CHAPTER 6: ENVIRONMENTAL BENEFITS OF FARMLAND: PERFORMANCE MEASURES

Agriculture and the environment are inextricably linked. Each depends upon the other for its preservation. The practice of agriculture requires making use of the natural landscape and, in return, the integrity of that land is maintained as open space. This symbiotic relationship has existed for hundreds of years. However, inappropriate use of land can create significant environmental problems. Overgrazing, for example, can lead to severely degraded soil, and the unnecessary use of fertilizers and pesticides may result in polluted soil and groundwater. Agricultural productivity is inevitably lowered, often leading to lower revenue. The U.S. government has chosen farm subsidies as an economic remedy to this cycle. Yet data from several sources has suggested that the employment of subsidies that are not attached to conservation practices has only exacerbated the situation.

The employment of sound agricultural management practices carries the greatest potential to produce environmental benefits. Examples include the conservation of rural landscapes, the propagation of plant and animal biodiversity, and the maintenance of vital ecosystems. Therefore, a change in the US government's subsidization program seems necessary to reallocate public subsidies based on farmland production of food, or lack thereof, to the environmental benefits of farmland on the agricultural landscape. A system of quantifiable measurements will be needed in order to assess such benefits. These measurements will indicate whether the employment of sound conservation practices benefit the environment, and agriculture. The following synopsis identifies the existing models that are used to determine this issue.

Heinz Model

The Heinz Center has defined farmland as including not only fields, orchards, pastures, and vineyards, but also hedgerows, streams, ponds, wetlands, prairies, and woodlots ("Indicators of the Condition and Use of Farmlands," available online at www.heinzctr.org/ecosystems/farm/index.shtml). Within this framework, the Center has delineated eighteen (18) separate indicators, categorized into four (4) groups, to describe the environmental condition and use of farmlands in the US. Each indicator is phrased in the form of a question, and followed parenthetically with information dealing with the indicator).

The first category, SYSTEM DIMENSIONS, looks at the size, extent, and scope of the farming operation itself. These indicators include: 1) How much land is used directly for production of crops and livestock? (cropland acreage has declined since the 1950s, but because official estimates vary, it is difficult to determine exactly how much farmland has been converted to other uses); 2) How much of the farmland landscape is forest, grassland or shrubland, wetlands, or developed land? (some non-cropland areas provide wildlife habitat or serve as streamside buffers or windbreaks, and all add to the visual character of the farmland landscape); 3) How intermingled are croplands and urban and suburban development? (increased development in farming areas can interfere with traditional farming practices and may make farming economically unviable); and 4) How much of the "natural" area in farmlands is in patches of different shapes? (the size and shape of these "natural" patches help determine the ecological services they provide).

The second category, CHEMICAL AND PHYSICAL CONDITION, examines the conditions of farmland surface and groundwater, and the state of the soil. These indicators include: 1) How much nitrate is there in farmland streams and groundwater? (high levels of nitrate in drinking water, especially untreated well water, are a human health concern); 2) How much phosphorous is there in farmland streams? (about three-fourths of farmland stream sites had phosphorous concentrations that exceeded the level recommended by the EPA); 3) How many pesticides are found in farmland streams and groundwater, and how often do they exceed federal standards and guidelines? (83% of monitored streams in farmland areas had at least one pesticide whose concentration exceeded aquatic life guidelines); 4) How much organic matter is there in cropland soils? (organic matter improves the ability of soils to hold water, provides nutrients for crops, reduces erosion, and can help to support soil microorganisms); 5) How much cropland is subject to erosion by wind or water?; 6) How much cropland soil has salt levels? (high-salinity soils, which typically result from irrigation in arid climates, can reduce the ability of soils to support plant growth).

The third category, BIOLOGICAL COMPONENTS, looks at the biological condition of farmlands. These indicators include: 1) What is the condition of the microscopic animal communities in cropland soils? (the condition of nematodes (roundworms) in the soil is a good indicator of overall soil condition); 2) What is the condition of wildlife in areas that are heavily dominated by farmlands?; 3) In areas that are heavily dominated by croplands, is most of the remaining non-cropland vegetation native or non-native? (non-native vegetation often provides less suitable wildlife habitat); 4) What is the quality of the habitat in streams in farmland regions? (stream habitat quality often reflects the effects of activities, including farming practices, in the watershed).

And the final category, HUMAN USE, analyzes aspects of production and other human uses of farmland. These indicators include: 1) How has the per-acre yield of major crops changed over time?; 2) How have farm output and the inputs (pesticides, fertilizers, labor, land, etc.) needed to produce that output changed over time?; 3) What is the value of the nation's production of crops and livestock?; 4) How much recreation takes place on farmland? (a considerable amount of recreation takes place on farmlands (hunting and fishing, for example) and some farmers depend on income from such activities).

ATTRA Model

Another model with which researchers might examine the environmental benefits of farming is presented by the ATTRA Group ("Protecting Riparian Areas: Farmland Management Strategies" Barbara C. Bellows, NCAT Ag Specialist, available online at www.attra.ncat.org/attra-pub/PDF/riparian.pdf). It is the contention of this organization that one of the best ways to determine the extent to which a plot of farmland benefits the environment is by examining the health of its water - and stream - systems. In conducting such an examination, a close scrutiny of the riparian areas provides the best evidence of a stream's health. The model divides its twenty-five (25) indicators into four (4) categories. The parenthetical information following the indicators represents the qualities that would ideally appear in a riparian area (specifically for that indicator).

The first category, VEGETATION INDICATORS, looks to the variety, coverage, diversity, and health of plants in farmland riparian areas. These indicators include: 1) Environmental function of plants (effective water infiltration, effective capture of sediments, structural support of streambanks, reduces stream velocity during floods, shade for reducing water loss and moderating temperatures, habitat for wildlife, birds, and aquatic species); 2) Plant species diversity (predominately native, water-loving riparian vegetation, combination of sedges, rushes, grasses, herbaceous plants, shrubs, and trees); 3) Diversity of plant ages (both young and mature trees and shrubs are present); 4) Plant vigor and reproduction (healthy plant growth and reproduction, plant growth exceeds 80% of potential production); 5) Palatable vegetation (diversity of plant species and plant ages provides palatable vegetation throughout the growing season, trees have an open or park-like appearance); 6) Plant and litter cover (full vegetation coverage throughout the year, litter layer present particularly during winter and spring, provides woody debris that serves as shelter for fish and habitat for aquatic insects); 7) Plant litter movement and plant lodging (uniform distribution of litter, plants remain standing following heavy rainfalls or snowmelts); 8) Width of riparian area (riparian vegetation at least two channel widths on each side of stream).

The second category, SOIL INDICATORS, examines the extent of organic matter, quality of topsoil, and vegetation cover. These indicators include: 1) Organic matter (soil covered by growing plants and plant residues throughout the year, organic matter has accumulated in the soil profile, high soil biological activity, topsoils are deep, soils are well aggregated); 2) Diverse microbial community structure (organic matter decomposes rapidly, effective loss of nitrogen through dentrification, good soil aggregation by microbial slimes); 3) Minimal compaction (soil is soft with high organic matter content, good water infiltration, good soil aggregation, healthy plant growth); 4) Good infiltration (vegetation coverage over the soil surface, good soil aggregation, relatively thick topsoil); 5) Limited runoff (good water infiltration, deep topsoil with good water holding capacity, high amount of organic matter in soil and good soil aggregation); 6) Limited erosion (complete vegetation cover over the soil surface, no indication of soil movement, stream is not muddied by runoff water).

The third category, STREAMBANK AND CHANNEL INDICATORS, looks at water tables, channelization, and streambank elevation. These indicators include: 1) Streambank stability (banks are at elevation of active flood plain, little or no streambank erosion, many strong, fine roots hold streambank in place); 2) Stream channel shape (channel is relatively narrow, banks are relatively straight with deep undercut that provides shade for aquatic species, stream has pools and meanders); 3) Frequency of riffles (relatively frequent occurrence of riffles, distance between riffles is no more than 7 times the measurement of the width of the stream); 4) Riparian water table (water table remains high and stable throughout the year, water loving vegetation predominates, riparian area provides an interface between wet and dry environments); 5) Channel alteration (stream has not been subject to channelization, stream alteration, or dredging).

The final category, INDICATORS OF AQUATIC AND RIPARIAN WILDLIFE, analyzes sedimentation, bird species, and water characteristics. These indicators include: 1) Water quality and quantity (adequate water supply and quantity throughout the year, presence of macroinvertebrate indicators of good water quality such as caddis flies and mayflies, water contains few contaminants such as pesticides, heavy metals, or excess nutrients); 2) Water temperature (streamside vegetation cools streams, undercut streambanks provide shade, presence of aquatic species used for fish food); 3) Stream pools (numerous both deep and shallow stream pools, woody debris present to form pools, complex channel structures); 4) Sediment load (low amount of sediments in streams, water is clear of tea colored); 5) Nutrient and pathogen concentration (natural concentrations of nutrients and pathogens from wildlife in area, little or no evidence of livestock access to streams); 6) Waterfowl habitat (native plant communities are dominant vegetation, land use delayed until chicks have left the nest, land is rested for several years to allow for homing, larger clutches, and earlier nesting, sufficient blocks of land are protected to provide corridors of movement and foraging).

NRCS Model

The Natural Resources Conservation Service (NRCS) has a number of working models to measure the environmental benefits of farmland to the natural landscape. Their "Action Plan on Providing Ecosystem-Based Assistance to the Management of Natural Resources" provides the best means for gauging the environmental aspects of farmland (available online at www.nrcs.gov/technical/ECS/agecol/eireport.pdf). It is a model broken into four (4) categories that implicate eleven (11) broad ranging indicators. The indicators are presented in the form of a question, followed by helpful information related to the indicator itself.

The first category, SYSTEM PROCESSES, examines the system-sustaining, ecological processes of farmland. These indicators include: 1) Are precipitation and ground water resources captured, stored, used, and released in a safe and stable manner? (hydrologic cycle, soil stability, soil infiltration rates, and vegetation cover); 2) Are kinds and flows of chemicals (minerals, nutrients, other) and energy in balance and optimized for plant and animal communities and biomass production requirements? (nutrient cycling, crop/biomass production/decomposition rates, atmospheric transport, energy flow, trophic accumulation); 3) Are annual cash flows, technical assistance and conservation incentives timely and adequate for desired community and landuser incomes? (financial viability, government/industry programs).

The second category, RECOVERY PROCESSES, considers ecosystem structure and the functioning of ecological and human community processes that determine system resistance and resilience to disturbance or stress. These indicators include: 1) Are soil, water, air, plant and animal resources, and biophysical processes in place and in a condition to allow timely and full recovery from stresses and disturbances, and to meet management objectives? (trophic diversity, niche diversity, soil potential/resiliency, disturbance regime, competition, gene pool quality/quantity, contaminant buffering, predator-prey relationships); 2) Are social and economic systems available to allow land-users, and communities and the resources they manage, to recover from environmental and socioeconomic stresses? (social safety nets); 3) Are there human and animal resource health concerns associated with the management of present or planned enterprises? (health problems and treatment).

The third category, LANDSCAPE AND COMMUNITY STRUCTURE, examines plant and animal species composition and human, cultural, social, and economic diversity. These indicators include: 1) Do landscape features and patterns facilitate use, protection, and optimization of ecosystem processes? (diversity, connectivity, land cover, community dynamics, patterns); 2) Do commodity markets, investment capital, and public programs encourage landuses, enterprises, and resource management that are compatible with ecosystem processes? (economic diversity); 3) Are decision-making processes available to communities and individuals to resolve conflicts regarding current and desired uses, management and protection of natural resources? (institutional incentives/constraints, ownership); 4) Does the social infrastructure (health care, education, multi-culture recognition, etc.) support and promote the desired quality of life for the communities and individuals? (infrastructure, cultural diversity, demographics).

Finally, the fourth category, ABIOTIC FEATURES, looks to the abiotic or physical characteristics of the farmland ecosystem. The sole indicator examines: 1) Are current and planned landuses and desired future conditions suited to the abiotic conditions (e.g. stream temperature, flow velocities, riffle/pool ratios, riparian shading, climate, topography, soils, and geology? (topography, soil types/potentials, geology, land uses, water quality/quantity, physical habitat, channel morphology).

Schenck & Vickerman Model

Rita Schenck (Institute for Environmental Research and Education) and Sara Vickerman (Defenders of Wildlife) have proposed a twelve (12) point list of biodiversity indicators that should be identified when considering the environmental benefits of farmland. The indicators are followed again with information pertinent to the indicators themselves.

The indicators are as follows: 1) Protection of priority habitats/species (the acreage of habitat that is physically protected (i.e. through fencing or other methods)); 2) Soil characteristics and soil health (the concentration of organic carbon in the soil); 3) Proximity to and protection of high priority vegetative communities (acreage of habitat set aside (not farmed) that is identified as "high priority."); 4) Interface between water and terrestrial habitats/buffer zones (total linear space of aquatic habitat (i.e. river, lakeshore, etc.) protected via physical means vs. total area managed); 5) Assimilative capacity of water and land and hydrologic function (depletion of water resources - annual use versus recharge rate); 6) Percent coverage of invasive species within protected area (for physically protected areas, density of non-native vegetation - area percentage); 7) Road density (miles of road per square mile); 8) Percent native-dominated vegetation (acreage in native species dominated areas/total area managed); 9) Restoration of native vegetation (acreage newly returned - in last 12 months - to native habitat); 10) Adoption of BMP's linked to biodiversity objectives (number of BMP's adopted); 11) Distribution (patchiness, evenness, etc.) - (size of native-managed acres vs. total acres managed, and size of native-managed acres vs. average field size); 12) Connectivity of native habitat (on managed acres - percent of native-managed land units that has at least one adjacency to other native-managed land).

USDA Model I

Of further interest is the "Pasture Condition Score List" produced by the USDA , which involves the visual evaluation of ten (10) indicators to rate pasture condition (available online: ftp://ftp-fc.sc.egov.usda.gov/GLTI/technical/publications/pasture-score-guide.pdf). The USDA has discovered through use of this model that poor plant growth, weedy species invasion, poor animal performance, visible soil loss, increased runoff, and impaired water quality are causes of concern to the environment. Thus, it has estimated that the higher the indicator scores (in ranking how a farm does with that indicator), the better off the overall environment will be.

These indicators include: 1) Percentage of desirable plants (determines if the pasture has the kind of plants that the livestock on it will graze readily); 2) Plant cover (percentage of soil surface covered by plants is important for pasture production, and soil and water protection); 3) Plant diversity (number of different forage plants that are well represented in a pasture); 4) Plant residue (plants in various states of decay provides additional surface cover and organic matter to the soil); 5) Plant vigor (if plant growth conditions suffer, bare soil will begin to appear); 6) Soil fertility; 7) Severity of use (close, frequent grazing (mown lawn appearance) often causes loss of vigor reducing yields and ground cover); 8) Site adaptation of desired species; 9) Climate stresses (extremely wet, hot, dry, or cold weather may threaten plant vigor even when climatically adapted forage species are present); 10) Soil pH levels, and insect and disease pressure (the former influences plant vigor primarily through its effect on nutrient availability and the latter damages the leaves, stems, and roots of farmland plants).

USDA Model II

The USDA has also produced "Interpreting Indicators of Rangeland Health," (available online:ftp://ftp-fc.sc.egov.usda.gov/GLTI/technical/publications/range-health-indicate.pdf), a collaboration between the BLM, NRCS, ARS, and USGS that provides a model to evaluate the soil/site stability, hydrologic functioning, and the integrity of the biotic community on rangelands. This model presents seventeen (17) indicators used to assess the environmental impact farmland has on the natural landscape.

These indicators include: 1) Rills (rills are small erosional rivulets that result from the interaction between raindrops, overland flow, and the characteristics of the soil surface; 2) Water flow patterns (these patterns are the path that water takes - i.e. accumulates - as it moves across the soil surface during overland flow); 3) Pedestals and/or Terracettes (these are important indicators of the movement of soil by water and/or by wind); 4) Bare ground (bare ground is exposed to mineral or organic soil that is susceptible to raindrop splash erosion, the initial form of most water-related erosion); 5) Gullies (a channel that has been cut into the soil by moving water); 6) Wind-scoured, blowouts, and/or deposition areas (accelerated wind erosion on an otherwise stable soil increases as the surface crust is worn by disturbance or abrasion); 7) Litter movement (the degree and amount of litter - i.e. dead plant material that is in contact with the soil surface. Movement, or redistribution, is an indicator of the degree of wind and/or water erosion); 8) Soil surface resistance to erosion (assesses the resistance of the surface of the soil to erosion); 9) Soil surface loss or degradation (loss or degradation of part or all of the soil surface layer, or horizon, is an indicator of a loss in site potential); 10) Plant community composition and distribution relative to infiltration and runoff (vegetation growth form is an important determinant of infiltration rate and interrill erosion); 11) Compaction layer (a near surface layer of dense soil caused by the repeated impact on or disturbance of the soil surface); 12) Functional/Structural groups (this indicator addresses the various roles that different species fulfill in energy flow and nutrient cycles); 13) Plant mortality/Decadence (the proportion of dead or decadent - moribund or dying - to young or mature plants in the community relative to that expected for the site, under normal disturbance regimes, is an indicator of the population dynamics of the stand); 14) Litter amount (litter in any dead plant material that is in contact with the soil surface); 15) Annual production (above-ground biomass - annual production - is an indicator of the energy captured by plants and its availability for secondary consumers in an ecosystem given current weather conditions); 16) Invasive plants (this indicator deals with plants that are invasive to the area of interest); 17) Reproductive capability of perennial plants.

OECD Model

In 2001, the OECD convened a meeting of international experts to develop indicators of agri-biodiversity as part of a wider project to develop agri-environmental indicators. (The proceedings of this meeting are available in OECD, (2003), *Agriculture and Biodiversity: Developing Indicators for Policy Analysis*, Proceedings From an OECD Expert Meeting, Zurich, Switzerland, November 2001, 278 pp, esp. p. 38. Available online at http://www1.oecd.org/agr/biodiversity/index.htm; The complete list of OECD Agri-environmental indicators is available in OECD, (2001), *Environmental Indicators for Agriculture Volume 3: Methods and Results*, Paris, France, 416 pp). Both sets of indicators are relevant when considering the environmental benefits of farmland. Though general, the OECD's agri-environmental indicators are very useful for assessing the holistic approach that is reflected in some of the more specific models above. Agri-environmental indicators are classified into 4 major categories and several sub-categories of each as follows:

I. AGRICULTURE IN THE BROADER ECONOMIC SOCIAL AND ENVIRONMENTAL CONTEXT:

1. Contextual Information and Indicators.
    - Agricultural GDP
    - Agricultural output
    - Farm employment
    - Farmer age/gender distribution
    - Farmer education
    - Number of farms
    - Agricultural supports
    - Land use
        - Stock of agricultural land
        - Change in agricultural land
        - Agricultural land use

6. Farm Financial Resources.
    - Farm income
    - Agri-environmental expenditure
        - Public and private agri-environmental expenditure
        - Expenditure on agri-environmental

II. FARM MANAGEMENT AND THE ENVIRONMENT:

1. Farm Management
    - Whole farm management
        - Environmental whole farm management plans
        - Organic farming
    - Nutrient management
        - Nutrient management plans
        - Soil tests
    - Pest management
        - Use of non-chemical pest control
        - Use of integrated pest management
    - Soil and land management
        - Soil cover
        - Land management practices
    - Irrigation and water management
        - Irrigation technology

III. USE OF FARM INPUTS AND NATURAL RESOURCES:

1. Nutrient Use
    - Nitrogen use
    - Nitrogen efficiency
2. Pesticide Use and Risks
    - Pesticide use
    - Pesticide risk

3. Water Use
    - Water use intensity
    - Water use efficiency
        - Water use technical efficiency
        - Water use economic efficiency
    - Water stress

IV. ENVIRONMENTAL IMPACTS OF AGRICULTURE:

1. Soil Quality
    - Risk of soil erosion by water
    - Risk of soil erosion by wind
2. Water Quality
    - Water quality risk indicator
    - Water quality state indicator
3. Land Conservation
    - Water retaining capacity
    - Off-farm sediment flow (soil retaining capacity)
4. Greenhouse Gases
    - Gross agricultural greenhouse gas
5. Biodiversity
    - Genetic diversity
    - Species diversity
        - Wild species
        - Non-native species
    - Eco-system diversity
6. Wildlife Habitats
    - Intensively-farmed agricultural habitats
    - Semi-natural agricultural habitats
    - Uncultivated natural habitats
    - Habitat matrix
7. Landscape
    - Structure of landscapes
        - Environmental features and land use patterns
        - Man-made objects (cultural features)
    - Landscape management
    - Landscape costs and benefits

The indicators of agri-biodiversity are more specific, yet remain flexible, common and transparent. They form part of an integrated Agri-Biodiversity Indicator Framework (ABF) that the OECD recommends could be adopted by both member and non-member countries. There are 4 main groups of indicators within the ABF: (1) Agricultural Genetic Resources; (2) Habitat Quantity; (3) Habitat Quality; and (4) Habitat Quantity and Quality, and the overall loss (gain) of biodiversity. These categories contain their own indicators as follows:

(1) *Indicators of Agricultural Crop and Livestock Genetic Resources*

(i) Total number of crop varieties/livestock breeds for the main crop/livestock categories (e.g. wheat, rice, cattle, pigs) that have been registered and certified for marketing, including native and non-native species and landraces.

(ii) Share of crop varieties in total production of individual crops (e.g. wheat, rice)

(iii) Share of livestock breeds in total livestock numbers for respective categories of livestock ((e.g. cattle, pigs, poultry, sheep).

(iv) Number and share of national crop varieties/livestock breeds used in agricultural production that are endangered.

(v) Number of available species and accessions (samples) conserved *in situ* and *ex situ* in national programs.

(2) *Indicators of Habitat Quantity*

(i) The current area and share (stock) of different habitat types across all agricultural land, including intensively or extensively farmed land (e.g., arable crops, rangeland, rice paddies), semi-natural areas (e.g. certain grasslands, heather moorland) and uncultivated land (e.g, fallow, areas of remnant native vegetation, ponds).

(ii) Changes in the area and shares of habitats (flows) both within agriculture (e.g. less arable land, more pasture) and between different land uses (e.g. from agricultural use to forestry or change from wetlands to agricultural use).

(3) *Indicators of Habitat Quality*

(i) Habitat Structure Indicator (Trends in the quality and quantity of habitat features and their spatial composition across agricultural land), e.g. extent of alpine meadows, area of field margins, area and fragmentation of remnant native vegetation patches on agricultural land, patch size and patch mosaic, fragmentation of habitats, linear features and networks. More detail is needed to refine indicators for:

- ***patch size*** **–** size of habitat patches, may be important for some species;
- ***fragmentation*** **–** extent to which a given habitat type is divided into several patches;
- ***linear features and networks*** **–** e.g. the length, age quality, and connectivity of hedges;
- ***vertical structures*** **–** habitat structures in terms of vertical layers (e.g, bushes and trees) which are especially important to bird and invertebrate communities;
- ***mosaic*** of different habitats in an agro-ecosystem, e.g. habitat diversity, location, juxtaposition and heterogeneity of land cover, and linkages to indicators of agricultural landscapes in countries where this is important.

(ii) Habitat Management Indicator (Trends in farm management practices and systems which affect biodiversity), e.g. timing of grass cutting, nutrient and pesticide management, stocking densities, integrated land management systems, area of organic farming.

(iii) Wild Species Indicator (Tends in the abundance (i.e. the number), richness (i.e. the diversity) and ecologically indicative value (i.e. species associated with specific habitats such as prairie grazing land) of wild species using agricultural habitats or affected by farming activities. This indicator is based on:

- a minimum set of wild species collectively representing a wide range of habitat types across agricultural land;
- a range of wild species that require different types of agricultural land and from various species groups (e.g. birds, mammals, arthropods, plants, etc.);
- rare, endangered, or widespread species;
- selecting wild species relevant to policy issues at different scales from the local to global level.

(4) *Indicators Linking Habitat Quantity to Quality*

(i) Habitat Species Matrix: Changes in the area and management of all agricultural habitat types and the identification, explicitly (i.e. direct observations) or implicitly (i.e. indirect information such as expert knowledge), of the impact of these changes on wild species (flora and fauna).

(ii) Natural Capital Index: The product of the *quantity* of agricultural habitat types and their *quality* in terms of wild species abundance, richness, habitat structure and management, measured between the current state of the agro-ecosystem and a baseline state.

These last two indicators, Habitat Species Matrix and Natural Capital Index, allow the effects and changes in agriculture on biodiversity to be summarized more succinctly, and provide the possibility to project the implications for wild species related to future changes in agricultural land use and cover.

The types of modeling described above helps in understanding the environmental benefits that farmland can potentially provide to its surroundings. In the case of water quality, properly managed farm and rangeland can reduce soil erosion and runoff, which in turn results in lower levels of nutrients, sediments, and pesticides entering water bodies. This changes the biological conditions of the water and directly affects what users of the water body value. For example, fishermen could benefit from larger fish populations, and boaters, swimmers, and non-contact recreationists benefit from clearer, more aesthetically appealing water. The relationship is similar in the case of wildlife - establishing grassland or forest cover creates suitable habitat for birds, small game, and large game. Along with improvements in water quality, this increases wildlife populations, and hunters and wildlife viewers alike will then benefit from these results. In the end, the key question is how well practical measures implemented by farmers match the environmental goals set by society. These decisions are influenced by the latest information on protective measures, and by the economics of these measures with respect to the farmers' individual holdings. Therefore, any model through which we might gain insight into the reasons for, or indications of, environmentally sound farmland will ultimately benefit us all.

Additional Literature

DEFRA, (2002), Using Economic Instruments to Address the Environmental Impacts on Agriculture. Available online at
http://www.defra.gov.uk/farm/sustain/newstrategy/econ/section2.pdf

Executive summary:

1. The publication of the Strategy for Sustainable Food and Farming provides an opportunity to take stock and discuss the best way to approach addressing the

environmental impacts of agriculture. 2. Many environmental issues arise because their costs or benefits are incurred by society as a whole rather than by the person creating them. For example, when pollution costs are not taken into account by those causing the pollution, because the costs are borne by others, then the market does not function efficiently. And the same is true when private business activity creates public benefits (e.g. through stewardship of the countryside) which are not fully rewarded in the market place. There may then be a case for Government intervention to improve the working of the market, and raise the efficiency of the economy and to deliver better environmental outcomes. There may also be a need to intervene to improve environmental outcomes in order to meet international obligations, for example under EC Directives and international agreements. 3. The effects of agriculture on the environment are significant and complex, with both positive and negative impacts operating at local, regional, national and global levels. Positive environmental impacts include: providing a 'carbon sink'; supporting and maintaining diverse and attractive landscapes with historic features; and providing a complex range of habitats and food sources for farmland wildlife. Major negative impacts include: greenhouse gas emissions (carbon dioxide, methane and nitrous oxide); soil erosion; water pollution; and adverse impacts on biodiversity. Estimates of the economic value of these impacts are necessarily broad brush and imprecise and studies to assess these impacts have used different methodologies. Three recent studies conclude that there are very large negative impacts (estimated in the range £1 billion to £11⁄2 billion for the UK). Research studies also show very large environmental and landscape benefits (estimated in the range £0.6 billion to £0.9 billion for the UK). Of course, other types of land use will also generate environmental impacts (both positive and negative). 4. In the case of agriculture, production subsidies have had a strong influence on agricultural practices and hence on environmental outcomes. Removal of these subsidies will help considerably, overall, to reduce pollution (although with some risks of reducing stewardship benefits in some locations). This document does not deal in any detail with reform of production subsidies, but focuses on policy instruments that can be used for specific environmental purposes. 5. The best mechanism for informing a decision on whether or not to take action – and the type and extent of any action – should be to assess costs and benefits wherever it is practicable. The 'best' instrument or package of instruments will have the highest environmental benefits for the lowest cost of implementation and compliance, although it will also be necessary to take into account possible wider economic impacts (e.g. on competitiveness) and social impacts, including the distributional effects upon farm incomes and other stakeholders. 6. The forms of intervention available include: facilitating change by providing information (e.g. offering free advice, running awareness-raising campaigns); encouraging voluntary action (e.g. supporting industry-led environmental initiatives); incentivising change using economic instruments (e.g. taxes, subsidies, tradable permits, tendering systems); and requiring change using regulatory instruments (e.g. limits on emissions, technology standards). 7. The most appropriate form of intervention depends upon a number of factors, but will be determined in part by the type of market failure. Where an adverse environmental impact results from the effects of production subsidies, then policy reform which removes (or “de-couples”) these subsidies represents the most obvious means of addressing the problem. Where there is an information failure, then providing advice, education or training services or running awareness-raising campaigns can help to reduce negative environmental impacts and increase provision of positive environmental impacts. Where there are negative environmental impacts, voluntary instruments (such as farm assurance schemes), regulation, taxes, charges, tradable permit schemes, or some combination of these, might be appropriate, according to the particular situation. 8. Subsidies (including agri-environment payments, grants for capital investment, tax breaks) can be used to address negative environmental impacts. The Polluter Pays Principle creates a presumption against using subsidies in this way, but there may be cases in which they offer the best solution to a problem particularly when the distributional effects upon farm incomes, and other stakeholders are taken into consideration. Subsidy is more appropriate where positive environmental impacts are being provided (the “Provider Gets” principle). They may be paid direct to farmers or via someone else (e.g. a conservation organisation). However, there are limits to what is affordable; and on what is permissible under EC State Aid rules. There may be other ways in which the market could be encouraged to deliver, such as through labelling, farm assurance or other voluntary schemes. 9. Economic instruments will generally be more advantageous for farmers than regulations. Regulations generally impose the same standards on all producers, regardless of how expensive it is for individual producers to change their environmental performance. Economic instruments allow those with high clean up costs to make smaller changes in their behaviour and incentivise those with low clean up costs to make relatively major changes. This means that economic instruments can sometimes achieve the same environmental benefits as regulation but at a lower cost to the economy and to the industry concerned. 10. No instrument is likely to perform better than alternative options in all respects and there will be trade-offs between the use of different instruments, reflecting their relative strengths and weaknesses. Frequently a single instrument does not operate in isolation. Combinations of different types of instrument work alongside each other to achieve a desired environmental outcome. This may be because, for example, there is more than one type of market failure; there is a need to take distributional consequences into account; or because it is necessary to encourage a transition from the current position to the optimum outcome, recognising that this will involve transition costs for those involved. A combination of regulatory and economic incentives, comprising both payments and taxes, may therefore provide an effective means of addressing the mix of positive and negative environmental impacts which arise from agriculture. 11. A review of policies in other OECD countries shows that only environmental subsidies or payments have been widely adopted. While all OECD countries have introduced some form of environmental payments, only a handful have introduced charges and none has chosen to apply tradable permits on any significant scale. 12. There is a need to look across a broader range of policy instruments – information, voluntary, economic and regulatory – and seek cost-effective options or packages of measures. In particular, it would be useful to assess the scope for using economic instruments

to address the environmental impacts of agriculture, as these can allow more flexibility for farmers, resulting in lower compliance costs.

Economics for the Environment Consultancy (eftec) and Institute for European Environmental Policy (IEEP), (2004), *Framework for Environmental Accounts for Agriculture*, Final Report, July 2004.

Abstract: This study '*A Framework for Environmental Accounts for Agriculture'* examines the potential application of monetised environmental accounting to the UK agricultural sector. Undertaken for Defra, DARDNI, Scottish Executive and the Welsh Assembly, the research responds to terms of reference that call for "a study to identify data sources for the environmental impacts of agriculture and to develop methodologies that would enable us to produce an account to give an adjustment to the aggregate agricultural accounts showing this impact". The main driver for creating environmental accounts is the recognition that the current national accounting system does not reflect the full costs and benefits to society of economic activities, and, therefore, is an inadequate indicator of well being or true economic progress. Given the primary importance of traditional accounting indicators such as Gross Domestic Product (GDP) and Net Domestic Product (NDP) in public policy making, adjustments of these measures for environmental outcomes of economic activities are a step towards a better understanding of the sustainability (or otherwise) of economic development. The work undertaken for this study draws from the large body of literature on green accounting which is grounded in the concept of sustainability, and which has sought to identify greener measures of national wealth and income. Practical attempts to operationalise these concepts include those undertaken by the United Nations' Statistical Office (UNSTAT) and its System of Environmental and Economic Accounts (SEEA), as well as the World Bank's annual cross-country estimates of genuine (or adjusted net) saving and its components. While many countries have satellite environmental accounts that record environmental inputs and outputs, as with the Environmental Chapter of the UK Agricultural Accounts, none have yet attempted to integrate these within the final accounts, although the potential benefits are well recognised. Once fully developed, a monetised environmental account for agriculture would be capable of providing: an economic measure of the sustainability of agriculture and a truer measure of the quality of life; an indication of the extent to which agriculture is a net contributor to the nation's wellbeing as well as how it affects the welfare generated by other sectors; information that can be used for priority setting within agricultural policy; and inputs to cost benefit analysis for agricultural and related environmental policies. As this report shows, current limitations on data and incomplete understanding of the linkages between agricultural practices and inputs, and environmental and economic outcomes mean that these remain goals, rather than reality, for the moment. Past attempts at monetary Environmental Accounts of *UK agriculture* and recent attempts to place monetary values on the environmental impacts of UK agriculture provide a useful starting point for this exercise. However, the study expands on previous research in a number of respects: (i) by focusing on positive as well as negative impacts of agriculture; (ii) by taking a systematic approach to identifying the accounting framework and how this would

apply to a particular sector; (iii) by undertaking a wide review of the economic valuation literature and (iv) by presenting recommendations for future research.