Framework to assess investments in agriculture

In response to FAO-OECD Guidance for Responsible Supply Chains

March 2016

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For quality of life

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This report has been commissioned by the Dutch Ministry of Economic Affairs

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1. Introduction

Investments in agriculture aim to improve production and supply of food and fibres and to result in economic revenues. To ensure that intensification is sustainable these investments should not compromise the natural environment of local communities.

This brochure provides an easy-to-use framework to make a rapid assessment of agri-environmental sustainability issues associated to investments. It allows governmental grant advisers i) to capture the awareness of applicants regarding sustainability issues related to investments, ii) to obtain an indication of potential risks and iii) to assess whether risk mitigation measures are considered.

The framework builds on the FAO-OECD Guidance for Responsible Supply Chains. It is complementary to these guidelines by providing more specificity on agri-environmental sustainability, in particular for the themes of soil, water, biodiversity, climate change mitigation and animal welfare.

This brochure contains a comprehensive set of questions per agri-environmental sustainability theme. Per theme objectives and attention points for good performance are indicated. The questions allow grant advisors to derive a preliminary assessment of the impact for each theme, and of what is needed to generate a positive impact. All questions are introduced and recommendations for further reading are included.

2. Attention points for environmentally sustainable agricultural land use

TREES

The roots improve soil structure and prevent nutrient leaching and runoff. Trees also store carbon and in this way help mitigating climate change. Furthermore, trees can create complex habitats that support a variety of birds, insects, and other animals

Roots can transport water upwards by capillary rise. In some regions this is desired or neutral, in other regions this can cause depletion of the aquifer. It is important to choose the tree carefully to prevent negative effects.

WATER QUALITY

Runoff can lead to surface and groundwater pollution. Runoff from frozen ground is a problem, especially where manure is spread during the winter. Vegetable handling, especially washing in polluted surface waters in many developing countries, leads to contamination of food supplies. Irrigation return flows carry salts, nutrients and pesticides.
Eutrophication forms a threat for the aquatic environment. It causes a decrease of oxygen, affecting the ecological balance in the water .
Buffer zones serve water quality protection. Grass strips and (woody) vegetation along streams trap suspended particles and nutrients.

CROP DIVERSIFICATION

Crop diversification with cover crops and crop rotation reduces plant diseases caused by soil-borne pests and pathogens. It can also can support suppression of pests by their natural enemies .

EROSION

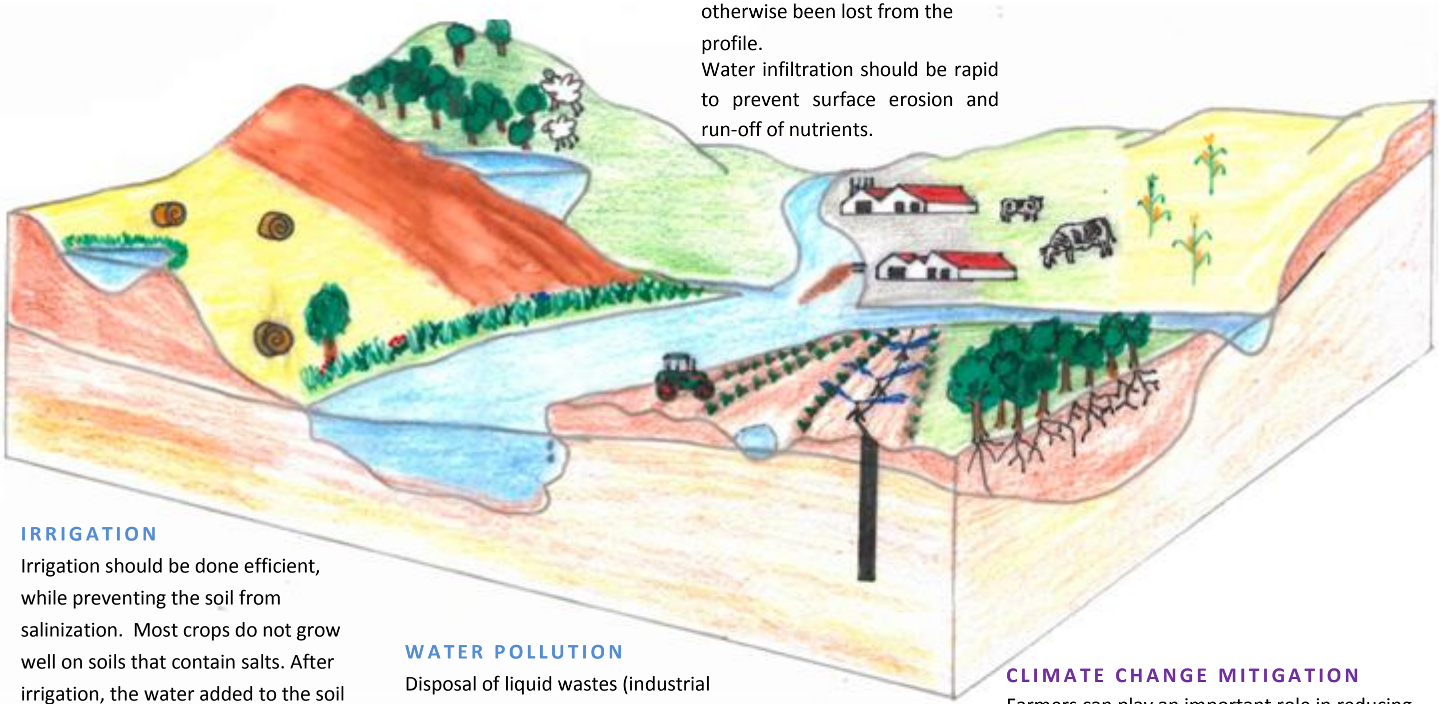
Bare soil is prone to erosion . Cover crops reduce nutrient leaching, because plant roots in the surface soil remove nutrients and water that would have otherwise been lost from the profile.
Water infiltration should be rapid to prevent surface erosion and run-off of nutrients.

ANIMAL HOOVES

Livestock can cause land degradation. The animal hooves, especially those of sheep and goats. Low stocking density and quick pasture rotation prevent soil and vegetation damage.

SOIL STRUCTURE

Cover crops, mulching and crop rotation contribute to maintenance of soil structure and organic matter and, thereby, reduction of soil erosion.
Soil compaction as a result of field traffic with heavy machinery is a major cause of poor root development and water stagnation. Choose for light weight machinery with adequate tire pressure.



IRRIGATION

Irrigation should be done efficient, while preventing the soil from salinization. Most crops do not grow well on soils that contain salts. After irrigation, the water added to the soil is used by the crop or evaporates. Salt is left behind in the soil. Salty groundwater can also cause salinization when it reaches the upper soil layers salts can accumulate in the root zone
If water is extracted at a faster rate than replenished can this cause drying up of wells, reduction of water in streams and lakes, deterioration of water quality, increased pumping costs and possibly land subsidence.

WATER POLLUTION

Disposal of liquid wastes (industrial wastes, biocides, antibiotics) can contain pathogens, metals and organic compounds which may be harmful for aquatic life, soil, crop yield and human health.

CLIMATE CHANGE MITIGATION

Farmers can play an important role in reducing greenhouse gas emissions

Methane mainly occurs as part of the natural digestive process of animals, and releases from manure. Fewer, but more productive animals can mitigate the impact livestock has on global warming.

Nitrous oxide is emitted with the application of fertilizer, storage of manure and use of fuel and energy. Favourable weather conditions and equipment for application can help to keep the emission to a minimum.

ANIMAL WELFARE

In many regions, a secure supply of food for people depends on the health and productivity of animals, and these in turn depend on the care and nutrition that animals receive. Both indoor and outdoor area should ensure that animals are comfortable. This entails a proper diet, suitable living conditions , health integrity, freedom of behaviour and avoidance of fear and distress of animals.

3. SOIL

Good soil maintenance is crucial for sustained agricultural productivity and contributes to food security. Through improper soil and water management, soil properties may be altered resulting in a serious loss of fertility. Without fertile soils, yields will drop and resilience of the land will decrease.

It is estimated that 95% of our food is directly or indirectly produced on our soils. Therefore, food availability relies on soils. The current rate of soil degradation threatens the capacity to meet the needs of future generations. The promotion of sustainable soil and land management is central to ensuring a productive food system, improved rural livelihoods and a healthy environment (FAO, 2015).

Questions in this assessment focus on soil structure and texture, erosion, organic matter and soil fertility, soil-borne pests and diseases, soil contamination and salinization. What these themes entail is briefly explained and suggestions for further reading are given.

Fertile soil under species rich pasture (Photo: Gerlinde De Deyn)

3.1 Soil structure and texture: Soil texture and soil structure influence pore space in a soil, and how easily air, water, and roots can move through a soil. Soil texture – proportions of sand, silt and clay – is unchangeable, in contrary to soil structure. Two soils with the same texture can behave very differently depending on their structure. Good soil structure enhances among others soil aeration, infiltration, root penetration, nutrient supply and workability. It reduces the susceptibility to compaction under heavy machinery. Soil structure degradation, compaction, leads to decreased water and fertilizer efficiencies and increased soil erosion. It increases the risk of crop failure under reduced water supply and it increases farming costs: higher input requirements and investments to alleviate the problem will be needed (FAO, 2008).

3.2 Soil erosion: Erosion is the process by which soil is removed due to natural factors (wind, water, ice, organisms, gravity). Erosion is a natural process, but human activities can greatly influence its rate, especially through agriculture and deforestation. Soil erosion has both on-site and off-site effects. Loss of soil productivity is the main on-site effect, resulting in productivity losses. These losses are often masked by increased amounts of fertilizers, leading to higher costs and bigger losses to the environment. Sedimentation and eutrophication of waterways and reservoirs are common off-site effects (from: FAOSTAT, 2013).

3.3 Organic matter and soil fertility: Soil organic matter is a substance which is vital for air, moisture and nutrient retention. It plays an important role in sustaining soil fertility, and hence in sustainable agricultural production. In addition to being a source of plant nutrients such as nitrogen (N), phosphorus (P) and potassium (K), it improves the physical-chemical and biological properties of the soil. Most of the organic matter is located in top soil. Soils with low organic matter content are often prone to erosion with poor soil structure (FAO, 2015).

3.4 Soil-borne pests and diseases: Soil is a habitat for many organisms, such as fungi, bacteria, viruses, nematodes and insects, and certain organisms in soil can cause diseases or pest outbreaks (FAO, c2016A). Soil-borne pests and diseases can cause heavy yield losses in both cropland and grassland. These problems are often managed using synthetic insecticide, fungicide and herbicide. This disrupts the natural crop ecosystem balance, and can exacerbate pest and disease problems as also beneficial organisms are affected. Crop diversification with cover crops and by crop rotation reduces the risk of plant diseases caused by soil-borne pests and pathogens (Peters et al., 2003).

3.5 Soil contamination: Nutrients, biocides and antibiotics can seep into the soil when they are dispersed in the environment through agricultural practice (fertilization, animals). Such spillage may cause serious soil or groundwater contamination. This affects crops, livestock and drinking-water, when consumed risks may occur (FAO, 1996).

3.6 Salinization: Most crops do not grow well on soils that contain salts. Salinization mostly occurs in irrigated areas. Most irrigation water contains some salts. After irrigation, the water added to the soil is used by the crop or evaporates directly from the moist soil. The salt, however, is left behind in the soil. If not removed, it accumulates. Salinization can be prevented by irrigating appropriate rates of water. Frequent and shallow (superficial) applications result in salt accumulation in the root zone, while larger applications, in longer intervals, will flush the salts below the root zone (from FAO, 1988).

Table 1: Questions regarding soil

1. Will the investment result in better/ similar/ poorer soil structure texture?	
	Objective: Support processes that improve soil structure and avoid practices that deteriorate soil structure Practices, measures and attention points for good performance: • Careful harvesting of products from the soil (like roots and tubers)[a, b] • Avoid use of heavy machinery [a, b] • Tillage only when needed [b, c] • Use deep rooting plant species • Adding sufficient amounts of organic material, for instance through mulching or planting cover crops[d] • Alternate crops that could cause risks for soil structure with beneficial crops • Avoid trampling damage by animals [e]
2. Will the investment result in less/ similar/ more soil erosion?	
	Objective: Avoid loss of soil through wind and water flows Practices, measures and attention points for good performance: • Keep the soil covered by perennial vegetation, planting cover crops or mulching [d], to avoid erosion • Limit stocking density of livestock to allow vegetation to regrow after grazing to maintain soil cover [e] • Plant wind breaks where needed
3. Will the investment result in more/ similar/ less soil organic matter and soil fertility?	
	Objective: Improve organic matter content, soil biota and soil fertility (through supply and better retention of nutrients). Practices, measures and attention points for good performance: • Provide nutrient amendments to compensate organic matter breakdown and withdrawal [d,f]
4. Will the investment result in less/ similar/ more soil-borne pests and diseases?	
	Objective: Avoid build-up of soil-borne pests and diseases by variations in soil use Practices, measures and attention points for good performance: • Implement a rotation system or a balanced and locally suitable multi-layer perennial vegetation consisting of trees, shrubs and herbaceous plants [g] • Add sufficient amounts of organic material, for instance through mulching or planting cover crops [d]
5. Will the investment result in less/ similar/ more losses of nutrients, biocides and antibiotics to the environment?	
	Objective: Avoid the release of nutrients, antibiotics and toxic substances that can pollute soil, water and air Practices, measures and attention points for good performance: • Tune the amount and timing of nutrient application in inorganic and organic fertilizers with crop requirement • Limit the application of herbicides and pesticides to the minimum • Use antibiotics only to cure acute animal health problems • Cover manure storage facilities to avoid gaseous emissions and leaching
6. Will the investment result in less/ similar/ more salinization of soils?	
	Objective: Avoid land degradation through salinization Practices, measures and attention points for good performance: • Use the amount of water the plants really need, plus a little extra to ensure that salts are leached out[h] • Use adequate form of irrigation
How will the investment impact land degradation and environmental damage?	

What is needed to generate a positive impact on soil?	
Documentation	
a.	Soil compaction as a result of field traffic with heavy machinery is a major cause of poor root development and water stagnation.
b.	There are good reasons to reduce tillage and field traffic: no till and other conservation tillage systems can protect soils against erosion (Gebhardt et al., 1985), reduce production costs (Al-Kaisi and Yin, 2004), and decrease the consumption of fossil fuels (Phillips et al., 1980).
c.	Soil disturbance from tillage is a major cause of organic matter depletion and reduction in the percentage and stability of soil aggregates and, as a result, soil erosion (Six et al., 1999).
d.	Cover crops, mulching and crop rotation contribute to maintenance of soil structure and organic matter and, thereby, reduction of soil erosion. Cover crops reduce nutrient leaching, because plant roots in the surface soil remove nutrients and water that would have otherwise been lost from the profile (Wyland et al., 1996).
e.	Livestock may promote land degradation. The action of animal hooves, especially the small cloven hooves of sheep and goats, is extremely damaging to the surface soil as it destroys vegetation cover (Taddese, 2001). As the vegetation cover declines under high stocking rates, the water infiltration rate decreases and sediment production increases (Mwendera and Mohamed Saleem 1997).
f.	The use of crop residues and animal manure is important for the maintenance of soil organic matter (Gerzabek et al., 1997; Maillard and Angers, 2013).
g.	Crop diversification with cover crops and by crop rotation reduces plant diseases caused by soil-borne pests and pathogens (Peters, 2003).
h.	Irrigating with sprinklers can use water more efficiently than surface irrigation, but it can also deliver salts right onto the plant itself if the irrigation water is saline. Drip irrigation, which involves delivering a metered amount to the area around the plant itself, is prefered (FAO, 2002).

Suggestion for further reading:

Koopmans, C.J., J.G. Bokhorst, C. ter Berg, N.J.M. van Eekeren (2015). Soil Signals: A practical guide to a fertile soil. Roodbond, Zutphen. 96 pp.

4. WATER

Water is essential for agriculture to bring forth the potential of the land and to enable plants and animals to produce optimal yields. It is a limited resource and without proper water management, clean water is not ensured.

Agriculture is the single largest user of freshwater resources, using a global average of 70% of all surface water supplies (FAO, 1996). Good water quality is one of the most vital resources for life. When water is polluted it is not only devastating to the environment, but also to human health. Judicious agriculture management practices are necessary to keep water quality standards (FAO, 1996).

Questions in this assessment focus on eutrophication, water contamination, runoff and aquifer depletion. What these themes entail is briefly explained and suggestions for further reading are given.

Channel irrigation in Morocco (Photo: Lena Schulte-Uebbing)

4.1 Eutrophication: Eutrophication is the enrichment of surface waters with nutrients. High applications of fertilizers can increase nutrients (especially nitrogen and phosphorus) in groundwater and surface waters. This incurs health and purification costs, and decreases fishery and recreational value (Tilman 2002). Fertilizer and pesticide application, at appropriate rates and times and with methods such as precision fertilization that minimize leaching, prevent eutrophication of ground and surface water (FAO, 1996).

4.2 Water contamination: Water pollution forms a growing threat. Disposal of biocides, liquid wastes from municipal wastewater effluents, sewage sludge (including remnants of antibiotics), industrial effluents and wastewater from home septic systems can contain pathogens, metals and organic compounds. This can be harmful, especially when the water is directly used for household use. When the water is used on agricultural land, the wastes dissolved in water may still affect soil, crop yield and human health (FAO, 1996).

4.3 Runoff: Surface runoff (or overland flow) is the flow of water that occurs when excess storm water, meltwater, irrigation water or water from other sources flows over the surface. There are two situations when runoff will occur. If the intensity of rainfall exceeds the infiltration rate at the ground surface, ponding will lead to surface flow. Alternatively, when the soil surface is saturated there will be surface flow when the rainfall intensity exceeds the percolation through the whole soil profile. As runoff flows over the land surface, it displaces potential pollutants that may include sediment, nutrients (from fertilizers), bacteria (from animal and human waste) and pesticides (from chemicals), which end up elsewhere in the environment and cause a loss of productivity on-site (from: FAO, 1993).

4.4 Aquifer depletion: Groundwater is the major source of water in many regions, supplying a large proportion of water globally. It is replenished from precipitation and from surface water, but the rate of abstraction (for example pumping irrigation water) may exceed the rate of natural recharge, leading to aquifer depletion. To ensure sustainable land and water management, there is a need for comprehensive monitoring of groundwater resources, and rates of recharge. Negative effects of ground water depletion entail among others drying up of wells, reduction of water in streams and lakes, deterioration of water quality, increased pumping costs and possibly land subsidence (from: FAO, 1999).

Table 2: Questions regarding water

7. Will the investment result in less/similar/more eutrophication of groundwater surface water?	
	Objective: Avoid pollution of water with surplus nutrients Practices, measures and attention points for good performance: • Limit doses and synchronise supply with requirements of nutrients that are prone to leaching [a] • Avoid animal wastes, fertilizers and pesticides nearby water sources [b] • Avoid removal of vegetation (including grasslands) that might cause a flush in the degradation of organic matter and release of nutrients
8. Will the investment result in less/similar/more contamination of groundwater/surface water with toxicants and/or pathogens?	
	Objective: Avoid contamination of water with synthetic, toxic and organic substances Practices, measures and attention points for good performance: • Use catch crops or semi-natural borders in locations with risks, to capture released nutrients and suspended particles [c] • Collect and correctly dispose of wastes and fluids that contain synthetic, toxic and organic substances like cleaning water and other effluents • Apply measures (like purifying wetlands) to remove unwanted substances from water resources
9. Will the investment result in less/similar of more surface water runoff?	
	Objective: Use water efficiently, avoid spoilage Practices, measures and attention points for good performance: • Avoid excessive water losses through evaporation, run-off (on soil surface) and preferential water flow [de] • Apply water in the place at the moment that is required [f]
10. Will the investment result in less/similar/more aquifer depletion?	
	Objective: Avoid overstressing of aquifers through pumping groundwater or planting vegetation disturbing the hydro-ecological balance Practices, measures and attention points for good performance: • Use water resources that are replenished and recharged at sufficient rate to compensate extraction, avoid disturbance of naturally occurring water flows • If trees are planted, investigate in risk of aquifer depletion
How will the investment impact water infiltration and water quality? What is needed to generate a *positive* impact on water?	

Documentation:

a. High applications of fertilizers and pesticides can increase nutrients and contaminants in groundwater and surface waters, incurring health and purification costs, and decreasing fishery and recreational value (Tilman, 2002).
b. Judicious use of fertilizers and pesticides, i.e. application at appropriate rates and times and with methods such as precision fertilization that minimize leaching, prevents eutrophication and contamination of ground and surface water. For example, animal wastes could be composted to create a fertilizer that no longer harbours pathogens (Tilman, 2002).
c. Buffer zones along streams draining a basin will serve water quality protection. Several zones of buffer vegetation are the most effective. A narrow grass strip at the upland edge traps suspended particles and phosphorus. A wider zone of woody vegetation traps nitrate to the receiving waters (Correll, 2005).
d. Water infiltration should be rapid so as to prevent surface erosion and run-off of nutrients. In low-rainfall areas high water storage and retention is also important so as to maintain or increase water use efficiency (Ali and Talukder, 2008).
e. This can be done combining biological water-saving measures with engineering solutions (modernization of irrigation systems, water saving irrigation methods, deficit irrigation,) and agronomic measures (proper crop choice, soaking of seeds, increasing soil fertility, addition of organic matter, conservation tillage and soil mulching). Where possible, water has to be recycled within the hydrological system (Ali and Talukder, 2008).
f. Possible effects of groundwater depletion are drying up of wells, reduction of water in streams and lakes, deterioration of water quality, increased pump costs and land subsidence (FAO, 1997).
g. Trees can reduce the recharge of aquifers used for irrigation (e.g. conifers in South Africa (Van Wilgen et al., 1998)).

Suggestions for further reading:

Molden, D. (ed). (2007). "Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture." London: Earthscan, and Colombo: International Water Management Institute. Report available at: http://www.fao.org/nr/water/docs/summary_synthesisbook.pdf

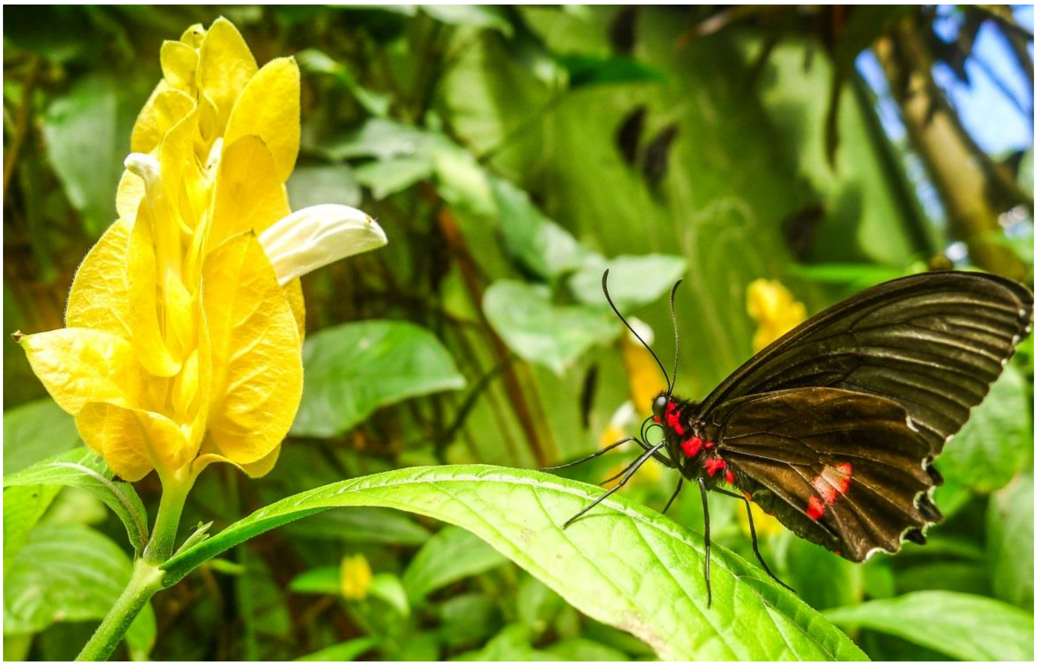
Hussain, I, L. Raschid, M. A. Hanjra, F. Marikar, W. van der Hoek (2002). Wastewater use in agriculture: Review of impacts and methodological issues in valuing impacts. Working Paper 37. Colombo, Sri Lanka: International Water Management Institute. Report available at: http://www.iwmi.cgiar.org/Publications/Working_Papers/working/WOR37.pdf

5. BIODIVERSITY

Agro-biodiversity covers life on the farm, from crop and cattle/livestock species to micro-organisms in the soil to wild flora and fauna in field borders or natural habitats which are part of the farm area or the landscape. Such non-productive areas are essential for resilient agro-ecosystems and are valuable to society (Costanza et al., 1997), therefore it is of importance to encounter biodiversity in agriculture investments.

Biodiversity contributes directly (through provisioning, regulating, and cultural ecosystem services) and indirectly (through supporting ecosystem services) to many needs for human well-being (World Resource Institute, 2005). Agricultural activities can negatively affect biodiversity, especially when natural land is converted.

Questions in this assessment focus on endangered species, habitat loss, invasive alien species, indigenous knowledge and ecosystem services. What these themes entail is briefly explained and suggestions for further reading are given.



Flora and fauna in one of the most biodiverse ecoregions in the world- Mindo, Ecuador (Photo: private collection)

5.1 Endangered species: Over the past few hundred years, humans have increased species extinction rates, partly by poaching and trading of endangered species, partly by conversion of natural ecosystems to agriculture leading to net habitat loss for wildland species. Extinctions can disrupt vital ecological processes such as biological control of pests and diseases, pollination and seed dispersal, leading to cascading losses, ecosystem collapse, and a higher extinction rate overall (Sodhi et al., 2009).

5.2 Habitat loss: Habitat loss occurs when natural environments are transformed or modified. It is the most significant cause of biodiversity loss globally. Common types of habitat loss include cutting down forests for timber, opening up land for agriculture, draining wetlands to make way for new development projects, or damming rivers to make more water available for agriculture and cities. Habitat loss can also cause fragmentation, which occurs when parts of a habitat become separated from one another because of changes in a landscape, such as the construction of roads. Fragmentation makes it difficult for species to move within a habitat, and poses a major challenge for species requiring large tracts of land (from: FAO, 2013A).

5.3 Invasive alien species: Invasive alien species are a major cause of biodiversity loss. These species can be harmful to native biodiversity, for example as predators, parasites, vectors (or carriers) of disease or direct competitors for habitat and food. In many cases invasive alien species do not have any predators in their new environment, so their population size is often not controlled. They may also cause economic or environmental damage, or affect human health. The introduction of invasive alien species can be either intentional, as with the introduction of new crop or livestock species, or accidental. Some of the main vectors for invasive alien species are trade, transport, travel or tourism, which have all increased in recent years (from: FAO, 2013A).

5.4 Indigenous knowledge: Indigenous knowledge is local knowledge unique to a given culture or society. It can be feasible, efficient, and cost-effective to learn from the village-level experts. Local people often have site-specific knowledge which can be useful for conserving biodiversity and ecosystem services (Warren and Rajesekaran, 1993).

5.5 Ecosystem services: Ecosystem services can be defined as "the benefits provided by ecosystems to humans" (FAO, c2016B). Many key ecosystem services provided by biodiversity sustain agricultural productivity: nutrient cycling, carbon sequestration, pest regulation and pollination. Promoting the healthy functioning of ecosystems ensures the resilience of agriculture (FAO, c2016B).

Table 3: Questions regarding biodiversity

11. Will the investment result in less/similar/more poaching/trading of endangered species?	
	Objective: Poaching and trading are avoided at all times Practices, measures and attention points for good performance: • Raise awareness among employees throughout the organization [a] • Protect plant and animal species that are native to the region
12. Will the investment result in less/similar/more habitat loss?	
	Objective: Avoid habitat loss Practices, measures and attention points for good performance: • Provide sufficient habitats for feed • ing, sheltering, reproduction, migration and hibernation of species that are present, also for species that might migrate or are present for only a part of the year • Compensate loss of habitat by reforestation and/or grassland regeneration
13. Will the investment promote/be neutral to/reduce the incidence of invasive species?	
	Objective: Manage and limit the presence of invasive species Practices, measures and attention points for good performance: • Apply measures that keep the species composition balanced, so that a food web is maintained. Avoid unbalances. • In case of compensation measures, introduced species should fit in the new situation.
14. Will the investment make more/similar/less use of the biodiversity knowledge of indigenous and local people?	
	Objective: Recognize knowledge, culture and rights of indigenous people and local communities Practices, measures and attention points for good performance: • Inventory sacred placed and indigenous use of biodiversity [b] • Consult available local people, use their indigenous knowledge to conserve (agro)biodiversity [c]
15. Will the investment result in less/similar/more negative impact on ecosystem services?	
	Objective: Recognize and strengthen ecosystem services Practices, measures and attention points for good performance: • List and evaluate local ecosystem services together with local people [d]
How will the investment impact biodiversity and ecosystem services? What is needed to generate a *positive* impact on biodiversity?	
Documentation: a. Besides the well-known (big) species, others are similarly overexploited, from marine turtles to timber trees. Not all wildlife trade is illegal. Wild plants and animals from tens of thousands of species are caught or harvested from the wild and then sold legitimately as food, pets, ornamental plants, leather, tourist ornaments and medicine (WWF, 2016). b. Biodiversity contributes directly (through provisioning, regulating, and cultural ecosystem services) and indirectly (through supporting ecosystem services) to many constituents of human well-being (World Resource Institute, 2005). It is therefore important to preserve biodiversity and benefit from ecosystem services and at the same time recognize the knowledge, culture and rights of indigenous people and local communities c. Not only wildlife diversity matters, but also agrobiodiversity sensu stricto, which refers to the genetic diversity of crop varieties and landraces of plants and breeds of cattle and livestock. d. Ecosystems provide several types of services (provisioning, regulating, habitat and cultural). Not all services are always clearly visible, some require knowledge from indigenous people.	

Suggestions for further reading:

Kremen, C. and A. Miles (2012). "Ecosystem Services in Biologically Diversified versus Conventional Farming Systems: Benefits, Externalities, and Trade-Offs." Ecology and Society 17-40.

Sodhi N.S, B.W. Brook, C.J.A. Bradshaw (2009). "Causes and consequences of species extinctions." The Princeton Guide to Ecology. 514–20.

Food and Agricultural Organization (FAO) and Platform on Agribiodiversity Research (2010). "Biodiversity for Food and Agriculture. Contributing to food security and sustainability in a changing world." FAO, Rome. 78pp. Report available at: http://www.fao.org/fileadmin/templates/biodiversity_paia/PAR-FAO-book_lr.pdf

6. CLIMATE CHANGE

Climate change affects people and the environment. Agriculture is an important cause and projections indicate that these emissions will increase if agricultural growth and development proceed with current technology and resource use. There is an urgent need to support (the design of) climate smart agricultural systems. This will contribute to better adapted farming systems for the future and reduced negative impact on the environment.

Agricultural activities - the cultivation of crops and livestock for food – impact global warming. Agriculture is, on the one hand, an important emitter of greenhouses gases (CO_2, N_2O and CH_4), but could also play a prominent role in efforts to reduce greenhouse gas emissions or take greenhouse gas out of the atmosphere.

Questions in this assessment focus on carbon sequestration and nitrous oxide and methane emissions. What these themes entail is briefly explained and suggestions for further reading are given.

Drought in Chile (Photo: private collection)

6.1 Carbon sequestration: Carbon sequestration is the storage of carbon in terrestrial, oceanic, or freshwater aquatic ecosystems to mitigate global warming. Atmospheric concentrations of carbon dioxide can be lowered either by reducing emissions or by taking carbon dioxide out of the atmosphere. Historically, land-use conversion and soil cultivation have been an important source of greenhouse gases (GHGs) to the atmosphere. Agriculture can play a major role in storing carbon in soil and plants, through restoration of degraded soils and widespread adoption of soil conservation practices (FAO, c2016C).

6.2 Nitrous oxide: Nitrous oxide is one of the primary greenhouse gases causing climate change. A major direct source of nitrous oxide from agricultural soils is that of synthetic fertilizer use. Widespread increase in the use of such nitrogen based fertilizers has been driven by the need for greater crop yields, and by more intensive farming practices. Where large applications of fertilizer are combined with soil conditions favourable to denitrification, large amounts of nitrous oxide can be produced and emitted to the atmosphere. Similarly, the widespread and often poorly controlled use of animal waste as fertilizer can lead to substantial emissions of nitrous oxide from agricultural soils (from Greenhouse Gas Online, 2015).

6.3 Methane: Agricultural practice is the primary source of methane (CH_4) emissions. The emission mainly occurs as part of the natural digestive process of animals, and releases from manure. The way in which manure from livestock is managed also contributes to CH_4 (and N_2O) emissions. Manure storage methods and the amount of exposure to oxygen and moisture can affect how greenhouse gases are produced. Other, smaller, sources of CH_4 emissions are rice cultivation and burning crop residues (FAO, c2016D).

Table 4: Questions regarding climate change

16. Will the investment result in more/similar/less carbon sequestration in soil and plant?	
	Objective: Foster carbon sequestration in farm management Practices, measures and attention points for good performance: • Conserve grassland, forestland, wetlands and rangeland [a,b] • (Re)plant perennial vegetation [a,b] • Minimize soil disturbance [c]
17. Will the investment result in less/similar/more release of N2O to the atmosphere?	
	Objective: Minimize release of nitrous oxide Practices, measures and attention points for good performance: • Base manure management on nutrient recycling [d] • Minimize use of fuel and energy [e] • Investigate in manure application equipment [f]
18. Will the investment result in less/similar/more release of CH4 to the atmosphere?	
	Objective: Minimize production of methane Practices, measures and attention points for good performance: • Optimize herd efficiency, especially for ruminants. This includes a balanced diet, which can reduce methane emitted during the digestion as well as the amount of CH4 and nitrous oxide (N2O) in the manure [g] • Re-consider herd size and breeding objectives. Fewer but more productive animals might decrease emissions [g]
How does the investment impact carbon sequestration and the release of greenhouse gases to the atmosphere? What is needed to generate a *positive* impact on climate change mitigation?	
Documentation: a. The conversion of grassland and forestland to cropland results in losses of soil carbon. Planting perennial vegetation will lead to increase of carbon sequestration of a land unit (Jones and Donnelly, 2004). b. Plants take up carbon dioxide (CO2) from the atmosphere and store it as carbon in stems, roots and soil. When the plant dies, part of the carbon from the plant is preserved in the soil (FAO, c2016C). c. If the soil is disturbed and the soil carbon comes in contact with oxygen in the air, the exposed soil carbon can combine with oxygen (O2) to form carbon dioxide (CO2) gas and re-enter the atmosphere, reducing the amount of carbon in storage (Pacala and Socolow, 2004). d. Nitrous oxide is emitted when people add nitrogen to the soil through the use of (synthetic) fertilizers. Agriculture contributes for about 35% to the global nitrous oxide pool. Nitrous oxide is also emitted during the breakdown of nitrogen in livestock manure and urine (Greenhouse Gas online, 2015). e. Nitrous oxide is emitted when transportation fuels are burned f. Emissions can be lowered by using inhibitors, splitting nitrogen applications, and using legume nitrogen and minimum tillage. Inhibitors slow the conversion of ammonium to nitrate and reduce the chances for nitrogen loss. g. Agricultural practice is the primary source of methane (CH4) emissions. The emission mainly occurs as part of the natural digestive process of animals, and releases from manure. The amount of methane emitted is affected by the enteric fermentation of the animal and manure management facilities (Steinfeld et al., 2006), but the most significant way to influence the amount of emission is increase or decrease of livestock density.	

Suggestions for further reading:

Dickie, A., C. Streck, S.Roe, M. Zurek, F. Haupt, A. Dolginow (2014). "Strategies for Mitigating Climate Change in Agriculture: Abridged Report." Report and supplementary materials available at: www.agriculturalmitigation.org

7. ANIMAL WELFARE

The increase in animal production of the last decades has raised attention for animal welfare. In general can be said that better animal welfare results in healthier animals and lower costs. This is closely linked to human welfare: a secure supply of food for people depends on the health and productivity of animals. Since attention for animal welfare is not yet common everywhere, there is a great need to support this within the design of farming systems.

Concern for animal welfare is often based on the belief that non-human animals are sentient and that consideration should be given to their well-being or suffering, especially when they are under the care of humans. (FAO, 2013B).

FAO-OECD Guidance for Responsible Supply Chains strives to 'ensure that the 'five freedoms' for animal welfare are implemented, i.e. freedom from hunger, thirst and malnutrition, physical and thermal discomfort, pain, injury and disease, fear and distress, and freedom to express normal patterns of behaviour'. All questions concerning animal welfare are directly taken from the five freedoms defined by the UK Farm Animal Welfare Council in 1979. The Five Freedoms outline five aspects of animal welfare under human control. These freedoms define ideal states rather than standards for acceptable welfare (Farm Animal Welfare Council, 2009).

Animals on their way to a pasture to graze, Peru (Photo: private collection)

Table 5: Questions regarding animal welfare

19. Will the investment result in more/ similar/ less satisfaction of nutritional needs of animals?	
	Objective: avoid exposure to thirst, hunger and/or malnutrition of farm animals (first of Five Freedoms[a]) Practices, measures and attention points for good performance: • Supply sufficient clean water and feed to maintain the animal and its growth and production [a] • Avoid exposure to pollution, parasites, pests and diseases in water, feed and bedding
20. Will the investment result in more/ similar/ less suitable living conditions for animals?	
	Objective: Avoid discomfort of animals (second of Five Freedoms [a]) Practices, measures and attention points for good performance: • Provide animals with safe and comfortable living conditions • Use suitable surfaces for walking and resting [b] • Provide clean air without dust and harmful gases, and sufficient light • Provide shelter against extreme ambient conditions like high or low temperatures, wind, drought, rain
21. Will the investment result in improved/ similar/ decreased health and integrity of animals?	
	Objective: Avoid exposure to pain, injury and/or disease of farm animals (third of Five Freedoms [a]) Practices, measures and attention points for good performance: • Avoid exposure to pollution, parasites, pests and diseases in water, feed and bedding • Take measures that support the functioning of the immune system of the animal to prevent disease and disorders • Provide curative measures after animals have become ill or are wounded or have trauma or disorders • Apply animal breeding strategies that result in balanced and robust animals, avoid exaggeration of particular traits [c] • Avoid practices violation animal integrity (like artificial hormone applications to provoke super-ovulation, dehorning, tail docking, etc.)
22. Will the investment result in more/ similar/ less freedom of behaviour for animals?	
	Objective: Provide opportunities for normal behaviour of farm animals (fourth of Five Freedoms [a]) Practices, measures and attention points for good performance: • Allow animals to behave in their natural way • Allow animals to move, explore, rest, interact and play • Allow sexual behaviour, allow adults to tend their offspring
23. Will the investment result in less/ similar/ more mental suffering of animals?	
	Objective: Avoid fear and distress of farm animals (fifth of Five Freedoms [a]) Practices, measures and attention points for good performance: • Avoid high-intensity stimuli like loud sounds and exposure to high voltage electricity • Provide animal management and interaction of people with animals that is respectful, calm and predictable • Monitor the living environment, behaviour and health status of the animals regularly
How does the investment impact welfare of farm animals? What is needed to generate a *positive* impact on animal welfare?	

Documentation:

a. Application of good quality feeds, together with application of outdoor areas and grazing strengthen the natural immune system of the animal (Borell and Sørensen, 2004).
b. Claw disorders are frequently reported in dairy cattle all over the world. Disturbed claw health is an source of suffering for animals, because the disorder is usually long term and painful (Somers et al. 2003).
c. Breeds should be selected to avoid specific diseases or health problems.
d. The high requirements for space allowance, for bedding and access to outdoor areas is in general seen as positive in relation to animal welfare allowing the cattle to move and to display normal behaviour (Borell and Sørensen, 2004).

Suggestions for further reading:

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