediction for 2020.* Biomass and Bioenergy, 32 pp 582-595

Milne, E., Easter, M., Cerri, C.E.P, Paustian, K. and Williams, S. (Eds.) (2005) *Technical Report of GEF Co-financed Project No. GFL-2740-02-4381. Assessment of Soil Organic Carbon Stocks and Change at National Scale.* Available from http://www.nrel.colostate.edu/projects/gefsoc-uk

Nemitz, E.; Misztal, P.; Langford, B.; Oram, D.; Phillips, G.; Di Marco, C.; Davison, B.; Hewitt, N.; Cape, N.. (2008) Fluxes and In-Canopy Gradients of Biogenic Volatile Organic Compounds Above Contrasting South East Asian Land Uses. Eos Trans. AGU, 89 (53, Fall Meet. Suppl.). Abstract A14C-07

Ouma, S. (2008) Development practice, agrifood standards, and smallholder certification: The elusive quest for GlobalGAP? Available from http://www.agrifoodstandards.net/en/filemanager/active?fid=179

Palm Oil HQ (2009) Statistical data accessed 27 March 2009 from http://www.palmoilhq.com/palm-oil-prices/

Pearson, T., Walker, S. and Brown, S. (2005a) *Sourcebook for Land Use, Land-Use Change and Forestry Projects.* BioCarbon Fund and Winrock International.

Pearson, T, Ambagis,S., Brown, S., Slaymaker, D. and Moore, N. (2005b) *Application of Multispectral 3-Dimensional Aerial Digital Imagery for Estimating Carbon Stocks in a Bottomland Hardwood Forest: Task 2 – Image Analysis*. Report to The Nature Conservancy. Conservation Partnership Agreement.

Perry, Chris. (2007) *Water Consumption and Productivity of Biofuels, Native Vegetation and Other Crops: Potential Contribution of Remote Sensing.* International Water Management Institute. http://www.iwmi.cgiar.org/EWMA/files/papers/Chris_Perry.pdf

Renewable Fuels Agency (2008a) *Carbon and sustainability reporting within the Renewable Transport Fuel Obligation: Technical Guidance Part two – default values and fuel chains*. Renewable Fuels Agency, UK.

Renewable Fuels Agency (2008b) *The Gallagher Review of the indirect effects of biofuels production.* Renewable Fuels Agency, UK.

Roelandt, C., Van Wesemael, B. and Rounsevell, R (2005) *Estimating annual N2O emissions from agricultural soils in temperate climates*. Global Change Biology (11) pp 1207-1711.

Roundtable on Sustainable Palm Oil (2008) *RSPO supply chain certification systems*. http://www.rspo.org/RSPO_Supply_Chain_Certification_Systems.aspx

Rusillo, A. (2009) *State of the Art in Measuring the Impacts of Social and Environmental Standard Systems.* RO81 Public Summary. ISEAL Alliance.

Seckler, D., Chalmers, J., Griffis, M. (Forthcoming) *Role of Water in Sustainable Supply of Biofuels.* Winrock International. Funded by the Packard Foundation.

Searchinger, T., Heimlich, R., Houghton, R. A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D. & Yu, T-H. (2008). *Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change*. Science 319, 1238-1240

Smeets, E., Bouwman, L., Stehfest, E., Vanvuuren, D., and Posthuma, A. (2009). *Contribution of N_2O to the greenhouse gas balance of first-generation biofuels*. Global Change Biology, 15 (1), pp 1-23

Stehfest, E., and Bouwman, L. (2006) N2O and NO emission from agricultural fields and soils under natural vegetation: summarizing available measurement data and modelling of global annual emissions. Nutrient Cycling in Agroecosystems, 74 pp 207-228

Sulistioadi, Y., Hussin, Y., Sharifi, A. (2004) The identification of high conservation value forest (HCVF) to support the certification of sustainable forest management in Indonesia using remote sensing and GIS. Available from http://www.itc.nl/library/Papers_2004/n_p_conf/hussin_identification_asc.pdf

t4cd. Website information available from http://www.t4cd.org/Technology/UnderstandingTechnology/Pages/DataCollectionintheField.aspx

Thenkabail, P.S.., Stucky, N., Griscom, B.W., Ashton, M.S., Diels, J., Van der Meer, B. and Enclona, E., (2004) *Biomass estimations and carbon stock calculations in the oil palm plantations of African derived savannas using IKONOS data*. International Journal of Remote Sensing, 25, pp. 5447–5472.

UNCTAD (2008) *Conclusions and Recommendations***.** Pre-UNCTAD XII Event on Making Sustainability Standards Work for Small-scale Farmers**.** Arusha, United Republic of Tanzania. Available from http://www.unctad.org/trade_env/meeting.asp?MeetingID=249

Reich P., H. Eswaran and F. Beinroth (2001) In : D. E. Scott, R. H. Mohtar and G. C. Steinhardt (eds). Sustaining the Global Farm. p: 838-846 (Last viewed on 04/10/09 http://www.tucson.ars.ag.gov/isco/isco10/SustainingTheGlobalFarm/P257-Reich.pdf

Winrock International (2009) *The impact of expanding biofuels on greenhouse gas emissions. White paper # 1: Accessing and interpreting existing data*. Report to the Packard Foundation.

Winrock International, University of Vermont and Iowa State University Extension (2009). *Pilot-Testing Performance-Based Incentives for Agricultural Pollution Control in Vermont.* Unpublished. Conservation Innovation Grant from the USDA Natural Resources Conservation Service under Agreement No. 68-3A75-6-184

Zeng, L., Song, K., Zhang, B., Wang, Z., Liu, D and Du, J (2009) *Spatial Mapping of Actual Evapotranspiration with MODIS products and Landsat TM data in the Songnen Plain during the growing season*. Paper presented to the International Conference on Land Surface Radiation and Energy Budget

http://www.landenergybudget.org/LED/download/post/%EF%BC%8857%EF%BC%89101%20Spatial%20Mapping%20of%20Actual%20Evapotranspiration%20with%20MODIS%20products%20and%20Landsat%20TM%20data%20in%20the%20Songnen%20Plain%20during%20the%20growing%20season.pdf

Personal Communication:

Berry, A. Head of Carbon and Sustainability. UK Renewable Fuels Agency. Telephone call (3/25/2009)

Calver, P. CMI Certification. Telephone call (1/15/2009)

Delgrosso, S. (2008) USDA – ARS. Telephone call (12/29/2008)

Loarie, S. (2009) Stanford University. Telephone call (3/27/2009)

Morton, M (2009) Sustainability Compliance Officer. Shell. Telephone call (3/31/2009)

Norman, B. (2009) Manager. Greenpalm. Telephone call (1/16/2009)

Proforest (2009) Meeting (1/7/2009)

Rankine, A (2009) Implementation Manager. BP. Telephone call (3/26/2009)

Saunders, B. (2009) BP. Telephone call (3/25/2009)