7.3.2. Ecosystem service maps in agriculture

Louise Willemen, Sarah Jones,
Natalia Estrada Carmona & Fabrice DeClerck

Introduction

Agricultural ecosystems are the largest ecosystems in the anthropocene. To produce food, fodder and fuels, these agricultural systems strongly depend on a reliable flow of ecosystem services; examples include water, pollination, pest control, soil fertility and the gene pool of wild crop relatives. At the same time, it is well known that many agricultural practices and the expansion of agricultural areas are a major threat to well-functioning healthy ecosystems. However, the inverse can arguably be just as true; agriculture, if well managed, can become an important means by which to secure and safeguard ecosystem services (ES). Agriculture has been the most direct way humans altered their natural surroundings and has brought major increases in well-being and income to humans. It is important to realise that most ES result in human benefits only after human input or activities, such as seeding and harvesting crops, travelling to attractive locations, or redirecting water (Chapter 5.1).

Agricultural systems are intensely managed by humans and are more controlled and regulated than most other 'ecosystems'. Many governance systems are in place to manage and distribute excludable and rival goods (e.g. water board for irrigation water, fishing quota, timber extraction licences). This high level of human management and regulation creates opportunities for securing and safeguarding ES for agriculture and non-agricultural production uses.

ES in agricultural landscapes operate across different spatial and temporal levels: before an ES reaches the field, it may have moved over various distances from different land cover types in the surrounding areas. For example, soil conservation practices on slopes reduce the negative impact of sedimentation or landslide risk on the downslope. Understanding this multi-level aspect (where ES come from and flow to and at what point in time) is crucial for an effective management of ES flows in rural areas.

In this chapter, we reflect on the role of spatial information on ES for the sustainable management of agricultural areas. The use and selection of ES to consider and their mapping approaches depend on: i) the strength of the relationship between agricultural production systems and ES supply and ii) the spatial extent of the supply, flow and management level of the ES.

Ecosystem services and agricultural production links

In 2014, The Economics of Ecosystems and Biodiversity initiative (TEEB) initiated a specific study on the value of ES and biodiversity across agricultural systems: TEEB for Agriculture and Food (TEEBAgFood). TEEBAgFood has identified the positive (provisioning and regulating services) and negative (environmental impacts) flows to and from agricultural systems. The quantification of these services helps to assess the dependence and impact of production systems on ES supply.

ample, the supply of the ES 'nutrient cycling' is particularly relevant for low input farming systems. In contrast, closely managing nutrient cycling via an ES based approach is not as relevant on farms where this is provided by

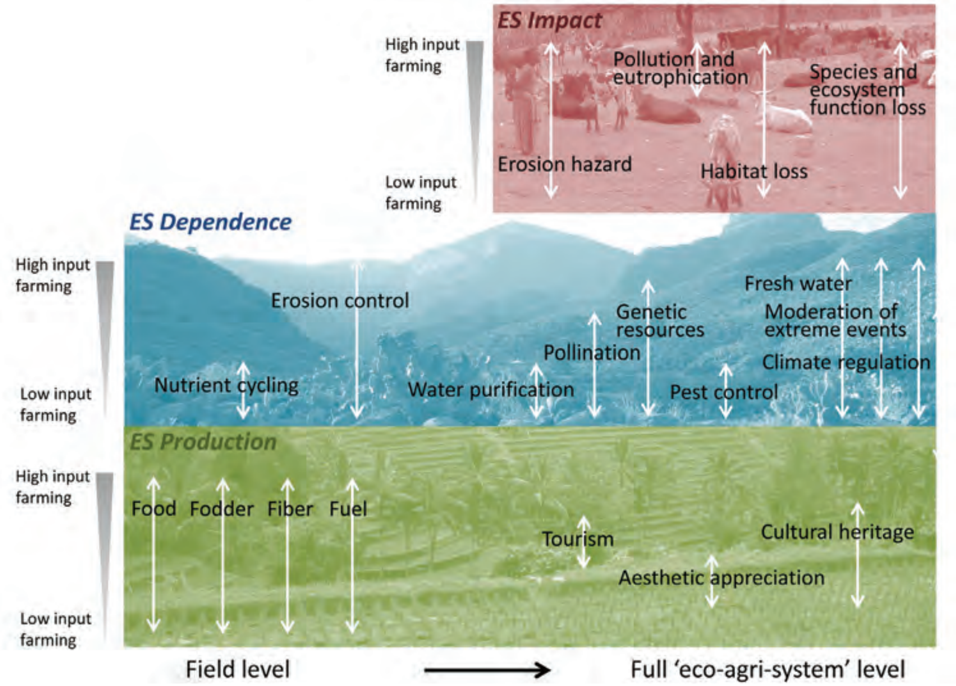


Figure 1. Linkages between ES and agricultural management types for ES production, ES dependence and ES impact per spatial level. The white arrows indicate to which farming type the ES relate, from low to high input.

However, not all ES have equal relevance for all farming systems. In Figure 1, we show the assumed and simplified link for high to low input farming systems to relevant ES based on their supply, ES dependence and ES impact. The figure also shows on which spatial level these interactions take place and therefore need to be managed. "Input" refers here to pesticides, fertilisers and water (not to labour or machinery). The white arrows in this figure indicate the farming systems for which the specific ES (and thus information on this ES) is relevant. The general assumption is that low input farms are more dependent and have less impact on ES compared to conventional high input farming. For example, the supply of the ES 'nutrient cycling'

synthetic fertilisers. In Figure 1, this is shown by the arrow indicating the lower input farming systems only for this ES. Some ES are relevant for all farming systems: all farms will produce food, fodder or fuel crops, they all rely on specific water and climate conditions and all conversions of land to agriculture will impact the natural habitat.

Figure 1 could be used as a general guide for selecting the specific ES to be mapped, in addition to the location-specific ES information needs and focus. Maps of ES play an important role in land management for: the assessment of the current state of ES in rural areas, impact analyses of agriculture on ES and the monitoring of ES to support sustainable management of agricultural areas. Land management, as well as the generation of spatial information, has so far mostly focused on the ES supply (agricultural goods) and ES impact (e.g. environmental impact assessments) and less so on the enabling of common public goods on which ES depend (central blue bar of Figure 1). The TEEBAgFood project calls these the 'invisible' positive flows. Maps can make these invisible flows 'visible', facilitating their inclusion in decision-making.

Ecosystem service maps for farms and beyond

Decisions on agricultural practices are typically made at farm level. However, most ES on which agriculture depends and impacts often have a spatial level exceeding the farm. Figure 1 shows that difference: few ES are purely linked to field level, while many ES are related to the 'full eco-agri-system' which can cover landscapes, watersheds or even the global system depending on the ES in question. Thus, when mapping ES to support decision-making in agricultural management, farm and field level maps alone are insufficient, as agriculture mostly supplies, impacts and depends on ES from larger spatial extents. The spatial extent of ES and the related mapping requirements (data resolution, accuracy) are described in Chapter 5.2.

Applications of ES mapping in agricultural areas

Current work demonstrates that ES maps and the process of generating maps can address important land management questions in agricultural areas across the globe. Studies have shown that the process of mapping ES as well as the maps themselves can be used to: i) visualise the scales at which different services operate; ii) assess locations of ES supply and beneficiaries highlighting dependencies; iii) visualise impacts which are often considered invisible externalities of agriculture, both positive and negative; iv) facilitate negotiations amongst stakeholders, including payment schemes and v) target intervention locations required to ensure or improve ES supply. An example of this type of ES mapping study is presented in Box 1.

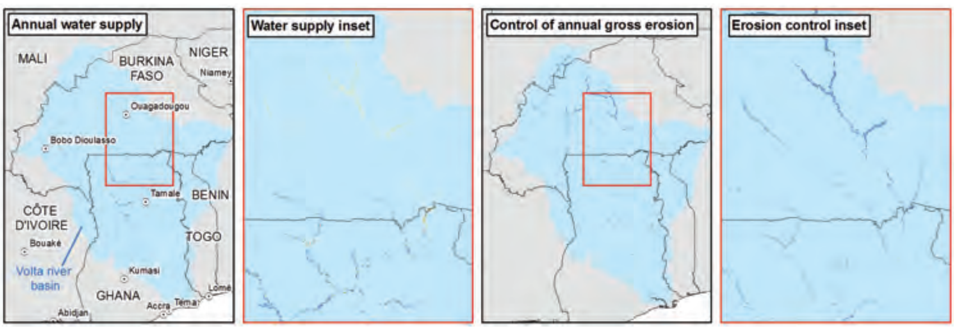
Box 1. Managing reservoir catchments to secure transboundary ES delivery in the Volta basin

The Volta River flows through six West African countries, draining a 407,000 km^2 area that is home to over 20 million people. The Volta basin is subject to highly variable rainfall, yet timely supply of a sufficient quantity of quality water is essential for the rural households that rely on crop, fish or livestock production for their livelihood. Over 1000 small and several large dams have been constructed in the basin since the 1950s to help maintain a year-round supply of agricultural water. Ecosystem processes in the reservoir catchments provide a service for reservoir-users by regulating the quality, quantity and timing of reservoir water supplies, making the network of land-users, reservoir systems and water beneficiaries tightly interconnected. Bioversity International and its partners are working with smallholder farmers and local and regional government in the Volta basin to facilitate evidence-based ES management decisions. Many of these stakeholders identify soil erosion and associated sedimentation as a key threat to reservoir water supplies and water management authorities are seeking to minimise erosion through improved management of land adjacent to the stream network. The ES model WaterWorld , is used here to investigate the effect on water supply and the control of soil erosion rates by ensuring: 1) 100 % herbaceous plant cover and 2)

100 % tree cover, on land within 100 m of waterways in dam catchments across the Volta basin. Results indicate that targeting herbaceous vegetation cover in riparian zones (Scenario 1) would be more effective than targeting tree cover (Scenario 2) for improving water availability, although benefits are unevenly distributed across the region and generally higher in the south. Local variations in annual water balance are expected particularly under the tree cover scenario, with the annual water supply falling to less than half of its baseline level (a decrease of more than 100 %) in several dispersed locations across the region. The area, highlighted in the annual water supply inset maps below, illustrates that water supplies are generally expected to decrease on the Burkinabé side of the border under both scenarios while, on the Ghanaian side, water balance is expected to increase by up to 10 % or more in most places under herbaceous cover (Scenario 1), but continue to fall under tree cover (Scenario 2). The difference in water supply results between the scenarios can be largely explained by a difference in evapo-transpiration losses which will be higher from tree cover than herbaceous cover. In contrast, both vegetation types appear to be effective at controlling sediment. Both scenarios indicate erosion control rates adjacent to waterways will increase across the basin where there is perennial vegetation cover, with the largest erosion prevention impacts occurring near the headwaters of the stream network where slopes are steepest. The erosion control inset maps below illustrate that reduced erosion rates may be up to 100 % compared to baseline levels in some areas. The model outputs show that ensuring year-round vegetation cover on land adjacent to waterways, particularly with herbaceous plants and near stream headwaters, could be an effective strategy to control sedimentation rates and improve regional water supplies. Much of this riparian land is currently used for crop and livestock production and restricting agriculture on this land would negatively impact on thousands of smallholder farmers. Careful management of vegetation cover on existing agricultural land combined with protection and restoration of natural vegetation in adjacent areas could represent a viable option for implementing a riparian management scheme with minimal losses to food production. This would mean agricultural land in riparian zones is selectively managed to ensure year-round plant cover by, for example, using perennial species such as bananas, perennial rice and cover crops, while natural vegetation is restored and protected on adjacent non-agricultural land.

Mapping relative changes in ecosystem servces across the Volta basin under two riparian buffer management scenarios.

Scenario 1: Herbaceous plant cover (natural, crops, cover crops) in 100 m buffer along waterways in dam watersheds.



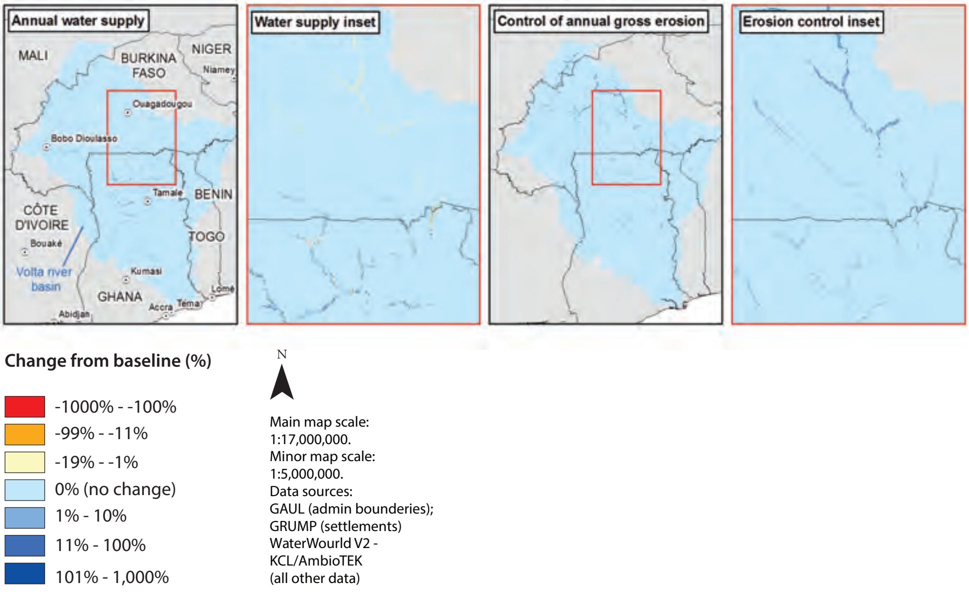
Change from baseline (%)

- -1000% - -100%
- -99% - -11%
- -19% - -1%
- 0% (no change)
- 1% - 10%
- 11% - 100%
- 101% - 1,000%

N

Main map scale:
1:17,000,000.
Minor map scale:
1:5,000,000.
Data sources:
GAUL (admin bounderies);
GRUMP (settlements)
WaterWourld V2 -
KCL/AmbioTEK
(all other data)

Scenario 2: Tree cover (natural, orchards, plantations) in 100 m buffer along waterways in dam watersheds.



Further reading

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