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A national approach to map management practices that improve soil condition

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Abstract
The Australian Collaborative Land Use and Management Program (ACLUMP) has identified the mapping of ground cover using remote sensing as a key tool for monitoring adoption of sustainable farming practices. Ground cover can be used as an indicator of soil condition. ACLUMP has been working towards the establishment of national standards for reporting of land management practices, field measurement of fractional cover, and selection of appropriate remotely sensed products such as fractional cover and land cover to monitor and interpret ground cover levels over time. Focus has been on the more intensively managed agricultural areas under cropping and modified grazing land uses. These ACLUMP activities are informing State and Australian Governments' natural resource monitoring programs and are linked to other initiatives such as the Terrestrial Ecosystem Research Network (TERN) providing nationally consistent time-series datasets underpinned by a network of observational sites.

Key Words
Ground cover, remote sensing, erosion, agriculture, soil carbon.

Introduction
Ground cover provides the protective layer of living and decaying plant material covering the soil surface. Ground cover limits erosion and improves the water infiltration and organic matter content of soil. Ground cover is a sub-component of land cover and can be used to infer land management practices and in particular practices impacting on soil condition.

Management and changes in management are critical for Australian agriculture to increase its productive capacity and resilience to changing climate patterns. The Australian Government through its Caring for our Country initiative has recognised the importance of recording information about ground cover especially with regards to its sustainable farm practices targets which includes practices related to soil condition (DEWHA and DAFF 2009). Under Caring for our Country, practices related to maximum ground cover levels are encouraged such as: reduced tillage; stubble retention; careful timing of, or where feasible, avoidance of long cultivated fallow for cropping areas; careful management of stocking rates and; increasing the proportion of perennial vegetation in pastures for grazing areas.

The Australian Collaborative Land Use and Management Program (ACLUMP), a consortium of State and Federal agencies under the auspices of the National Committee for Land Use and Management Information (NCLUMI), is developing nationally consistent land management practice mapping based on characteristic patterns of ground cover maintenance in agricultural systems (NCLUMI 2009). These ACLUMP activities will support the information obtained through the Australian Bureau of Statistics' Agricultural Resource Management Survey (ABS 2009) funded under Caring for our Country.

ACLUMP have selected remote sensing as the tool to measure ground cover over large spatial extents. A fractional cover time-series product of ground cover levels where bare soil, photosynthetic and non-photosynthetic vegetation can be distinguished is favoured for monitoring land management practices that impact on ground cover (Leys *et al.* 2009; Stewart and Rickards 2010). Currently, there are no methods developed that have been designed or calibrated for the range of intensive agricultural systems (i.e. cropping and improved pastures) in Australia (Schmidt *et al.* 2010b).

Methods
Leys *et al.* (2009) reported on ground cover measurement techniques developed for Australia that are suitable for erosion modelling. Schmidt *et al.* (2010b) compared these satellite-based ground cover time-series products and assessed their accuracy and utility for monitoring ground cover levels in selected intensive agricultural areas. To calibrate and validate ground cover levels estimated from satellite imagery a

network of national reference sites are required. Field sampling methods for collection of calibration data were also trialled by Schmidt *et al.* (2010b).

The States and the Northern Territory through ACLUMP have compiled calendars of operations indicating the timing of typical management practices for the major cropping and improved pasture land uses occurring in a natural resource management (NRM) region or sub-region. The calendars of operations are based on expert opinion and provide an overarching context for interpretation of the satellite imagery for ground cover maintenance. They will also assist with the location and number of ground cover reference sites and supplement the results of the Australian Bureau of Statistics' Agricultural Resource Management Survey 2007-08.

The ACLUMP State and Northern Territory partners also undertook an assessment of existing monitoring sites that collect information on ground cover and/or land management practices for their suitability as reference sites for calibrating and/or validating remote sensing products and in particular fractional cover. Methods of ground cover collection were compared with a modified discrete point transect sampling which measures the bare soil, photosynthetic and non-photosynthetic vegetation fractions of ground cover as described in Schmidt *et al.* (2010a). This method is used in Queensland's and now New South Wales' statewide landuse and trees study (SLATS) programs. It has been proposed that this method be adopted nationally as a consistent approach for measuring fractional cover in the field (Stewart and Rickards 2010).

Results and discussion

Half of all Australian agricultural businesses are engaged in cropping activities and these enterprises collectively cover 8 % of the area under agriculture (ABS 2009). Over the last 12 years the adoption of some key practices that improve soil condition and minimise erosion risk has increased. Stubble retention in 2008 was undertaken on 58 % of the stubble treated area (up from 31 % in 2001 and 22 % in 1996). This represents 43 % of agricultural businesses undertaking stubble treatment (27 % in 2001). No tillage (apart from the actual sowing operation) occurred on 57 % of the land prepared for crops (38 % in 2001 and 21 % in 1996), accounting for 53 % of agricultural businesses preparing land for crops (35 % in 2001). Further breakdown of these trends to State and NRM regions can be used to target where to invest to change management practices.

Figure 1 shows the timing of typical management practices for dryland wheat for some NRM regions. These calendars will determine when to visit a region to measure ground cover fractions for a particular crop and the likely sequence of practices. For calibration of fractional cover, site visits should coincide with the satellite overpass. Site visits should at least occur at times of minimum and maximum cover (e.g. March-May and November-December in the case of Western Australia). Consideration of climatic conditions will determine when a farmer is likely to implement a particular practice within the available window of opportunity.

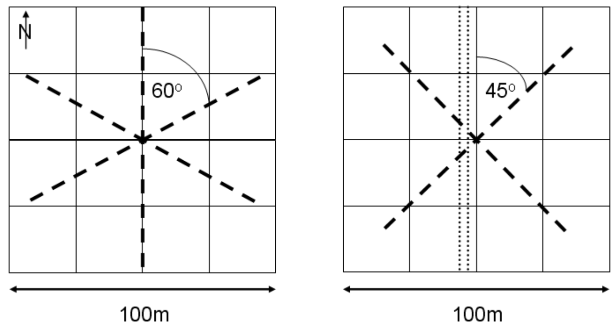
Figure 2(b) shows the cross transect method with the diagonal across the row, trialed for agricultural crops sown in lines, to measure ground cover fractions. This complements the star transect approach currently used for pastoral environments in Queensland (Figure 2(a)). Stewart and Rickards (2010) support adoption of these methods as national protocols for measuring ground cover fractions. Schmidt *et al.* (2010b) recommend testing the cross transect method for a range of crop types and at different stages of the cropping cycle. This method at 1 ha scale should use Landsat (30 m) as an intermediate step if upscaling to MODIS (Moderate Resolution Imaging Spectroradimeter) (500 m) type resolution is required. Spectral signatures of different ground covers are also required for calibrating fractional cover.

Queensland and New South Wales currently collect ground cover measurements using the star transect approach in pastoral environments. Other States use different but often similar approaches in their pastoral monitoring to measure ground cover (e.g. South Australia, Tasmania and Northern Territory). There is some interest in trialing the star transect approach to compare with existing methods (e.g. Northern Territory). Few States have established monitoring sites for the purpose of calibrating or validating remote sensing products. Generally new sites would need to be established and separately funded to meet the requirements for remotely sensed fractional cover and land cover data, particularly in cropping areas.

Assessment of MODIS-based data showed the benefit that increased temporal frequency has for estimating ground cover through the annual cropping cycle. Based on paddock size, the lower spatial resolution of MODIS is not appropriate for monitoring most cropping systems. Fractional cover products are being developed using Landsat within the Queensland Department of Environment and Resource Management, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Geoscience Australia. Low-cost or free access to the Landsat archive would greatly improve the temporal frequency of imagery at an appropriate scale for monitoring ground cover and related practices in cropping and modified pasture land uses. The MODIS fractional cover product of Guerschman *et al.* (2009) needs further calibration covering a range of environments (including pastoral) to improve its estimates. Several hundred calibration sites within each State may be required to achieve a reliable ground cover estimate (T Danaher pers. comm. 2009).

	Month											
State NRM region NRM sub-region	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**
New South Wales Murrumbidgee	Graze	Plant (no tillage)							Harvest			stubble
Victoria Wimmera	Cultivate (site prep)	Plant (min tillage)							Harvest and graze stubble		Mulch stubble	
Queensland Maranoa Balone	Stubble left intact		Plant (zero tillage, controlled traffic, opportunity crop)						Harvest	Stubble left intact		
South Australia Eyre Peninsula	Graze	Plant (no tillage)							Harvest			stubble (light-mod)
Western Australia Avon		Cultivate (site prep)	Plant (min tillage)						Harvest		Graze stubble (time based)	
Tasmania North Northern Midlands	Harvest and graze stubble (heavily)		Plant (no tillage)							Harvest and graze stubble (heavily)		

Figure 1. Timing of management practices influencing ground cover levels for dryland wheat for selected NRM regions as derived from the calendar of operations. Zero tillage (at sowing < 10 % soil disturbance e.g. disc planters); no tillage (at sowing < 30 % soil disturbance e.g. knife points); minimum tillage (one or two cultivations prior to sowing). In the examples above, a chemical fallow is common (no soil disturbance) or a cultivated fallow in the cases where minimum tillage is used.



(a) **(b)**

Figure 2. Layout of 100 m transects for measurement of ground cover at 1m intervals under (a) pastoral environments (rangelands and improved pastures) and (b) intensive agricultural systems (cropping) for calibration of Landsat imagery (from Schmidt *et al.* 2010b).

Recommendations

Ground cover information will be used to monitor land management practices and their effects on soil erosion and landscape condition across the continent. Recommendations from Schmidt *et al.* (2010b) and Stewart and Rickards (2010) for national ground cover monitoring include:

- National protocols developed for quantitative field sampling of fractional cover
- A spectral library developed for Australian land cover types that captures the spectral characteristics of each land cover type at various stages of the dynamic cycle
- A network of calibration sites for priority landscapes, land uses and management practices for reliable estimates of fractional cover

- Collaboration and coordination with other initiatives such as the Terrestrial Ecosystem Research Network (TERN), the Australian Collaborative Rangeland Information System (ACRIS) and soil condition monitoring through the National Committee for Soil and Terrain including erosion monitoring (roadside surveys) for remote sensing products (i.e. land cover and fractional cover) and to extend network of reference sites
- A comprehensive, spatially explicit, national database of land management practices is required to complement and inform the remote sensing products (see ACLUMP 2009)
- Access to ancillary data (in particular land cover, land use and climatic data) to put interpretation of fractional cover in context
- New fractional ground cover products using Landsat or sensors at similar resolution developed and implemented across Australia. These products could be augmented with MODIS-based products (e.g. Guerschman *et al.* 2009) to provide the temporal resolution sometimes required to adequately monitor intensive agricultural systems.
- Investigate the influence of climate and land management practices on fractional cover dynamics. De-coupling these effects will help to understand natural and human-induced variability in ground cover levels and provide for more informed policy and natural resource management.

Acknowledgements
Partners in ACLUMP who have contributed to these activities are: Department of Environment and Resource Management (Queensland); Department of Environment, Climate Change and Water (New South Wales); Department of Primary Industries (Victoria); Department of Primary Industries, Parks, Water and Environment (Tasmania); Department of Water, Land and Biodiversity Conservation (South Australia); Department of Agriculture and Food (Western Australia); Department of Natural Resources, Environment, the Arts and Sport (Northern Territory); Geoscience Australia; CSIRO Land and Water. Refer to www.brs.gov.au/landuse for further information on ACLUMP activities.

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Building a 'whole of soil' policy framework

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Abstract
This paper describes an approach taken in Victoria, Australia, to describe the role for policy for comprehensive aspects of soil use and management. Political changes in governments and the structure of government departments generate redundancy in policies. An enduring policy framework for soil health should be adaptable to these political changes whilst maintaining a core of principles to guide new policy and investment by government. Soil serves multiple uses that may cut across responsibilities of different government departments. Negotiating shared policy across departments and creation of a 'whole of government' policy for soil health may be seen as a solution, however the path to that solution has the potential to be protracted and without complete resolution. An alternative to this is to develop a soil health policy framework that is a 'whole of soil' framework to which the changing roles of government departments can be fitted. A simple conceptual model that relates soil ecosystem services, threats to soil, and governance for soil protection is described. An example of how this may be applied in the Victorian Department of Primary Industries is outlined.

Key Words
Soil health, ecosystem services, soil degradation, soil protection.

Introduction
Policies and practices that have an impact on soil are diverse and need a framework through which integrity of soil resources can be maintained. There is a diversity of codes, strategies and legislation that affect soil. Planning legislation may or may not have provision for zoning to protect prime agricultural land. Codes of practice may be prescribed for removal, storage and rehabilitation of soil associated with mining and extractive industries. The success of policies concerned with water management have a direct dependence on land use practices within catchments but, except in the case of proclaimed or protected catchments, do not usually exercise any governance over soil use and management within land uses.

Soil conservation developed as the first focus in Victoria for government intervention following the Soil Conservation Act of 1940 and the Soil Conservation and Land Utilisation Act of 1949. Changes in attitude to land management during Australia's 'Decade of Landcare' led to a devolvement of some responsibility for soil and land condition from the State to 10 Victorian Regional Catchment Management Authorities formed under the Catchment and Land Protection Act of 1994. This Act incorporated earlier soil conservation legislation as well as some other acts and is administered by the Department of Sustainability and Environment. Many of the regional authorities have independently developed soil health strategies.

Crawford *et al* (2006) described an initiative to develop a soil health policy framework in Victoria, largely in response to a government committee inquiry into soil acidity. They reported on the need for better partnerships between soil scientists and policy-makers to support evidence-based policy making and proposed a framework in which the onus would be on for government to achieve soil health outcomes of wide benefit through providing land managers with the knowledge, tools and choices to improve soil health, rather than by legislation or directive. This draft policy framework resulted in major investment into a 'Healthy Soils' project to deliver better information to farmers and their advisers in partnership with cropping groups in western Victoria from 2007-2010.

Subsequently, other issues including land use change, climate impacts, the role for soil Carbon sequestration in greenhouse gas mitigation, questions concerning protection of prime agricultural land from peri-urban development, and a growing interest in 'biological farming', have become more prominent. All of these issues have a bearing on soil and its health.

Methods

The Department of Primary Industries (DPI) is taking leadership in addressing the need for a policy framework that has the potential to be inclusive of diverse issues that may lie within the jurisdiction of other government departments but without dictating the policies that those departments might develop. A four project team comprising policy and technical specialists is charged with writing a framework.

Definitions

Agreement concerning terminology, definitions and scope for the framework was achieved through consultation with a broader reference group and DPI executive. There is a substantial body of international literature on soil health and soil quality and this was reviewed previously (DPI 2007). There are several definitions but all have common ground in affirming the importance of soil functions. The performance of these functions depends on biological, chemical and physical soil properties and processes. However, much of the published material on this subject is highly technical and not suitable for explaining policy, particularly when trying to determine societal benefits whether they are private or public.

Ecosystem Services versus threats

Past policies have largely focussed on threats or hazards but the language and objectives in natural resource management (NRM) have recently become more holistically focussed. The notion of 'ecosystem service' provision now has currency as the major criterion for assessing the functional worth or capacity of the natural and the managed environment. This is in contrast to the more reactionary alternative approach in NRM that has been more focussed on negative aspects associated with environmental degradation. There are many programs and initiatives that have been, and are being, implemented to address these issues e.g. the National Soil Conservation Program was developed to progress management improvements to prevent or ameliorate erosion, salinity, acidification, soil structure decline. However, the underlying reasons for dealing with them have always been positive, for example, that by addressing these issues, land management will be more productive and sustainable and water quality will be improved. The ecosystem service concept provides an integrated positive driver for NRM just as the soil health concept provides an integrated (albeit symbolic) paradigm for managing the diverse issues that arise in soil management.

Governance

Soil health can be viewed in terms of its functional capacity to deliver ecosystem services and it can also be considered in relation to the threatening processes that would impair that capacity. Governance is required wherever serious threats to sustained service provision exist. This governance may include: accepted 'best management practices', documented Codes of Practice (e.g. forestry), government strategies, polices and Acts of Parliament. The degree to which legislation is required, including penalties and enforcement, depends on the judgements exercised at a policy level. Determinations for government investment to support practices for improving or maintaining soil health require a balancing of private and public benefit, and an economic assessment of 'market failure'.

Results

Definitions

For the purposes of the soil health policy framework, the following definition was agreed:
Soil health is the condition of the soil in relation to its potential to provide ecosystem services and resist degradation.

The Millennium Ecosystem Assessment (MA) defined ecosystem services as:
'the benefits people obtain from ecosystems'. 'These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth' (MA 2003).

The MA framework can be used to describe ecosystem services from soil. However, although the majority of literature concerned with soil health refers to functions of soil in a similar way the emphasis is specific to soil. In this report we have adopted the terminology used in key literature concerning soil quality and soil health. A summary of the functions and services expected from healthy soils (illustrated in Figure 1) in relation to the MA (2003) ecosystem services (provisioning, regulating, cultural and supporting) follows. The importance of particular aspects of these services to some government departments and authorities is noted.

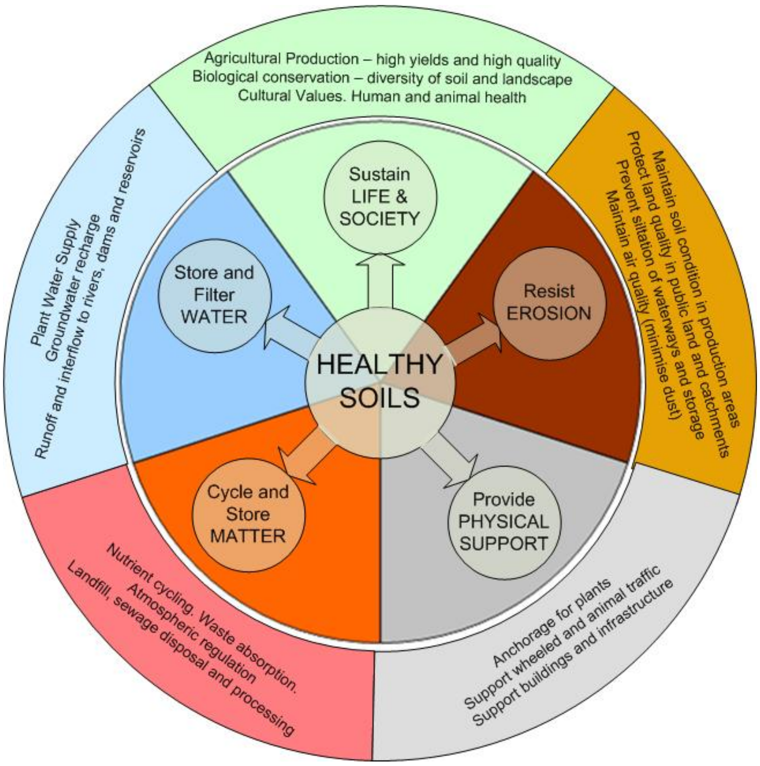

Figure 1. A summary of the functions and services expected from healthy soils.

Sustain life and society

Essentially, the provisioning services (primary industries) for food, fuel, fibre and other genetic resources, discovered or undiscovered, associated with global biodiversity, are encompassed here. Also included are cultural services — the recreational, aesthetic and spiritual values invested in significant sites and landscapes (sports turf, gardens and sacred sites). Multiple agencies share an interest in, or accountability for, soil issues in this sector: DPI (agricultural productivity and animal health); DSE (biological conservation); DPCD (sports, heritage, community development); DoH (human health).

Store and filter water

Soil performs regulatory services in the hydrologic cycle. It is the interface between rainfall and terrestrial flows, regulating recharge to groundwater, runoff and stream flow. The storage of plant available water in soil is a vital supporting service required for provisioning plant growth. Filtering water on its path to groundwater, rivers and storages is an important supporting service influencing water quality. All of these hydrologic services are highly dependent on soil conditions that are sensitive to management. Consequently, this is an important area for soil health policies. Principal agencies concerned with soil issues in this sector are: DPI (understanding and managing soil water use in farming systems); DSE (surface and groundwater management, catchment management) and water authorities (land use, water supply and quality, catchment management).

Cycle and store matter

The suite of processes that regulate the cycling of matter through and within soil influence services that support plant growth via nutrient cycling, and those that have a role regulating atmosphere. The dynamics of carbon storage, release of greenhouse gases and relation to soil type, soil health and management are critical to the development of relevant soil health policies. Soil is also expected to perform regulatory and supporting services related to waste disposal, management and absorption. These services may be site specific as in the use of soil for containing and capping landfill, and for land application of wastes as fertilizers. Waste absorption services are also linked to hydrologic functions in which soil serves as an environmental buffer between land-based water-borne pollution sources and receiving surface and ground water resources. These latter services are diffuse, extensive and catchment based. The DPI (nutrient cycling, atmospheric regulation / greenhouse abatement), DSE (atmospheric regulation / greenhouse abatement) and EPA (waste management) are key government agencies with interest or jurisdiction within this sector.

Provide physical support
In natural and agro-ecosystems, soil provides anchorage for plant roots and physical support for machinery and animals. These functions support services that are cultural (e.g. sports turf, parks and gardens) and provisioning (agricultural production systems). Soil that is strong enough to support heavy machinery is too compacted to support plant growth, and soil that has optimal physical conditions for roots is easily degraded (compacted) by foot and wheel traffic. This example demonstrates that fitness of soil conditions depends on use — controlled traffic cropping practices solve this dilemma by consistently restricting wheels to specific tracks. In the built environment, soil provides a source of building material as well as the underlying support for buildings and protection for buried infrastructure and utilities. There are significant hazards to infrastructure associated with certain soil types and soil degradation processes. For example: acid sulfate soils , if allowed to oxidise, generate large volumes of corrosive sulfuric acid; shrinkage of reactive clay soils can damage building foundations; landslides can cause destruction of buildings, roads and buried utilities (e.g. water and gas pipes). Maintaining the supporting services of soil in the built environment requires a combination of hazard avoidance (appropriate planning and development) and hazard management (e.g. drainage for landslides, saturation of potential acid sulfate soils). The DPI (tillage, traffic and soil health), DPCD (land use planning and assessment, local authorities (planning, development) and utility managers (underground distribution networks) all have responsibilities in this sector.

Resist erosion
This is a supporting service. Provision of ecosystem services requires that soil is resistant or resilient to the pressures that are imposed on it. Healthy soils are more resilient and able to sustain functions and resist degradation than soils in poor condition. Loss of soil through erosion obviously reduces the capacity to provide those services. Soil erosion is a natural process, but accelerated, or management-induced, erosion is a significant global phenomenon. Well-managed soil has qualities that make it more resistant to erosion by wind and water. Surface ground cover as a protecting layer is extremely important here but healthy soils, high in organic matter and with stable structural units can resist detachment and erosion. The DPI (soil management to minimise erosion from agricultural land) CMAs (monitoring and reporting land condition under the CaLP act), DoH and EPA (air quality and human health), DSE (water quality, catchment condition, monitoring), DPCD (land use planning and assessment), local government authorities and VicRoads all have accountabilities within this sector.

Conclusion
We are developing a soil health policy framework that has a strong technical base in the literature on soil health, soil quality and ecosystem services. This can be used to map out areas where governance exists or is needed to manage threats to services. In this way it can serve the changing needs of governments and different accountabilities of departments. It doesn't necessarily provide an instant means of reconciling differences but, by collecting all the issues into one conceptual space, it provides a framework for debate.

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Evolution of European Union policies relevant to soil conservation in agriculture

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Abstract
Six of the soil degradation processes recognised at EU level are closely linked to agriculture. Soil degradation implies a need for protection, maintenance and improvement of soil quality. However, due to the public good characteristics of soil quality, the market does not sufficiently assure its provision. Thus, policy intervention is required to reach desired levels of soil quality through appropriate practices. This paper provides an overview and evolution of European Union policies relevant to addressing soil degradation in agriculture. Such policies evolved from focusing on protection against agriculture's negative externalities towards emphasising its positive externalities. To date, soil protection is not a specific objective of EU legislation, nor does a targeted policy framework for soils exist. Existing EU policies pursuing other environmental objectives have nevertheless scope for soil conservation. Currently, the most important EU environmental directives for soil quality are the Nitrates Directive and the Water Framework Directive. Under the Common Agricultural Policy, the compulsory requirement to keep land in good agricultural and environmental condition plays an important role in soil conservation. Rural development policy, in particular agri-environment measures, offers member states or regions options for encouraging farmers to achieve environmental quality beyond a predefined reference level.

Key Words
European Union policies, soil conservation, agriculture, environmental public goods.

Introduction
Soil performs multiple functions for humans and ecosystems. Intensification of production in some regions and concurrent abandonment in others remain the major drivers (threats) to the ecology of agro-ecosystems, impairing the state of soil, water and air and reducing biological diversity in agricultural landscapes in Europe (Stoate *et al.* 2009). For example, six of the soil degradation processes that are recognised in the European Union (EU) (COM(2006) 131) are closely linked to agriculture: erosion, organic carbon decline, soil biodiversity decline, compaction, contamination, and salinisation and sodification. Degradation of abiotic resources inhibits their proper functioning and thus implies a need for protection, maintenance or improvement of their quality. However, due to a market failure, policy intervention is required to reach satisfactory levels of quality.

To date, soil protection is not a specific objective of EU legislation, nor does a targeted policy framework for soils exist. Existing EU policies pursuing other environmental objectives have nevertheless scope for soil conservation. The SoCo project (sustainable agriculture and soil conservation: http://soco.jrc.ec.europa.eu/) provided a comprehensive overview of their relevance and effectiveness. This paper reiterates those policies that are relevant to protection, maintenance or improvement of soil quality in agriculture. In addition, it explores how policies for soil conservation in the EU conceptually evolved over time. Such evolution reflects the changing challenges and needs of society over time, and its response to these changes.

Why policy intervention?
Most environmental problems can be seen as problems of incomplete, inconsistent, or unenforced property rights regimes (Hanna *et al.* 1995). In the case of soil quality, land in the EU is mostly privately owned, and farmers, who at least have the temporary use rights to soil, suffer first from soil degradation. Depending on the time horizon of their use rights, they have a genuine interest in a good condition of their land. When considering soil as a production factor with private good characteristics, other users can be excluded from using the land for agricultural or other production. However, self-interest in this property rights regime normally coincides with society's needs for soil quality, as soil has additional functions, which have the character of public goods (e.g. carbon sequestration, long-term provision of food, landscape). Public goods have two main characteristics: their quantity of supply does not decrease with consumption (non-rivalry) and their access and consumption is general and free (non-exclusion) (Weimer and Vining 2004). Nevertheless,

the provision of these public goods depends often on the quality status of the private good 'production factor'. Thus, overall society needs for soil quality may differ from the quality level farmers provide. Exactly due to the public good character of soil quality, the market does not sufficiently assure its provision (market failure). Property law further reinforces this market failure by assigning no property rights to ecosystem service benefits (Lant *et al.* 2008). Policy intervention is therefore required to reach satisfactory levels of this quality through appropriate farming practices.

Policy types and levels of environmental quality
In analysing whether a policy has scope for protecting, maintaining or improving soil quality, it is important to assess to which degree the desired soil quality can be achieved. When targeting soil quality, the policy process defines soil quality levels (reference, target) in line with property rights regimes (Figure 1) (Bromley 1997; OECD 2001; Pearce 2005). Parallel, in line with their influence on famers' behaviour, policies can be classified as mandatory, voluntary incentive-based, and awareness-raising measures (Baumol and Oates 1979; Weersink 2002).

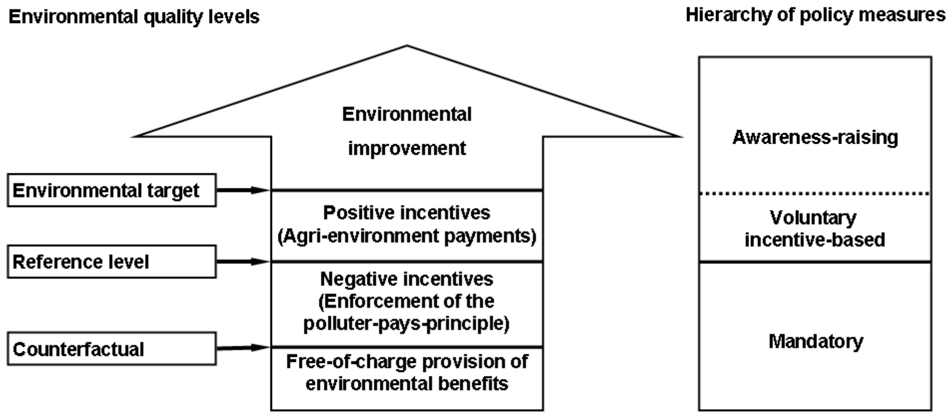

Figure 1. Environmental quality levels and related types of policy measures (Sources: Baumol and Oates 1979; Weersink 2002; Scheele 2008).

Whereas targets relate to the economic criterion of an optimal allocation of resources, reference levels reflect the distribution of costs between farmers and society. The reference level thus distinguishes between what is considered a minimum or mandatory requirement and what exceeds this level and should therefore be obtained contractually or on a voluntary basis. This level thus separates two types of policy measures: mandatory and voluntary incentive-based measures. Under mandatory measures (e.g. cross compliance rules) farmers have to respect the reference level of soil quality at their own expense. Farmers can choose to target a higher level of soil quality (target) under voluntary incentive-based measures (e.g. agri-environment payments). The related payments compensate for income losses due to reduced productivity or extra costs incurred when implementing the contract. Policy measures aiming at a level of soil quality that goes beyond the environmental target are called awareness-raising measures. Advice to farmers fits in the latter category.

Evolution of approaches in EU environmental policies and their relevance for soil conservation
Since the mid-1970s, environmental protection has gradually obtained the status of being a precondition for sustainable economic development in the EU (McCormick 1995). Creation of environmental policies has since become a core part of EU policy making. In the development of EU environmental policies, one can recognise distinct phases. Up to the mid-1990s, the emphasis was very much on protecting the environment against negative effects of human action, thus controlling the risks for human health. Since, the environmental scope has gradually been widened to maintaining or improving environmental quality in its own right (inherent value), a process that coincided with the introduction and development of the EU Treaty.

Protecting the environment for public health
A number of directives directly regulate the discharge of (potentially) harmful substances into water and soil. The Groundwater (80/68/EEC and 2006/118/EC) and Nitrates (91/676/EEC) Directives aim at protecting water quality, whereas the Sewage Sludge Directive (86/278/EEC) primarily affects soils. Parallel, the Plant Protection Products Directive (91/414/EEC) considers effects on both soils and water. Finally, the Birds (79/409/EEC) and Habitats (92/43/EEC) Directives target biotic resources, but have nevertheless positive implications for soil.

Parallel, environmental provisions were incorporated into the Common Agricultural Policy (CAP). The Agricultural Structures Regulation (Council Regulation (EEC) 797/85), authorised member states to introduce special national schemes in environmentally sensitive areas, i.e. particular areas of recognised importance from an ecological and landscape point of view. Nevertheless, even though this regulation paid attention to the permanent conservation of the natural resources used in agriculture, its main focus laid in assisting the continuous development of agriculture in the Community in order to improve the efficiency of holdings and to help develop their structures.

Environmental integration for provision of ecosystem services and sustainability
Environmental integration, i.e. making sure that environmental concerns are fully considered in the decisions and activities of other sectors, has become a priority since the mid-1990s. Against the background of sustainable development, this priority was incorporated into the EU Treaty and subsequently put into practice with the Cardiff Process (1998). Since, environmental objectives have to be integrated into EU sectoral policies, including the CAP. The EU Sustainable Development Strategy (Lisbon 2001) put a further emphasis on policy coordination and integration. This current, coordinated approach coincides with a new generation of environmental directives whereby so-called framework directives aim to harmonise existing policies on the respective topics, and fill gaps where needed. The Water Framework Directive and the Framework Directive on the Sustainable Use of Pesticides are examples of such overarching policies. However, a targeted policy framework for soils is currently missing. To fill this gap the European Commission proposed the Soil Framework Directive (COM(2006) 232). Its overall goal is to protect soils and use them sustainably and would require member states to preserve soil functions, to identify where degradation already occurs and to set their own level of ambition and timetable to combat such degradation.

Parallel, since its conception in the Treaty of Rome (1957), the CAP underwent a series of reforms, mainly driven by international trade obligations and EU budget concerns (Ackrill *et al.* 2008). These reforms also responded to an increasing pressure to deal with the environmental implications of the early CAP. With the 1992 reform, member states were required to introduce agri-environment measures throughout their territory (as opposed to the target areas in the 1985 provision). Thus, farmers got an incentive to voluntarily deliver environmental quality at a level beyond the reference quality level. In 1999, the provisions of this regulation were incorporated into the Rural Development Regulation. The aim of their incorporation was to help achieve coherence within Rural Development Plans (EC 2005). Since, the CAP comprises two main elements: market price support and direct income payments (Pillar 1), and incentive payments targeting rural development (Pillar 2). The most recent reform of the CAP, in 2003, included decoupling of payments from production, introduction of cross compliance, extension of rural development measures and, gradual transfer of funds from farmers' income support to rural development (modulation). Finally, the CAP Health Check revision (2009), i.e. an intermediate review of the CAP after introduction of the CAP direct payments, included minor changes for some of the environmental provisions. In particular the requirement to keep land in good agricultural and environmental condition, a cross compliance instrument, and agri-environment measures, financed under rural development, are relevant to and facilitate the targeting of soil quality.

Discussion and conclusions

Since the mid-1970s up to nowadays, EU environmental directives and environmental measures in the CAP have evolved from focusing on protection against agriculture's negative externalities towards emphasising its positive externalities and providing a range of ecosystem functions and the benefits humans derive from them (ecosystem services). Policies relevant to the environment thus evolved from addressing a single concern and environmental component (e.g. pollution of water by nitrates), often restricted to target areas, to overarching policies, addressing different aspects of the same environmental domain (e.g. aiming at a good status of all waters) or even including policies with multiple objectives (e.g. agri-environment measures). This evolution has gone along with a gradual shift in society's and farmers' minds from seeing soil exclusively as private goods, towards respecting the public good characteristics of these resources as well. We can reasonably assume that the policies that are relevant to soil quality have also contributed to raising awareness for their conservation.

Nevertheless, as it takes time for ecosystems to reach a new equilibrium, it also takes time before impacts of policy measures on soil quality are recorded. In this respect, the history of soil-relevant policies incorporated into the CAP is relatively young. Even though agri-environment measures exist since 1985, they were at first restricted to targeted areas. Since 1992, they became more widespread, both in terms of covering more territory as well as covering more environmental objectives and thus touching more farming operations. The view of agri-environment measures broadened in particular with their inclusion in rural development policy. This evolution occurred in synergy with, since 2005, making direct payments conditional on complying with a series of environmental policies (cross compliance).

Overall, a range of EU policies is relevant to soil conservation. However, very few policies directly address soil degradation processes, and even if they do, are not oriented towards specific results of soil quality. A lack of defining quality levels has in a lot of cases resulted in policies that only describe the farming operations required (action-oriented) to address soil degradation. Unlike the Water Framework Directive (2000/60/EC) for water quality, a coordinating instrument for soil quality is currently missing.

Disclaimer

The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

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Participatory action by the community in sustainable land use management for agricultural systems on the Ban Eang watershed Saluang sub district Maeteang district, Chiang Mai province, Thailand

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Abstract
Participatory action by the community on the Ban Eang watershed in Saluang subdistrict Mae Teang district, Chiang Mai, Thailand was studied to assess soil chemical characteristics for the purpose of land use management for sustainable agriculture. This watershed has an area of about 830 ha and land uses were paddy rice, terrace paddy rice, orchard, field crop and forest. The community in Ban Eng watershed showed strong participatory action. Soils were developed from the residuum gneiss. Soil reaction was very strongly acid (pH 4.84) to strongly acid (pH 5.30) in topsoil and very strongly acid (pH 4.89) to moderately acid in subsoil (pH 5.82). Organic matter decreased with soil depth in the range of very low (0.79 g/kg) to high (56.39 g/kg). The extractable phosphorus was low (5.36 mg/kg) to moderately high (21.52 mg/kg) in topsoil and very low (0.79 mg/kg) to moderately low (8.45 mg/kg) in subsoil. Extractable potassium was high (92.5 mg/kg) to very high (178 mg/kg) in topsoil and very low (25.7 mg/kg) to moderate (97.9 mg/kg) in subsoil and extractable calcium was low (617 mg/kg) to moderate (1099 mg/kg) in topsoil and very low (54.3-91.4 mg/kg) in subsoil and magnesium was low (106 mg/kg) to moderate (289 mg/kg) in topsoil and very low (35.3 mg/kg) to low (107 mg/kg) in subsoil. The community established a programme for soil management. Dolomite and organic fertilizer were recommended to improve soil properties. Moreover, mulching, vetiver grass strips and sprinkler technique were applied in this watershed as a basis for sustainable agriculture.

Key Words
Land use management, watershed, participatory action.

Introduction

Non conservation strategies for cultivating on steep slopes were the initial cause of the problem of land degradation, soil erosion, deterioration of soil physical properties and a steady decline of soil fertility in watershed regions in tropical areas (Aneckasampant *et al.* 1992). Most areas in the watershed of northern Thailand are hilly and mountainous and subjected to shifting cultivation. Since the end of the 1970s, the rapid development of Thailand has brought into focus the need for integrated resource management as a basis for overcoming increasingly severe problems of drought and flood (Krairapanond 1998). Shifting cultivation leads to the rapid degradation of soil productivity, while soil fertility declines rapidly. The contents of soil organic matter, total N, and total P in agriculture land in watersheds were significantly lower than for forestland (Jiang 2006). The land of Ban Eang watershed has to be used to intensify crop production within rotational systems. This has led to degradation of the unfertile soil to low levels of productivity; with non-conservation cultivation techniques being, the main problem in this area. This research aims to study land use for agricultural, and soil characteristics assessed to determine management plans to ensure land use systems become sustainable through participatory action between community and researcher.

Methods

This study was carried out on the Ban Eang watershed in Saluang subdistrict Mae Teang district, Chiang Mai province, northern Thailand (between UTM 478780 N 2106881 E to 481943 N 2104563 E and 477516 N 2015485 E to 481261 N 2103650 E, 500 to 600 msl in altitude) (Figure 1 (a)) an area of about 830 ha. The results of the study are based on a questionnaire, focused group meeting discussions (Defoer 1998) to defined the context of community, problem, solution of land use, soil management, a field trip (in a succession area which has soil conservation practice and soil management) and soil science research integration. Soil samples were collected from the surface layer (about 0-20 cm depth) and subsurface layer (20-40 cm, 40-60 cm, 60-80 cm, 80-100 cm depth) with 4 replicates of each land use and about 80 subsamples (0-20 cm and 20-40 cm) were collected by the farmer for chemical soil analysis such as soil pH, organic matter, available phosphorus and extractable potassium, calcium and magnesium (USDA 1996).

Results

Community context

Ban Eang watershed has an area of about 830 ha. The surrounding landforms are hilly and undulating with a 2-50 percent slope. The population is approximately 450 people (150 families), who are farmers and non timber hunters with a career and average income is about 21,000 bath/family/year. The community in Ban Eang watershed has a leader and a committee. Buddhism is the majority religion. Soils have developed on residuum and colluvium from gneiss under a semi-humid subtropical climate. Clayloam is the texture of topsoil. The amount of clay fraction depends on soil depth. Land uses consist of paddy rice, terrace paddy rice, orchard, field crop (such as soy bean, upland rice and corn) and forest follow a topography sequence (Figure 1 (b)).

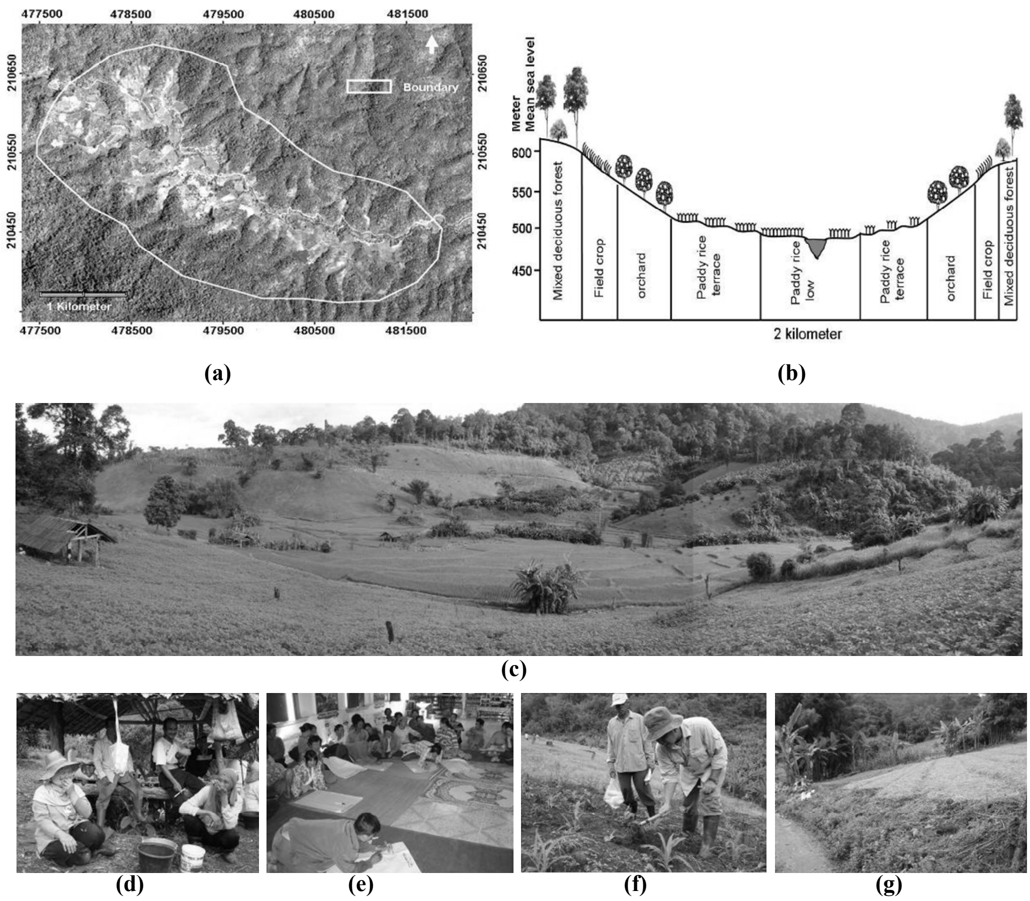

Figure 1. (a) photo aerial of study area (b) topography sequence land use (c) land use characteristic (d) farmer (e) group discussion (f) soil sampling by farmer (g) soil mulching.

Soil chemical properties

The pH values were in a range of very strongly acid to strongly acid (pH 4.84-5.30) in topsoil and a range of very strongly acid to moderately strongly acid (pH 4.89-5.82) in subsoil. Organic matter decreased with soil depth in range from 0.79-56.4 g/kg. Available phosphorus ranges from low to moderately high (5.36-21.5 mg/kg) in top soil and very low to moderately low in subsoil (0.79-8.45 mg/kg). The amount of extractable potassium ranges from high to very high (92.5-178 mg/kg) in topsoil and very low to moderate (25.7 - 97.9 mg/kg) in subsoil. The concentration of extractable calcium in topsoil showed low to moderate (617 -1099 mg/kg) and very low (54.0 -91.4 mg/kg) in subsoil while extractable magnesium as run from low to moderate (106 -289 mg/kg) in topsoil and very low to low (35.3-107 mg/kg) in subsoil (Table 1.)

Participatory action by community

From participatory approaches, the community was established in agreement and programme for soil management and conservation follow;

- The applications of dolomite for increasing soil pH, Ca and Mg
- Chemical fertilizer management following soil analysis
- Compost fertilizer for improving soil physical and chemical characteristics
- Mulching, vetiver grass strip and sprinkler water technique were used in cultivation

Table 1. Soil chemical properties at Ban Eang watershed in Saluang subdistrict Mae Teang district, Chiang Mai, Thailand.

Land use	Depth (cm)	pH (H_2O)		OM (g/kg)		P		K		Ca		Mg	
						(---mg/kg---)							
Field Crop*	20	4.95	v.st.ac	37.43	H	5.36	L	135.29	VH	617.29	L	105.71	L
	40	4.96	v.st.ac	27.91	MH	2.61	VL	80.86	M	300.29	VL	81.00	L
	60	4.98	v.st.ac	19.60	M	1.50	VL	62.57	M	184.00	VL	75.14	L
	80	5.07	st.ac	15.31	M	1.21	VL	75.43	M	138.00	VL	76.00	L
	100	5.16	st.ac	12.28	ML	2.31	VL	63.71	M	91.43	VL	73.86	L
Orchard	20	5.28	st.ac	36.19	H	5.45	L	177.83	VH	579.67	L	154.50	M
	40	5.35	st.ac	26.73	MH	1.69	VL	63.67	M	162.67	VL	84.17	L
	60	5.24	st.ac	17.77	M	1.10	VL	67.00	M	142.17	VL	81.67	L
	80	5.28	st.ac	11.03	ML	0.92	VL	58.67	L	97.33	VL	69.17	L
	100	5.12	st.ac	8.81	L	0.79	VL	54.50	L	5.40	VL	58.67	L
Paddy rice Terrace*	20	5.30	st.ac	48.17	VH	10.14	M	93.00	H	1012.33	M	110.67	L
	40	5.71	mo.ac	39.93	H	6.40	ML	77.00	M	884.33	L	93.00	L
	60	5.55	mo.ac	24.00	M	3.95	L	52.67	L	782.67	L	98.33	L
	80	5.80	mo.ac	22.95	M	2.20	VL	63.00	M	392.00	VL	75.67	L
	100	5.82	mo.ac	13.33	ML	2.32	VL	25.67	VL	162.67	VL	35.33	VL
Paddy Rice*	20	4.84	v.st.ac	42.00	H	21.52	MH	92.50	H	858.50	L	109.00	L
	40	4.89	v.st.ac	28.31	MH	6.36	ML	50.75	L	679.25	L	63.00	L
	60	5.23	st.ac	18.48	M	5.32	L	44.25	L	590.25	L	60.00	L
	80	5.46	st.ac	13.45	ML	3.96	L	34.00	L	376.50	VL	48.75	L
	100	5.52	mo.ac	14.32	ML	2.47	VL	33.00	L	385.50	VL	49.75	L
Mixed Deciduous forest	20	5.35	st.ac	56.39	VH	13.48	M	105.71	H	1099.14	M	289.86	M
	40	5.38	st.ac	19.53	M	7.63	ML	97.86	H	231.14	VL	107.14	L
	60	5.43	st.ac	9.16	L	8.45	ML	85.86	M	72.00	VL	70.57	L
	80	5.57	mo.ac	7.17	L	8.25	ML	65.71	M	68.57	VL	69.57	L
	100	5.73	mo.ac	4.97	VL	5.56	L	37.14	L	63.57	VL	55.29	L

v.st.ac = very strongly acid, st = strongly acid, mo.ac = moderately acid, Available P, K, Ca, Mg
VH = very high, H= high, M = medium, L = low, VL = very low
* included 0-20cm, 20-40cm, collected by farmer

Conclusion

From this study, the community in Ban Eng watershed showed strong participatory involvement. Soil chemical properties in this area were reported as low to moderate levels. Hence, soil amendment application such as dolomite and organic fertilizer is recommend to improve soil chemical properties. Moreover, mulching, vetiver grass strips for soil erosion and sprinkler water technique for cultivation will be apply in the Ban Eang watershed to enable sustainable agriculture and best environmental management practices.

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Soil acidification with various planting patterns in Lhasa, Tibet, China

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Abstract
The spread of vegetable production around Lhasa, Tibet, China, with high nitrogen fertiliser use may cause accelerated acidification which has consequences for soil productivity. In order to understand the different patterns of soil acidity in Lhasa, Tibet, China three patterns of land use were studied namely: grain, open-field vegetable, and greenhouse vegetable. Fertilizer application was higher in vegetable cultivation and greenhouse vegetable cultivation among the three patterns of land use. Soil pH for greenhouse vegetable production was lowest, while soil pH for grain production was the highest. Higher fertilization and the higher evaporation coupled with very low leaching in vegetable greenhouse caused a dramatic change of soil quality. We should improve management to increase nitrogen uptake efficiency and to reduce nitrogen application.

Key Words
Soil pH, N and P over accumulation, soil quality, vegetable land, semiarid area, Tibet Plateau.

Introduction
Several studies have found that the additions of nitrogen fertilizers can result in an acceleration of soil acidification compared with no fertilization in arid climates with naturally alkaline soils (Bowman and Halvorson 1998; Xu *et al.* 2002). Soil pH was lower in cropped and fertilized treatments compared to the fallow treatment in China's Loess Plateau (Wei *et al.* 2006). Soil pH is decreasing in many soils in the semiarid Great Plains of the United States (Tarkalson *et al.* 2006).Nitrogen fertilization significantly reduce soil pH by 0.3 and 0.5 units for low and high rates respectively (Rodriguez *et al.* 2008). The soil ecosystems are fragile and sensitive in the semi-arid middle Tibet Plateau. Some papers had reported on biological fertility and its dynamics in degraded soil of this area (Qian *et al.* 2006).Changes of cropland soil pH have occurred in the semiarid middle Tibet Plateau since the Second National Soil Survey in 1980s, with average pH values decreasing from 7.70 in the 1980s to 7.22 in 2008(Zhou *et al.* 2009). Although the Tibetan Plateau may have been little affected by industrial activities, land use change is occurring, with an increasing trend towards vegetable land. There is an increasing trend of land use change from grain to vegetables, with or without plastic film covering, since the early days of the 1990s in Lhasa, Tibet, China. There were only 493 ha of vegetable lands in Lhasa in 1990, but 3953 ha in 2006. This land use change was driven by a dramatic increase in demand for vegetables due to both improved living standards and increased urban populations. There was, however, scarce information on the soil acidity changes in vegetable land. Hence there was a need to understand differences in soil acidity between the three patterns of land use namely: grain, open-field vegetable, and greenhouse vegetable.

Methods
Study area
This study was conducted in Lhasa (29º14´-31º04´N, 89º45´-92º37´E, 3600-4100m), Tibet autonomous region, China. This region is dominated by a continental temperate climate with annual mean of 1.5-7.8ºC. Annual precipitation is 340-600 mm, with 75% concentrated during June-August. The mean annual sunshine duration is 2400-3150 h. According to the genetic soil classification of China, alluvial soil (Inceptisols, Soil Taxonomy) in the study area are sandy loam or loam in texture. These are the major vegetable production soils in the area. The common grain tillage system of the study area is winter wheat or Tibet barley continuous farming, with nearly 11 months growing period from mid or later October for sowing to early next September for harvest. The growing period of open-field vegetable cultivation covers 7 months from April to October. But the growing period of greenhouse vegetables occurs all the year.

Soil sampling and analysis
In 2008, 53 representative sites were selected and geographic coordinates recorded using a hand-held global

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positioning system (GPS). At each site, 5-7 topsoil sub-samples were gathered in a 0.1 ha area at a depth of 0-20 cm and then pooled and mixed. Soil samples were air-dried and ground to pass through a 2-mm sieve before analysis. Soil analysis for pH (1:2.5 soil: water), total N (Kjeldahl digestion), total P (molybdenum method), total K (flame photometer method)-according to the methods described by Liu (1996).

Statistical analysis
All statistical analysis procedures were conducted using SPSS 11.0. Duncan's multiple range tests was used to test for differences of soil groups. Significance was determined at the 0.05 probability level.

Results

Soil pH
Compared with the Second National Soil Survey in the 1980s, average soil pH of 53 soil samples value declined 0.30 units ($P < 0.05$). Average soil pH value for grain, open-field vegetable, and greenhouse vegetable land use were 7.56 ±0.61, 6.92 ±1.16, 6.07 ±0.99, respectively. Soil pH was significantly different between grain or open-field vegetable and greenhouse vegetable.

Soil nitrate and phosphorus accumulation
Noticeably, soil total N and P content in greenhouse vegetable soils was higher ($P < 0.05$) than for other soils (Table 1). Soil N has accumulated in greenhouse vegetable land. Soil total N was significantly different between grain and greenhouse vegetable soils. Soil total P was significantly different between the three types of cultivations. Soil total K was significantly different between grain and open-field vegetable.

Table 1. Effect of land use on total N, total P and total K in soil (0-20 cm depth).

Land use	Total N (g/kg)	Total P (g/kg)	Total K (g/kg)
Grain	1.33 ± 0.32^{b}	0.76 ± 0.14^{c}	24.2 ± 2.46^{a}
Open-field vegetables	1.57 ± 0.33^{ab}	1.09 ± 0.31^{b}	21.8 ± 1.99^{b}
Greenhouse vegetables	1.87 ± 0.63^{a}	1.51 ± 0.58^{a}	22.6 ± 2.18^{ab}

Means ±1 SD. Significant differences among land uses are denoted by different lowercase letters.

Soil acidification
Soil pH depends on the intrinsic factor like soil parent material and exogenous factors such as acid deposition and farming practices. In the semi-arid middle Tibet Plateau, each factor played a difference role in soil pH changes. Firstly, the soils experienced weak pedological development, resulting in a high level of free base cations and a weak cations exchange capacity; so nutrient loss was prone to occur. The study soils were sensitive to acidification (Pan 1990). Secondly, addition of ammonium N fertilizer accelerates nitrification. Annual N application of Lhasa City has overloaded the national threshold of 150 kg N/ha (Zhou *et al.* 2009) and total soil N has accumulated. High Nitrogen caused losses of up to 70 % of exchangeable base cations (Högberg *et al.* 2006). Annual N and P application of greenhouse vegetable was the maximum in three patterns of land use. Among three patterns of land use, soil pH of greenhouse vegetable was the lowest, but soils used for grain production was the highest. A significant increase of fertilizer input, particularly ammonium N fertilizer, most likely caused the severe acidification in greenhouse vegetable land. Higher fertilization and the higher evaporation coupled with very low leaching in vegetable greenhouse caused dramatic change of soil quality.

Conclusion

Soil pH value of greenhouse vegetable areas was the lowest among the three patterns of land use. Soil pH was significantly different between grain or open-field vegetable and greenhouse vegetable. These results suggest that surface soils under greenhouse vegetable production are acidifying under current management practices. Although soil pH in this region was neutral in 2008, if this trend continues, it will adversely affect soil properties such as heavy metal bioavailability, fertility, and microbiology; and plant growth will be threatened. Improved management to increase N uptake efficiency from applied fertilizer would help reduce the rate of acidification. We should fertilize evenly, improve utilization efficiency of the fertilizer, and avoid using ammonium N fertilizers.

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‘Soil protection – are we moving in the correct direction? Experience from England and the European Union’

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Abstract
This paper describes the context for legislation and policy to protect soil in England and the European Union. A common will to protect soil does exist but administrative differences between nation states have led to an impass in achieving a shared agreed legislative framework. A way forward is needed.

Key Words
Ecosystem services, soil degradation, soil policy, legislation.

Introduction
In the latter part of the twentieth century and the first decade of the twenty first century there has been increasing recognition of the importance of soil within the global environmental context. The pedosphere (soil) is now viewed by many as playing an often key role at the interface of the lithosphere, hydrosphere, biosphere and atmosphere, interacting with these other environmental components to provide many of our needs and enabling us to occupy and sustain our lives on the surface of the earth as well as sustaining natural terrestrial ecosystems. Whilst this essentially non-renewable resource comprises a layer at the surface of the Earth which ranges in thickness from just a few centimetres to at a maximum a few metres its often key role in the provision of services to sustain the human population has resulted in the recognition that we must protect the soil to prevent its damage and its potential loss. This recognition of the essential roles played by soil has, in many countries perhaps somewhat belatedly, resulted in the development of legislative frameworks to outline why the soil should be protected together with the presentation of frameworks of strategies to ensure the maintenance of this provision of services. In many situations this is supported by a regulatory system which monitors the state of the soil and seeks to ensure that actions which degrade or destroy the soil are prevented. Many of these strategies to protect soil focus on the functions or environmental services provided by the soil and the threats to the performance of these functions, as a result of misuse or mismanagement of the soil resource, as a result of environmental change, or by external non-soil related actions.

Legislative and policy approaches in the UK and European Union
Some of the approaches adopted by national and supra-national governments to protect soil and its functions and services, are illustrated by examples from England and the European Union. In England a ‘Soil Action Plan 2004-6’ (DEFRA 2004) was followed in 2009 by a ‘Soil Strategy for England’ (DEFRA 2009) In the European Union, following a period of data gathering and discussion across Europe from 2002, ‘The Thematic Strategy for Soil Protection’ was produced in 2006 (European Commission 2006a), with plans to produce a ‘Soil Framework Directive’ to provide the legislative context and requirements to support soil protection cross the Member States of the European Union (European Commission 2006b).

Future directions
To date there has been no agreement amongst Member States as to how, or indeed whether, to proceed towards such a common Directive (see, for example DEFRA 2007). The strengths and weaknesses of the various approaches will be discussed, with the identification of potential pitfalls which might inform others beginning to move towards a legislative framework to protect soils. In conclusion, given the many actions to protect soils at National and other levels, consideration will be given to whether now is the time to consider moving towards an international convention to protect soils. Should we seek to develop a United Nations Convention to Protect Soil (see for example Hannam and Boer 2004)?

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Translating policy into practice: purpose and potential of engaging landholders in monitoring soil condition

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Abstract
This paper explores the Australian perspective on the purpose and potential of engaging landholders in monitoring soil condition to manage agricultural landscapes sustainably. This particular perspective examines the difficulties in reconciling national interests in conserving and maintaining soil health with landholder's interests in and concerns over soil monitoring, especially about how the data will be used. Ultimately the information gained through monitoring soil condition is to make decisions that will be relevant for varied audiences and at different points in the decision-making process. However, in designing a 'one-size-fits-all' soil monitoring scheme that appeals to a varied audience it can unintentionally miss one of its targets – the land manager. Involvement by landholders in soil monitoring, in New South Wales (NSW), Australia, could occur at different points in the monitoring cycle but so far their involvement has been limited to site access for soil sampling, and completing a land management site survey. It appears many areas of the soil monitoring cycle are fixed with little flexibility for local or contextual variation, as the demand for date to report on Natural Resource Management (NRM) outcomes at the national, State or regional levels takes precedence over landholder or local needs.

Key Words
Soil monitoring, soil condition, soil quality, landholder engagement, Natural Resource Management (NRM) policy, farmer-led monitoring.

Introduction
Soil, due to its slow rate of formation, should be considered a non-renewable resource (CEC 2006), and as such if used and managed inappropriately could be lost, and possibly irretrievably (De La Rosa 2005), with limited possibility of recovery to its former functional capacity. Soil is the foundation of life, home for a wealth of above- and below-ground biodiversity, driver of landscape functions, and medium for ameliorating off-site impacts when in good condition. Soil is also the base for many production systems, and the long-term economic and social sustainability of communities depending on them. To improve the long-term sustainability of the agricultural landscape (including natural ecosystems that are affected by surrounding land uses and their management) requires maintenance or improvement in soil condition and continued management in a sustainable manner. The continued degradation of soil condition is a cost to the landholder, but more importantly a public cost (often at least four times greater than the private costs; Crosson 2004) as reflected by loss of biodiversity, salinisation and degradation of wetlands and waterways, and threats to World Heritage Areas (Crosson 2004; CEC 2002).

Can the information required to guide soil policy and land management practices be obtained through monitoring or other means and will monitoring soil condition be viewed as: enhancing information and knowledge requirements for key audiences or an 'exercise' with no obvious merit or value for decision-makers? In general, we would not have to monitor our actions if we were certain or confident of their outcomes. Without monitoring we cannot learn and we cannot adapt our management of natural resources (such as soil), and hence we cannot appreciate if the actions of land managers are having deleterious or positive impacts on the soil. Without monitoring we cannot understand if the goals or targets set by individual landholders or others (including natural resource management agencies and governments at many levels) are being met. Without monitoring we cannot gauge the impact of policy measures on the activities of land managers nor inform policy development to improve land or environmental management. Without monitoring we cannot assess the achievement of goals or targets, which in turn, have been set as an incentive for funding or as a requirement by funding agencies to demonstrate greater accountability of allocated funds. For example, in Australia, access to Federal Government funds for 'on-ground' land improvement activities that will enhance the sustainability of agricultural enterprises and natural resource condition are only available to natural resource management (NRM) regions (often Catchment Management Authorities, CMAs) once they have an accredited Regional Plan (Catchment Action Plan, CAP) which sets targets for achievement in resource condition and management of land (includes soil), water, biodiversity and community (NRMMC 2005). At the State-level in NSW the requirement for standards is to:

> ... demonstrate transparent and effective decision making. The application of state-wide standards by CMAs will be audited, to ensure that CMAs are accountable to the community and to the Australian and NSW Governments for the expenditure of government funds (NRC 2004, p13).

In Australia, the National Land and Water Resources Audit (NLWRA) (1997-2002) had six objectives and the sixth was: "Providing a framework for monitoring Australia's land and water resources in an ongoing and structured way." The National Natural Resource Management Monitoring and Evaluation Framework (NM&EF) was established in 2002 by the State, territory and Federal Governments and approved by the Natural Resource Management Ministerial Council (NRMMC). NM&EF (Woodhead *et al.* 2004) has both 'end in itself' and 'means-to-ends' goals respectively with monitoring and evaluating the: health of Australia's land, water and biological resources, and performance of government programmes, strategies and policies (NRMMC 2005). This paper explores the purpose and potential of engaging landholders in monitoring soil condition to manage agricultural landscapes sustainably, through the current literature and soil monitoring initiatives operating at national, regional and local scales in particular, New South Wales, Australia.

Results and discussion

Purpose of landholder engagement in soil condition monitoring

Hence, is there a reason to involve landholders in soil monitoring and at what stage in the monitoring cycle could they be involved? Landholder interest, co-operation and participation in soil monitoring is necessary, given that many of the monitoring sites are on privately-owned land (90% in Australia; NRC 2004), and subject to their management practices, consent for site access, and information on site land use history. However of more critical importance for widespread landscape improvement in soil condition is the influence of different institutional designs on landholders' participation in soil monitoring. More often than not the agenda for soil monitoring has been set at the National (NLWRA 1997-2002) or global levels (UNCCD) by policy-makers and panels of experts working on committees, with in some cases, periods of community consultation (e.g. United Kingdom Soil Indicator Consortium, European Commission Thematic Strategy for Soil Protection, Natural Resource Commission (NRC) State-wide Standards and Targets). However, the consultation process seems to have minimal impact on the eventual outcome – soil monitoring structure and protocol. In the case, of Australia's national NRM monitoring and evaluation framework it was principally focused on a monitoring process to allow regional NRM organisations to report on the impact of a Federal Government funding programme (in relation to: management action targets (MATs) and resource condition targets (RCTs) (NRC 2004). In the case of RCTs an assessment is made whether there has been a change as a result of 'point of investment' monitoring, that the regional organisations will report on overall resource condition and trends as part of 'surveillance' or 'ambient' monitoring in their State of Catchment Reports (NRMMC 2005). The NRM regions have some flexibility in that they can set and monitor those matters for resource condition targets (RCTs), and associated indicators, which are relevant to their particular circumstance. However, tracking progress towards RCTs where there are no obvious established thresholds or reference points would be seen as problematic, as in the case of the current NSW, State RCTs (NRC 2004): By 2015 there will be an improvement in soil condition. (Accessed 30 March 2010, http://www.nrc.nsw.gov.au/content/documents/Standard%20and%20targets%20-%20The%20Standard%20and%20targets.pdf)

The responsibility for data collection towards progress in the set resource condition targets at the regional level is through regional NRM organisations (56 across Australia), with the structure and protocols for soil monitoring having been derived by National Co-ordination Committees, and developed by State Government agencies (DECC 2009). In a recent evaluation of regional programs (NRMMC 2005) over 2004-05, 50% of the regional organisations were unable to report on soil condition as they had yet to set RCTs for soil condition (NRMMC 2005). In addition, ability to report on RCTs was low, with only 12 of the regional organisations (out of 56 across Australia) able to report progress towards their RCTs (NRMMC 2005).

However, the design and implementation of a monitoring program is often viewed by those undertaking it as an 'end in itself' rather than a 'means-to-ends'. Noss and Cooperrider (1998, p. 305) suggest:

> The root cause of most of these problems is that those doing the monitoring have not had a clear vision of what they wanted to achieve and why they were monitoring. Furthermore, they often had neither a real commitment to monitoring nor to using the information in decision making.

In the case of soil condition, the national indicators were limited to four: soil acidification, soil erosion by wind, soil erosion by water, and soil carbon content. At June 2005, across 38 NRM regions (out of 56 across Australia) there were 10 studies examining baseline, trend or condition studies for soil condition targets, and 229 sites had been monitored (NRMMC 2005). Hence, the indicators of choice for monitoring soil condition are attributes that can be: easily measured, improve soil productivity; or protect the soil. Often attributes that have intrinsic value; maintain function in ecosystems; and are difficult to measure are ignored as soil condition indicators. Often too the indicators chosen are not relevant to certain audience members, particularly landholders, and they should be tailored to meet the target audience, be accessible and the data produced by their use interpretable at the appropriate audience level (Lobry de Bruyn and Abbey 2003). This observation seems also to equally apply to site selection where there is often a bias towards the productive soil landscapes. In NSW, by May 2009, there were 850 sites monitored for baseline conditions (sheet and gully erosion, wind erosion, soil pH, soil organic carbon, soil structure, acid sulphate soil, where applicable), and 497 landholder surveys returned that were on site management and land management history according to the sampling and testing protocols developed by Department of Environment and Climate Change (DECC 2009; Gray *et al.* 2009).

Potential for landholder involvement in soil condition monitoring
At present the level and nature of soil condition monitoring by rural landholders is largely unknown, even though there are some good examples of farmer-led soil monitoring projects both in Australia (Healthy Soils for Sustainable Farms Programme, URL accessed 29 October 2009: http://lwa.gov.au/programs/healthy-soils-sustainable-farms), and overseas in developing (Stocking and Murnaghan 2001), and developed countries such as USA (Romig *et al.* 1996). Despite these efforts soil monitoring would not be considered a widespread landholder phenomenon. McKenzie *et al.* (2002) elaborated on the institutional, technical and social challenges of monitoring soil condition, under Australian conditions, especially at the national-scale and stated that community motivation to be involved in soil monitoring is considered to be lower than other aspects of the environment which have proven appeal (e.g. birds, weather and rivers). State government agencies provides technical support and guidance to CMAs through a soil monitoring sample kit - SoilWatch kit - which is specifically used for performance monitoring on local soil condition projects by examining control and intervention sites using undisturbed soil cores, photographs and GPS (Greg Chapman pers. comm.).

The NLWRA will facilitate co-ordination of regional data to report on the indicators developed under the national NRM monitoring and evaluation framework to ensure national consistency in data collection (Woodhead *et al.* 2004; NRMMC 2005). Hence, the opportunity to co-evolve a soil monitoring system with all audience members (Government, regional NRM organisations and their constituents, i.e. landholders) and reach consensus on the steps (goals, indicators, procedures, data custodianship and interpretation) in the monitoring process has not been considered. Despite the NRC (2004) and others touting the advantages of setting natural resource condition targets to the landholder it is difficult to see those benefits becoming realised, when soil condition monitoring is not a co-operative process, and indeed may be viewed with some suspicion by landholders when terms like “surveillance” monitoring are used by governments. It is questionable whether a ‘top-down’- derived model of soil monitoring in which government agencies in partnership with regional NRM organisations conduct the monitoring and are responsible for its outputs and outcomes will meet their targets if community support is not forthcoming. Even though, recent documents claim that “Developed Plans have required the involvement of all stakeholders to ensure accredited plans have community support” (NRMMC 2005).

Monitoring that is conceived and executed in a collaborative arrangement (Singleton 2001) or adaptive management framework (Holling 1978) has the potential to resolve several points of tension between different audiences for soil monitoring data. These tensions may lie in: monitoring design (objectives, structure and protocols); data collection procedures; data storage and retrieval mechanisms; and level of landholder input to, access to and ownership of data. Ultimately, these tensions arise from the inability of soil monitoring systems to assess and communicate soil condition data satisfactorily for all key audiences. Indeed, there is increasing recognition internationally of the need to design soil monitoring systems that can cope robustly with: organisational, technical and staff changes; multiple scales; asymmetry in the transaction costs of different decision-makers accessing monitoring data; and demands from multiple decision-makers, including government, to monitor a raft of soil functions (Singleton 2001; Loveland *et al.* 2002, Van-Camp *et al.* 2004). By engaging landholders at some point in the soil monitoring cycle there is an increased potential: to affect their trust in, and on-ground co-operation with efforts to manage soil resources across a catchment; to create interest in, and provide means to access their data for their own needs, and allow for meaningful output; and to re-assure them that confidentiality will be maintained when their data is used for public interests. Strategies for engaging landholders in soil monitoring include:

1. Inclusion and Integration – of all interest groups by recognising the importance of local knowledge, lived experience, land stewardship, and locally-derived solutions – and engaging these 'resources' in soil condition monitoring efforts. Such recognition, for instance, can help landholders to be 'part of' rather than 'apart from' processes and products intended to inform their management of the soil. Notably, the hurdle here includes tensions between scientists and practitioners over the 'rigour' and 'scientific merit' of soil data collected through joint monitoring procedures.
2. Enabling Processes – developing distinctive strategies and mechanisms to allow for active participation of key interest groups in soil asset condition monitoring such as the SoilWatch kit.
3. Creating Opportunities – for active learning and two-way interactions from past and proposed attempts at soil condition monitoring, and for meeting continuing needs to evaluate the impacts of monitoring systems on landholders' practices and adapt the design of these systems accordingly such as Property Management Planning or one-on-one property visits.
4. Simplify – the task and accept the need for adaptive management, rather than overwhelm interest groups immediately with the complexity, scale and urgency of the issues.
5. Responsive – to different needs of interest groups in a timely manner with information that can align advice and practice to appropriate scales, and be geographically referenced.

In the final analysis, a national soil monitoring scheme (one-size-fits-all approach) and the requirements of it may satisfy the information needs of policy makers and auditing requirements for funding at the national level, but in terms of motivating and generating lasting practice change at the local, and possibly, regional level it has yet to demonstrate its potential. To engage with landholders, in particular, there needs to be the opportunity within a national soil monitoring scheme to create discrete, purpose-built soil monitoring modules that may draw information from some of the same resources, but provide more immediate and relevant feedback at the local and regional level. Especially for landholders concerned about their farm management and what they can do to prevent the loss of soil condition. This is evident in the Western Australian Soil Quality web site that allows farmers to interact and interrogate their soil data, and others (http://www.soilquality.org.au/). In monitoring the condition of the soil resource land managers or landholders need to value soil as an 'end in itself' rather than solely as 'means-to-end', so that soil can continue to be nurtured, and provide for the livelihood of future generations.

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United States policy approaches for assessing soil health

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Abstract
There is worldwide recognition of the need for a more holistic vision of soil health and for the development of tools to guide soil conservation policy, management and restoration. To meet this need, United States (US) conservation programs in the US Food, Conservation, and Energy Act of 2008 (the farm bill), including the Conservation Stewardship Program (CSP) and the Environmental Quality Incentives Program (EQIP), have recognized soil quality in their efforts to promote soil conservation. The first soil quality assessment in CSP was based on the Soil Conditioning Index (SCI), a simple linear model used to predict trends in levels of soil organic matter (SOM). Other efforts mandated by Congress include the Conservation Effects Assessment Project (CEAP), which entails both watershed monitoring and process modeling efforts. While these intense efforts are resulting in environmental outcome estimates at large scales, for conservation on the ground, such intense efforts are not practical. Even the simple model, SCI has now been replaced by a practice-based tool in CSP. Initial validation efforts, comparing practice-based tools with measured soil data showed good representation of soil outcomes. Practice-based assessment tools, validated and calibrated using measured data, are practical, easy to use, well-accepted by producers, and representative of both conservation effort and outcome.

Key Words
Soil Quality; Soil Health; Practice-based Assessment; US Policy.

Introduction
To meet mandates in the current US farm bill for the Conservation Stewardship Program, a practice-based resource assessment tool, the 'Conservation Measurement Tool' (CMT) was developed. Although the original tool for this purpose, the SCI, is technically well-documented within Natural Resources Conservation Service (NRCS) for predicting soil carbon trend under a specific management and climate, many individuals and groups voiced concerns about the SCI's use. Frequently mentioned concerns involve low SCI scores for organic and specialty crop production systems or systems in warmer climates, despite strong conservation efforts. Additionally, while SOM is a primary measure of soil quality, it is not a complete measure of a soil's ability to provide ecosystem services or functions. To address key ecosystem functions and services of soil (i.e. soil quality) and improve equitable application of CSP, a Soil Quality (SQ) Eligibility Tool was developed, based on conservation practices applied. The new tool was combined with an existing water quality tool and called the Soil and Water Eligibility Tool (SWET). Initial efforts to validate the soil portion of the SWET compared the tool outcomes with SCI values and measured soil carbon. The 2008 farm bill stipulated the use of a "conservation measurement tool" to determine CSP eligibility. Therefore, the SWET was combined with practice-based tools for other resources to form the CMT. The ensuing tool combined multiple practice-based tools to estimate resource outcomes for eight concerns, including soil quality and soil erosion. Validation of the CMT is underway.

Methods
The SQ portion of the SWET was calibrated and validated exhaustively in comparison with the SCI. We compared SCI & SWET results from hundreds of hypothetical scenarios, with differing combinations of tillage, rotation, cover crops and amendments management, repeated in 10 representative states, each centrally located in one the 10 US Department of Agriculture, Economic Research Service climatic regions for the US.

The SWET was then validated in comparison with measured soil quality data for medium- and long-term research plots. Shown here are those from Iowa (IA) and California (CA), for organic and conservation tillage systems experiments. In each state, one organic systems experiment and one tillage comparison

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experiment was selected for use (Andrews *et al.* 2007a). Each system experiment differed by location, treatment, crop, replication number and plot size. We compared SWET outcomes for treatments at the experimental sites with multiple measured soil quality parameters. We also compared outcomes with other tools: the SCI and the Soil Management Assessment Framework (SMAF), a well-validated tool used by USDA-Agricultural Research Service to interpret measured soil parameters in terms of soil function (Andrews *et al.* 2002). Comparisons were made using JMP by SAS (Cary, NC) for ANOVA, t-tests, Student's t means comparisons tests and non-parametric ranking methods.

Current efforts to validate the entire CMT use data-mining programming techniques to develop a database of management practices and measured properties that represent resource concerns. This database is supporting meta-analysis of management practice effects on natural resource outcomes to summarize the data into overall effects. Computer science tools have developed rule sets for this analysis. Rule sets include development of key terms and protocols to transform or normalize the data for use in the meta-analysis and other comparative analyses. This technique is uniquely applicable to this validation because the CMT is to be applied across the US and will allow us to compare tool outcomes with a plethora of research results from around the US. Discrepancies between the NRCS tool outcomes and the statistical-rules we have developed will identify areas in need of more focused study or changes to the CMT. Other agency tools will likely benefit from this protocol for validation (e.g. EQIP ranking, RUSLE2 and SCI).

Results

Linear regression analysis of SWET and SCI outcomes for all management scenarios combined showed strong coefficients of determination (R^2), within each state (Figure 1 Only two states shown selected to maximize contrast: Tennessee, with warm, wet climate and weathered soils, and North Dakota, with cool, dry climate and deep, high SOM soils). Figure 1 again illustrates the strong influence of climate on tool outcome, and especially the determination of CSP eligibility using current SCI thresholds and those proposed for the SWET.

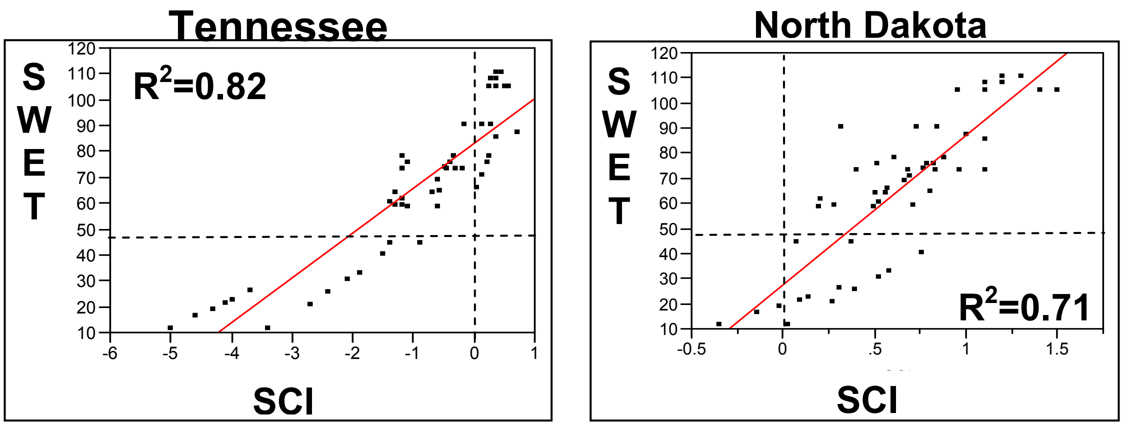

Figure 1. Comparison of SCI and SWET v.1 eligibility outcomes in states with highly contrasting climates and soils.

Although the hypothetical management scenarios were identical in each state, climatic differences inherent in SCI outcomes resulted in large differences in eligibility. In Figure 1, the vertical dotted lines show policy- and expert-determined cut-offs for eligibility using SCI (again for identical management scenarios under different climatic conditions). Horizontal dotted lines illustrate the approximate cut off for eligibility using SWET, which has no climatic component but was determined by expert opinion of effects of practices and to some extent practice interactions. For points in the upper right quadrant, both tools agree that system is eligible; for the lower left, both agree about ineligibility. For TN, many systems are ineligible using SCI but eligible with SWET (upper left quadrant); in ND, more systems are eligible using SCI than with SWET (lower right quadrant). Despite strong correlation between the tool outcomes within a given climate, eligibility is greatly affected by climate using SCI, due to model effects on decomposition and yield, while SWET considers only practices applied.

Table 3. a-d) Select soil properties and tool outcomes for the four experiments.* The measured parameters selected here include total organic carbon (TOC) for each experiment and the parameter with the highest correlation coefficient compared with the SMAF score: percent macroaggregates (Macroagg%); potentially mineralizable nitrogen (PMN); microbial biomass carbon (MBC); and bulk density (Db).

a. IA Organic Transition

Function / Indicator / Trt	C seq. TOC (g/kg)	Physical Macroagg (%)	Overall SQ SMAF	FB Tools SWET	SCI
C-S	24.9a	20.3b	78.3b	37 (fail)	-0.02 (fail)
C-S o/A	26.3a	21.7b	77.7b	69 pass	0.33 pass
C-S-o/A-A	26.1a	26.6a	81.6a	74 pass	0.35 pass

b. CA SAFS Organic, Low Input

Function / Indicator / Trt	C seq. TOC (g/kg)	Nutrient PMN (mg/kg)	Overall SQ SMAF	FB Tools SWET	SCI
Conv-2yr	9.6c	…..	92.6ab	9 (fail)	0.24 pass
Conv-4yr	9.9c	18.1b	90.8b	21 (fail)	-0.21 (fail)
Low-input	11.0b	21.5b	91.8ab	34 (fail)	-0.03 (fail)
Organic	12.0a	41.5a	94.7a	52 pass	0.21 pass

c. IA Tillage

Function / Indicator / Trt	C seq. TOC (g/kg)	Nutrient MBC (mg/kg)	Overall SQ SMAF	FB Tools SWET	SCI
CT	16.7b	273.1a	73.1a	21 (fail)	0.30 pass
MT	19.2a	325.0a	77.0a	51 pass	0.73 pass

d. CA Tillage & Cover Crops

Function / Indicator / Trt	C seq. TOC (g/kg)	Physical Db (g/cm^3)	Overall SQ SMAF	FB Tools SWET	SCI
CTno	5.4b	1.3a	71.9a	13 (fail)	-1.10 (fail)
CTcc	7.6ab	1.3a	72.8a	50 pass	-0.79 (fail)
RTno	5.9b	1.2b	75.5a	42 (fail)	0.16 pass
RTcc	10.4a	1.3a	75.0a	94 pass	0.51 pass

*different letters denote significantly different outcomes among system treatments.

Experimental plot results showed strong correlation between SWET & SCI at two of four experimental sites. At both IA experimental sites the SCI and SWET outcomes exhibited identical relative rankings for the treatments. SCI outcomes were relatively lower compared with SWET for both conventionally tilled (CT) systems at the CA Till and cover crop (cc) experiment. There was only a slight difference in overall relative ranking of the treatments by the two tools: SWET ranked reduced till (RT) slightly lower than CT with cover crop (CTcc), whereas SCI ranked RT much higher than CTcc. However, the largest differences were seen in the CA organic systems experiment. The conventional 2-yr (conv-2yr) tomato-wheat rotation was ranked higher than the other three systems by the SCI, presumably due to the presence of a high-residue crop, wheat, every other year. SWET ranked conv 2-yr lowest compared with the other three systems. The SMAF scores were only marginally correlated with the SWET and SCI outcomes.

When tool results were examined in relation to the measured parameters (Table 3), SWET outcomes were found to be more similar to soil TOC results than SCI in 3 of 4 experiments, using a simple ranking technique. In the fourth, the IA organic transition, where the SWET and TOC ranking was slightly different, the TOC results were not significantly different and, therefore, assigning different ranks may have been inappropriate. Nevertheless, for this experiment the SCI and TOC ranks were in agreement. Similarly, in this same experiment, IA ORG, there was less correlation between SMAF and its most representative single indicator and the two farm bill tools, than was seen in the other three. These results suggest that both tools, particularly the SCI, may benefit from additional calibration using data from experiments with organic amendments and cover crops. In general, however, these results indicate that SWET provides an adequate representation of soil quality outcome in the conditions tested (Andrews *et al*. 2007b).

Conclusions

Initial validation efforts show that practice-based tools can be as effective or in some cases more effective at predicting soil health outcomes than empirical models. Process-based models, like EPIC/APEX, used for Conservation Effects Assessment Project, may eventually replace the current practice-based tools. However, a user-friendly interface and validation of newly added practice subroutines will need to be accomplished first. In the meantime, well-validated, practice-based tools are the current 'standard of care' for the US Conservation Stewardship Program.

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Watershed-scale soil quality assessment: Assessing reasons for poor canopy development in corn

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Abstract
Soil quality assessment is a critical component in understanding the long-term effects of soil and crop management practices within agricultural watersheds. Additionally, simple, robust assessment methodologies are needed for policy planning and implementation. In the South Fork of the Iowa River Watershed, an aerial survey was conducted during the summer of 2006, and fields that were planted to corn and appeared to have sections with underdeveloped canopy were marked. Our objective was to determine if a soil quality assessment could suggest the reasons for the poor canopy development. Fifty-one marked fields were assessed in autumn of 2006. Four composite samples were taken at the 0-10 cm depth in each field, three from the dominant soil types in the field and the fourth from the area with poor canopy. Bulk density (BD), aggregate stability, texture, pH, extractable P, K, Ca, Mg, NO_3, Cu, Fe, Mn and Zn, electrical conductivity (EC), soil organic carbon (SOC), total N, microbial biomass C (MBC), potentially mineralizable C (C_{min})and N (N_{min}), and β-glucosidase (BG) activity were measured. The Soil Management Assessment Framework (SMAF) was used to assess soil quality. There was no single cause for poor canopy across in all fields. Overall, the SOC, MBC, C_{min}, N_{min}, and BG activity were lower in the areas with poor canopy development. SMAF indicator scores for carbon, which compensate for differing soil types, were significantly lower for the poor canopy areas. When the data means were analysed, SOC, MBC, BD and EC, as well as the soil quality index (SQI, mean of the 11 scored indicators) were significantly different between the normal and poor canopy areas. On a field to field basis, there were specific problems such as low SOC and other indications of poor nutrient cycling: low extractable P, high BD, and low water-filled pore space at time of sampling. When the fields were separated by slope position, most indicators and indicator scores were significantly lower in the poor canopy areas. Using SMAF to determine specific problems will help land managers develop management practices to ameliorate poor performing field areas. Policy makers can use information like this to assess overall effectiveness of management systems on ecosystem functions.

Key Words
Soil quality, SQI, β-glucosidase, carbon, pothole topography, maize.

Introduction
While the concept of a performance-based rating for soil is not new, it has most often been related to crop productivity. The soil quality concept has been broadened to include the soil's impact on the environment. It has been suggested that enhancing soil quality is critical for maintaining and improving water quality (Kennedy and Papendick 1995). There continues to be a number of soil quality issues in the United States, including continued high rates of erosion, reductions in soil fertility and production, and exposure to chemical and heavy metal pollution (Karlen and Stott 1994; Andrews *et al.* 2004). A robust method is needed for soil quality assessment to provide information on management impacts on soil functions for both landowners and policy makers. In 2003, the Conservation Effects Assessment Project (CEAP) was initiated to provide a scientific basis for a national assessment of conservation practices by the USDA Natural Resources Conservation Service (Richardson *et al.* 2008). Initially, the primary thrust of CEAP was to assess the impact of implementing conservation practices within agricultural watersheds on water quality. In 2006, a study was initiated to assess the effects of these same conservation practices on soil quality within the USDA Agricultural Research Service's (ARS) fourteen CEAP experimental watersheds. As part of this study, the soil quality of the Iowa River's South Fork Watershed consisting of about 78,000 ha (Tomer *et al.* 2008), was assessed.

For cropland, soil quality for a specific site can be affected by the interaction of many factors including climate, soil type, crop rotation, tillage, and other management factors. Assessment tools are needed to evaluate the impact of management systems on critical soil functions related to soil quality, including nutrient cycling and water partitioning. For CEAP, the tool selected to help assess impacts of management on soil was the Soil Management Assessment Framework (SMAF) (Andrews *et al.* 2004). The SMAF provides site-specific interpretations for soil quality indicator results, with the most recent version is available from us. The SMAF uses measured soil indicator data to assess management effects on soil functions using a three step process that includes indicator selection, indicator interpretation, and integration into an index (SQI). The SMAF uses soil taxonomy as a foundation for assessment, allowing for the modification of many of the scoring indicator values to be based on soil suborder characteristics. Currently, SMAF includes thirteen management-sensitive indicators with scoring curves consisting of interpretation algorithms. They are water stable aggregation (WAS), plant-available water holding capacity, water-filled pore space (WFPS), bulk density (BD), electrical conductivity (EC), pH, sodium adsorption ratio, extractable P and K, soil organic carbon (SOC), microbial biomass C (MBC), potentially mineralizable N (N_{min}), and β-glucosidase (BG) activity (Andrews *et al.* 2004; Stott *et al.* 2010; Wienhold *et al.* 2009).

There are two primary strategies have been suggested for assessing soil quality on a watershed scale : surveys or paired comparisons (Karlen *et al.* 2008). We used a combination of these two strategies. An aerial survey was conducted in late spring and field sections planted to corn that had poor canopy development compared to the rest of the field were noted. Two transects through the watershed were sampled and included the zones of deficiency. Our hypothesis was that a soil quality assessment of the fields, using the SMAF, would be able to characterize possible reasons for the deficient canopy development.

Materials and methods

Watershed characteristics

The landscape is dominated by the Clarion-Nicollet-Webster soil association, forming a sequence, respectively, of moderately well drained Typic Hapludolls, somewhat poorly drained Aquic Hapludolls, and poorly drained Typic Haplaquolls, with Harps soils (Typic Calciaquolls) occupying glacial potholes with Webster soils (Soil Survey Staff 2004). Most of the soils have a loam texture. About 85% of the watershed is under corn and soybean rotation, and 6% in grass (CRP) and pasture, mostly along riparian valleys in the lower watershed where cattle can then have free access to streams.

Soil sampling

In October 2006, soils were sampled in fields marked during the aerial survey. each of Three samples were taken in within the field under areas with normal canopy development, each sample was taken from a different, dominant soil map unit (SMU); a fourth sample was taken in the area that had poorly developed canopy. A sample consisted of a composite of 20 cores taken at the 0-10 cm depth in a transect across the SMU. The cores were sampled proportionately from the within and between row positions. Any surface residue was cleared from the sampling area so that all samples start at the soil surface. Samples were stored in zip lock plastic bags and transported back to the lab.

Samples were weighed for BD and water content determinations. A 10 g subsample was placed in an oven at 104 °C for 24 h to gravimetrically determine field water content. Soil was passed through an 8-mm sieve. A representative 150 g subsample was removed, placed in a plastic bag and stored at 4 °C for MBC determination. Another representative portion was hand sieved to pass a 2-mm sieve, air-dried and stored at 4°C until used for determining C_{min} and N_{min}. At least 25 g was set aside to air-dry and used for the WSA assay. The remainder of the sample was air-dried, ground to pass a 2-mm sieve, bagged and stored at 4 °C until use.

Soil assays

Water stable aggregation was determined using a 25 g air-dried, 8-mm sieved sample using a modified Yoder sieving machine, set to 30 strokes per minute for 5 minutes. Soil texture was determined using the hydrometer procedure. Using 20 g of air dry, 2 mm sieved soil, EC and pH were determined using a 1:2 soil-to-water ratio. Mehlich III extractable P, K, Ca, and Mg concentrations were determined using an inductively coupled plasma-atomic emission spectrograph (ICP-AES). KCl extracted NO_3-N, and DPTA extracted Cu, Fe, Mn, Zn were also determined using standard methods. Total soil C (TC) and total N were measured by dry combustion and inorganic carbon (SIC) was quantified (Sherrod *et al.* 2002). Soil organic C was calculated as the difference between TC and SIC. The MBC was measured with standard soil fumigation and chemical extractions (Tate *et al.* 1988). Organic C in fumigated and non-fumigated extracts will be determined and biomass C will be calculated using a correction factor (k = 0.33; Sparling and West 1988). An aerobic 28-day incubation method was used to determine C_{min} and N_{min}., with alkali basetraps used to absorb the CO_2. Aliquots of the base trap were acidified and the CO_2 concentration was measured using a gas chromatograph equipped with an autosampler and a thermal conductivity detector. Mineral N ($(NO_2+NO_3) + NH_4$) was determined colorimetrically using a flow injection system. β-glucosidase activity was determined by the method of Eivazi and Tabatabai (1988).

Soil management assessment framework

The soil measurements used to calculate the SQI were: BD, AGS, WFPS, pH, EC, extractable P and K, SOC, MBC, N_{min}, and BG activity. The data were scored and then used to compute the indices for each site (Andrews *et al.* 2004; Stott *et al.* 2010). To score the various indicators, knowledge of the soil taxonomic classification, texture, and general climate was required. Data were examined combined (*n*=203) as well as grouped by normal (*n*=150) vs. poor (*n*=50) canopy development. Data were also further grouped by landscape position. Using least significant difference (LSD, *P*=0.05) calculations, data from the individual fields were examined to explore possible reasons for the poor canopy development.

Results

When the data means were analysed, SOC, MBC, BD and EC, as well as the SQI (mean of the 11 scored indicators) were significantly different between the normal and poor canopy areas (Table 1). SMAF assessment takes into account differing soil taxonomic classes and textures. A score of 0.8 means that the soil indicator is at 80% of the optimum for that soil type. There was no single indicator that scored significantly less in the poor canopy areas as compared to normal canopy areas across all fifty fields. When considering landscape positions (Table 2), 52% of the normal and 18% of the poor canopy sections were on hilltop and sideslope positions, while 20 and 30% were in depression areas, respectively.

Table 1. Soil quality indicator measurements from fields sampled in the South Fork Watershed, Samples were taken from sections that had normal canopy development (*n*=153), and one from the section displaying poor canopy development during the growing season (*n*=50).

Soil Quality Indicator	Normal Canopy		Poor Canopy	
	Mean	S.D.	Mean	S.D.
Soil organic C (g/kg)	32.1	22.6	25.6	22.7
Microbial biomass C (mg/kg)	530	226	426	201
Total N (g/kg)	28.3	19.1	23.3	20.2
Nitrate N (mg/kg)	17.2	10.3	13.9	12.9
Mineralizable N (mg/kg)	50.7	15.7	46.3	19.1
β-Glucosidase (mg p-nitrophenol/kg)	153	49	132	43
Bulk Density (g/cm^3)	1.2	0.2	1.2	0.2
Water-filled Pore Space (%)	53.1	10.2	44.8	11.1
Wet Aggregate Stability (%)	88.4	3.3	87.9	3.3
pH	6.9	0.8	7.1	0.8
Electrical Conductivity (ds)	0.29	0.10	0.23	0.10

Table 2. Mean soil quality indicator scores, calculated using the Soil Management Assessment Framework (SMAF), as affected by slope position and canopy development in the South Fork Watershed.

Slope Position	Hilltop		Sideslope		Toeslope		Depression		
Canopy Development	Normal	Poor	Normal	Poor	Normal	Poor	Normal	Poor	LSD†
Indicator Score *n*=	31	15	61	5	18	4	43	26	
Total Organic C	0.69	0.44	0.75	0.71	0.68	0.50	0.76	0.47	0.02
Microbial Biomass C	0.94	0.89	0.95	0.93	0.92	0.85	0.95	0.90	0.01
Potentially Mineralizable N	0.97	0.98	1.00	0.91	0.97	0.98	0.99	1.00	0.01
β-Glucosidase Activity	0.20	0.14	0.25	0.19	0.18	0.12	0.15	0.17	0.01
Bulk Density	0.95	0.99	0.95	0.98	0.97	0.91	0.98	0.87	0.01
Water-filled Pore Space	0.92	0.81	0.94	0.91	0.92	0.87	0.91	0.89	0.01
Wet Aggregate Stability	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
pH	0.88	0.87	0.91	0.86	0.90	0.85	0.85	0.88	0.01
Electrical Conductivity	0.99	0.87	0.97	1.00	0.96	0.94	1.00	0.92	0.01
Extractable P	0.86	0.60	0.89	1.00	0.95	0.99	0.94	0.94	0.02
Extractable K	0.97	0.93	0.96	0.87	0.96	0.95	0.98	0.97	0.01
Standard SQI‡	0.85	0.78	0.87	0.85	0.86	0.81	0.87	0.82	0.04

†Least Significant Difference, *P*=0.05

‡The Soil Quality Index (SQI) is a simple mean of the 11 scored indicators.

In three of the landscape positions (hilltop, sideslope, and depression), the mean SQI scored significantly lower (LSD, *P*=0.05) in the areas of poor canopy development vs. the normal canopy areas. The fourth landscape position (toeslope) trended less, but did meet the statistical requirement. All indicator scores, except PMN, WAS, BD and pH, were lower in the poor canopy areas within a given slope position. Many fields had multiple indicators that were scored at least 10% (0.1) less in the poor vs. normal canopy areas. The 3 the soil organic matter indicators, SOC, MBC, and β-Glucosidase activity, scored at least 10% lower in 54% of the poor canopy areas, while 22% of the fields showed no differences between the poor and normal canopy areas. Seventy percent of the fields had at least one soil fertility indicator (P, K, or N_{min}), that scored 10% lower in the poor canopy areas, and 78% of the fields had one or both of the soil chemical reaction indicators (pH, EC) that scored 10% less.

Conclusion

SMAF was able to pinpoint specific problems in fields where canopy development was poor. Using SMAF to determine specific problems will help land managers develop management schemes ameliorate the poor performing areas of the fields. Policy makers can use information like this, on a watershed basis to assess overall effectiveness of management systems on soil ecosystem functions.

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