

The role of ecosystems in food security

J.C. Mohamed-Katerere and M. Smith



FAO/I KODIKARA

A farmer tends a water buffalo calf in Padukka, Sri Lanka. Ecosystems provide essential services for global food security

Food-security policies should be “ecosystem-aware” by encouraging diversity at different scales, maintaining natural infrastructure, and ensuring social justice.

Agricultural production cannot be sustained without ecosystem resilience and integrity. Ecosystems are communities of plants, animals and other organisms that live, feed, reproduce and interact in an area or environment. They underpin agricultural production by, for example, protecting soil and water, helping to maintain soil fertility, and providing habitat for wild pollinators and the predators of agricultural pests. Ecosystem degradation, coupled with weak ecosystem governance (see box), compromises the ability of people to farm, access and use food effectively and, in so doing, undermines the effectiveness of food-security policies. Poor people and other vulnerable groups, including women and children and particularly those in rural areas, are most at risk from any erosion of food security.

This article examines the many roles of ecosystems in food security and argues the case for an “ecosystem-aware” approach to food-security policy-making.

Ecosystem governance

Ecosystem governance can be defined as the interaction of laws and other norms, institutions and processes through which a society exercises powers and responsibilities to make and implement decisions affecting ecosystem services and to distribute benefits and duties. Governance of ecosystem services emerges from the interplay of governmental, intergovernmental and non-governmental institutions, the private sector and civil society, based on rules and policies established by statutory and customary law as well as through practice.

Source: Greiber and Schiele, 2011

Jennifer Mohamed-Katerere is at the International Union for Conservation of Nature (IUCN) Commission on Environmental, Economic and Social Policy and the IUCN Natural Resource Governance Framework, and **Mark Smith** is at the IUCN Global Water Programme.

AN ECOSYSTEM-AWARE APPROACH

An ecosystem-aware approach to food security aims not only to alleviate hunger in the short term but also to build long-term “food resilience” – defined here as the capacity of ecosystems to support food production and the ability of people to produce, harvest or buy food in the face of environmental, economic and social shocks and stresses. An example of such a shock was the 2012 drought in the United States of America, which reduced maize production and sent global prices soaring (Da Silva, 2012); another example was the 2004–05 locust invasions in the Sahel, which decimated crops and contributed to a major food crisis there (IFRC, 2005). Stresses are slower-onset changes such as increasing aridity or temperature changes, the intensification of conflicts, discrimination, a lack of access to resources, debt, and inflation. In theory, stresses are easier to respond to because they have a higher level of predictability; for poor people and developing countries, however, low levels of social and economic well-being make coping with stresses a considerable challenge.

Preparing better for shocks and stresses can help boost food production. A study of 73 countries, for example, found that those countries with more equitable initial land distribution achieved economic growth rates 2–3 times higher than those without (Deininger, 2003). FAO (2011) found that if women had the same access to productive resources as men they could increase yields on their farms by 20–30 percent and total agricultural output in developing countries by 2.5–4 percent. This would reduce the number of hungry people in the world by 12–17 percent and lift 100–150 million people out of hunger. IUCN experience in the Tacaná Volcano area in Central America shows that ecosystem restoration, greater agricultural and ecosystem diversity, and investment can boost food security (see box).

Food-security policy-makers in all countries have much to gain from integrating ecosystem management and good ecosystem governance in their

Ecosystem restoration, social inclusion and diversity enhance food security in the Tacaná Volcano area in Guatemala and Mexico

In the high-altitude upper watersheds of the Suchiate River and the Coatán in Guatemala and Mexico, the IUCN Water and Nature Initiative has co-executed projects that combine the rehabilitation of ecosystems with the development of social capital through income generation. Activities such as aquaculture, honey production and agro-ecology (community gardens); reforestation and mangrove conservation; solid waste recycling and earthworm production; and septic tank initiatives have helped reduce soil erosion and the risk of flooding and increase food security. Reforestation activities, including the establishment of forest nurseries and the planting of 45 000 plants to reforest 45 hectares of land with native tree species threatened with extinction, have contributed to slope stabilization and watershed protection. To help increase household income, women and the young received training on how to start new businesses. Gender and age-dependent skills’ training was vital for curbing unemployment and migration. Households have gained more access to food and higher nutrition as a result of greenhouse production, mushroom-growing, crop diversification and agroforestry, as well as the restoration of the irrigation system.

Source: M. Smith, personal communication, 2013

policy measures and from collaborating with other sectoral policy-making initiatives to ensure that all such initiatives support food security. Effective policies will also address the social aspects of an ecosystem-aware approach to food security by strengthening land tenure, access rights to natural resources, local organizations, and gender equality.

THE FOUR DIMENSIONS OF FOOD SECURITY

Food security can be thought of as comprising four dimensions (FAO, 2008):

- availability – the supply of sufficient quantities of food of appropriate quality, from both natural and cultivated systems;
- access – the ability of individuals to obtain food at all times through their own production or from markets or other sources;
- utilization – the means by which individuals are able to gain energy and nutrition from food;
- stability – the availability of sufficient and adequate food that is accessible and usable on a reliable, sustainable basis.

Only when all four dimensions are fulfilled simultaneously does an individual, household, community or nation achieve food security.

ECOSYSTEM CONTRIBUTIONS TO FOOD SECURITY

Ecosystems, including forests, contribute to all four dimensions of food security, as illustrated in Figure 1. For example:

- Forests contribute to soil processes, including the maintenance (and sometimes increase) of fertility, and reduce soil erosion, and they provide habitat for wild pollinators and the predators of agricultural pests.
- Forests provide access to food both directly (through the edible wild plants and animals found there, and as a source of genetic material for domestication) and indirectly (via forest-product income that can be used to buy food).
- Medicinal plants obtained from forests contribute to people’s health, increasing the efficiency of, and benefits obtained from, food consumption.
- Mangrove and other coastal forests help protect coastal areas from

1
Ecosystem contributions to the four dimensions of food security

flooding, thereby increasing the stability of food production in nearby fields and fish ponds.

WHY SHOULD FOOD SECURITY POLICY-MAKERS WORRY ABOUT ECOSYSTEMS?

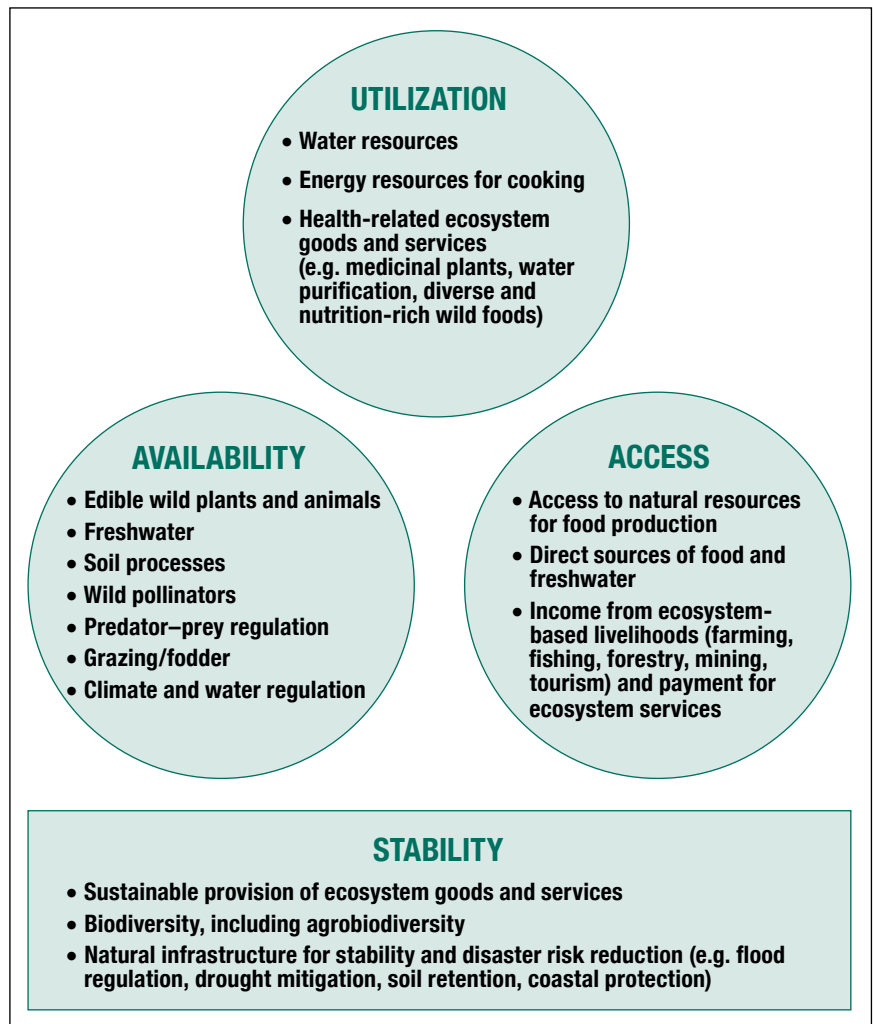
Ecosystem degradation can undermine the effectiveness and impacts of food-security policies, while inappropriate policies can damage ecosystems and their ability to support food systems. Some of the consequences of ecosystem degradation for food security are described below.

Availability of food

Food availability depends on the productivity of both cultivated and natural systems. Globally, poor rural people are most severely affected by food insecurity, with 80 percent of these communities being food insecure (compared with 20 percent of poor urban populations), and they rely heavily on natural resources to maintain their livelihoods. About half of all food-insecure people live in smallholder farming households and roughly one-fifth are landless (Sanchez *et al.*, 2005). In poor rural communities, therefore, resource degradation can make the difference between having food and going hungry. Worldwide, almost half a billion poor people are estimated to meet a significant proportion of their food needs from the harvesting of wild plants and animals (Sanchez *et al.*, 2005). Ecosystem degradation and natural disasters that reduce the availability of these food sources will also have a large impact on food security.

Access to food

Globally, about 1 billion people earn income from the use of wild natural resources (Pimentel *et al.*, 1997). Marine, freshwater and forest resources are particularly important: according to FAO (2010),



fisheries and aquaculture – which, in turn, often have a significant dependence on forests – support the livelihoods of 8 percent of the world’s population. Many poor people rely on the sale of timber and non-timber forest products (such as wild meat, honey, medicinal plants and woodfuel) to buy food and meet other important household expenses (Sunderland, 2011). In general, ecosystem-based activities (such as agriculture, forestry, fisheries and tourism) are critically important sources of income for poor people, especially in rural areas. Threats to these income sources – from, for example, ecosystem degradation, natural disasters, conflict and the collapse of commodity prices – have severe knock-on effects on food security.

Use of food

Rural and urban poor people in developing countries depend on natural biomass (particularly wood) for cooking and certain forms of food preservation (e.g. smoking and drying). Access to woodfuel expands the choice and range of foods that are consumed, including important protein sources such as beans and meat that require higher levels of energy for preparation. The loss of access to woodfuel through deforestation or resource-use restrictions, therefore, can affect both the quantity and quality of food. Insecure environmental conditions – caused, for example, by high winds, floods, pests and plant diseases – can reduce effective food storage.

STABILITY OF FOOD SUPPLY

A stable food supply implies food systems that ensure sustainable food availability, access and use. It also requires that food systems are resilient to social, economic and environmental shocks and stresses. Some such shocks and stresses, and their policy implications, are outlined below.

Unsustainable development

Economic development that appropriates resources and ecosystems and gives tighter control over them to the state or through them to private investors tends to restrict access by poor people to critical food-security assets such as forests, coasts and water resources. Infrastructure

development for coastal tourism (e.g. hotels, piers and recreational facilities), for example, increases effluent discharges, disturbs coastal ecosystems such as mangrove forests, and reduces access to coastal flats that, in many countries, serve as seaweed- and mollusk-harvesting grounds for local people. Rapid urbanization can also lead to reduced access to food because the poor people in urban areas are less connected to wild foods and therefore have less potential to earn income using natural resources.

Unsustainable agricultural and industrial development is causing widespread damage to ecosystems through the pollution of land and water. UNEP (2006) reported that, globally, little or no progress had been achieved in preventing, reducing or controlling pollution of the marine environment. Fertilizer runoff, for example, damages marine and freshwater ecosystems, including coral reefs, and diminishes the availability of fish and molluscs, which are critical protein sources for many. The impact of nitrogen pollution has been particularly severe, resulting in a 50–90 percent decline in mangroves in most regions over the last four decades (UNEP, 2006). The number of coastal dead zones has increased dramatically in recent years. Of the 169 coastal dead zones worldwide, only 13 are recovering, and 415 coastal areas suffer from eutrophication (UNEP, 2006).

Around 80 percent of marine pollution is caused by land-based activities. Pollution, climate change and increased catches have contributed to an unprecedented deterioration in fish stocks in the last 20 years (Gaddis *et al.*, 2012). Although catches more than quadrupled between the early 1950s and the mid-1990s, they have stabilized or diminished since then, despite increased fishing (Gaddis *et al.*, 2012). Some 1 141 fish species are vulnerable to endangerment, 486 are endangered



FAO: TUNGSAGUL GRANT

Children play in clean water in a forest in Thailand. Ecosystems provide clean water for downstream agriculture and for human consumption

These trees in central Sudan have been cut by refugees from a nearby camp who were in search of wood and fodder. Conflict and other shocks and stresses make it more difficult for affected populations to produce and access food and obtain the water and energy needed for food preparation

and 60 are extinct (FAO, 2010; IUCN Red Data List¹). Coastal-zone degradation has resulted in increased human health risks and agricultural losses and the reduced availability of highly valued wild-harvested foods.

Climate change

A range of potential changes to climate, such as reduced rainfall, temperature extremes, rising sea-levels and more frequent floods and droughts, can affect food security. While the impacts of climate change on food production could be positive in some regions, overall they are likely to be detrimental to food security and nutrition. For example, it is estimated that climate change will cause a ten percent increase in the number of malnourished children worldwide by 2050, relative to a “no climate change” future (Committee on World Food Security, 2012). Climate change could also initiate spirals of ecosystem degradation, magnifying the direct impacts of climate change on food security. Extreme weather events could damage food transportation and storage infrastructure, reduce state capacity to respond to crises, increase food prices and yield fluctuations and lead to a deterioration in social cohesion, all of which are likely to increase food insecurity.

Inequitable tenure

Where land tenure is insecure or unclear, or where the state claims legal title, agricultural development tends to favour large-scale over smallholder production. Insecure tenure also acts as a disincentive for local land users to make long-term investments – such as tree-planting – to maintain ecosystem functions and improve



FAO/E. MCDONOUGH

food production. The possibility of the state extending its claim to resources, such as forest carbon as part of climate mitigation policies and medical plants as part of patent protection, remains a real threat to land and natural-resource security for rural communities. Tenure over water and fishery resources is commonly claimed by the state, even when indigenous and other local communities have customary rights.

A recent consequence of insecure, inequitable tenure regimes is the proliferation of foreign investments in land. This expansion – estimated to amount to up to 134 million hectares in Africa and 203 million hectares worldwide between 2000 and 2010 (Anseeuw *et al.*, 2012) – reduces the availability of, and access to, both wild and farmed food for marginalized communities. Many foreign investments in land are for biofuels, minerals, timber and food exports. The rapid expansion of biofuel production is expected to contribute to an increase of up to 3 million undernourished preschool children in Africa and South Asia by 2050 (FAO, 2009).

Conflict

Weak ecosystem governance can heighten conflict and contribute to the primary causes of such conflict by exacerbating

injustice, inequity and poverty. Conflicts over land and water are expected to increase as demand grows for these resources in the face of climate change, increasing population pressure and restrictions on access. Conflicts can have profound impacts on food security by causing institutional decline, worsening social relations and increasing violence, which tend to decrease local food production and increase its cost (Bora *et al.*, 2010; Sayne, 2011; Schöninger, 2006; Teodosijević, 2003). Conflict makes it more difficult for affected populations to produce and access food and obtain the water and energy needed for food preparation. Food insecurity is often compounded by the destruction of rural infrastructure, the loss of livestock, deforestation, the widespread use of landmines, the poisoning of wells, and large-scale population movements caused by conflict.

FOOD SECURITY POLICIES: WHAT'S MISSING?

Development and conservation efforts contribute to food insecurity if they do not take into account the strong connections between food security and ecosystems. High levels of vulnerability to food insecurity among the poorest groups in society are generally linked to a heavy dependence

¹ www.iucnredlist.org

on natural ecosystems that are undergoing rapid degradation and change and to the ecosystem governance systems in place and how they are implemented. When either or both these factors – development and conservation on the one hand and inequitable and exclusionary ecosystem governance on the other – reduce the productivity or accessibility of, for example, wild foods, agricultural crops and water, they undermine livelihoods as well as the social relations that hold communities together. The resulting food insecurity is often accompanied by conflict within and between communities and neglect of the most vulnerable groups, including women and children.

Many food-security policies have improved in the last decade, including by increasingly acknowledging the right to adequate food and the importance of equitable and secure tenure. But the focus generally remains on agricultural productivity, trade and macroeconomic policies, while the central role played by ecosystems in food security continues to be neglected.

Knowledge of the importance of ecosystems to the various dimensions of food security has grown, but there continues to be insufficient investment in maintaining environmental quality, building positive social relationships around natural-resource use (institutions, organizations and learning) and developing linkages between stakeholders and sectors. The idea that there is an inevitable trade-off between agricultural productivity and ecosystem conservation is outdated, given current understanding of the dependence of agriculture on wider ecosystems and the many options for sustainably managing productive ecosystems. There is no choice but to do both – otherwise, food security will remain a pipe dream.

A farmer works the land on the banks of Burera Lake, Rwanda. Few food-security policies acknowledge the importance of maintaining and sustainably managing ecosystems, with the common result that they lead to land degradation and therefore food insecurity

Gaps in food-security policy-making

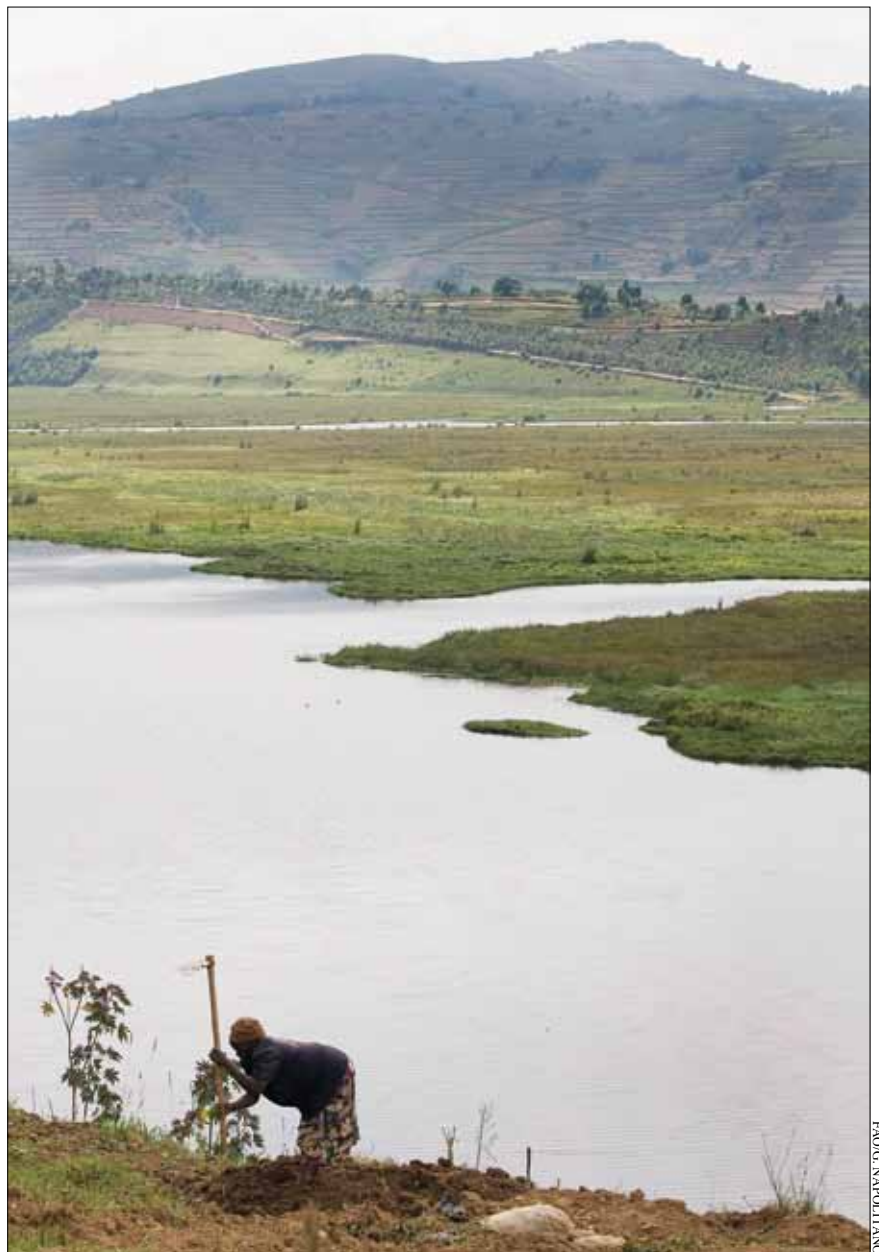
Food-security policies and practices have a number of shortcomings, some of which are discussed below.

Lack of a multisectoral approach.

Food-security issues are too often dealt with in “policy silos”, in which the relevant institutions (e.g. on agriculture, forestry, trade and environment) rarely collaborate to ensure that their various policies are coherent and address food security and

nutrition in consistent ways. This lack of coordination between sectors leads to disconnected, sometimes contradictory policies and the neglect of intersectoral linkages and synergies (e.g. food–water–energy and food–health–nutrition).

Lack of integration of ecosystem factors. Few food-security policies acknowledge the importance of maintaining and sustainably managing ecosystems, with the common result that policies are



FAO/G. NAPOLITANO

ill-informed and ineffective and contribute to ecosystem mismanagement and degradation and therefore to food insecurity.

Lack of participatory decision-making. Key actors are frequently left out of food-security decision-making; consequently, decisions do not always reflect the rights, cultures and interests of local people. Even where some degree of local participation is sought, it is often limited to men. Poor rural communities, smallholders, women and other “front-line” stakeholders are often the primary custodians of ecosystems and are usually the most affected by food insecurity. Policies that ignore their voices are unlikely to be effective.

Commitment to climate-change action. There has been little sign of commitment to redress the underlying drivers of climate change and in particular the patterns of consumption and production that use energy unsustainably and generate unmanageable amounts of pollution and waste. The understanding that ecological degradation will limit opportunities to ensure food security and development opportunities is well-established in the policy and academic literature

(UNEP, 2012; Rockstrom *et al.*, 2009) but largely absent from policy debate about food.

Recognition of wild resources. Food-security and other natural-resource-related policies still fail to acknowledge that wild resources are critical to the food security of a significant proportion of the world’s poorest people. Without this recognition, such policies risk cutting off access to foods such as wild meat and fish, thereby depriving many rural people of vital sources of protein.

HOW TO MAKE FOOD-SECURITY POLICIES MORE EFFECTIVE

Focus on food resilience

Ecosystem-aware food-security policies aim not only to alleviate hunger in the short term but also to build long-term food resilience, which is critical if food-security objectives are to be achieved and sustained in the long term. Ecosystem-aware food-security policies strengthen both:

- the resilience of food-insecure communities to manage uncertainties and stresses such as food-price hikes and climate change;

- the resilience of ecosystems to maintain their support for the production of both wild and farmed foods in the face of shocks such as extreme weather events and stresses such as pollution.

Policy-making can best support food resilience by addressing three key issues: diversity, natural infrastructure and social justice. Each of these is described below.

Diversity

The term diversity is used here to refer to ecosystem, biological and livelihood diversity. Diversity in the ecosystems present in a landscape and the biological resources within these ecosystems can reduce the sensitivity of local people to shocks and stresses (including price volatility) by supporting diverse livelihood and adaptive activities (e.g. agriculture and livestock farming, fisheries, forestry, tourism and hunting). Together, the various aspects of diversity can strengthen food security by reinforcing the resilience of local food systems, and policies that maintain or boost diversity will therefore support food-security objectives. For example, policies that promote diversity within a



A forest ranger monitors wild bird populations in the Lake Ichkeul area in Tunisia. Wetlands help clean effluent, similar to water treatment facilities

FAO/G. NAPOLI/TIANO

cropping system (e.g. crop diversity, soil biodiversity and pollinator diversity) can increase the capacity of agriculture to adapt to fluctuations in growing conditions by (Boelee, Chiramba and Khaka, 2011):

- increasing water availability and thus the resilience of rural livelihoods;
- providing nitrogen-fixing capacity through the incorporation of trees and leguminous crops;
- strengthening habitat connectivity for pollinators through the incorporation of areas of natural habitat.

Natural infrastructure

The term natural infrastructure reflects the ability of ecosystems to deliver some of the same services that can also be provided by engineered infrastructure. For example:

- Forests help provide clean drinking water, similar to water filtration facilities.
- Mangroves help protect shorelines from storm damage, similar to sea walls.
- Natural floodplains help prevent flooding, similar to dikes and canals.
- Wetlands help clean effluent, similar to water treatment facilities.

Natural infrastructure services contribute to the food resilience of communities, for example by protecting farmland against storm surges and safeguarding communities from contaminated drinking water. To help maintain these ecosystem services, food-security policies need to be better integrated with those of other economic sectors, such as environment, forestry, fisheries, tourism and energy.

Social justice

Social justice embodies the ideas of good governance, economic fairness, human rights, solidarity, equality and equity. It is central to food security because it plays a large part in determining access to food within households, communities, societies and nations. Where social justice is weak, there is a high risk of food insecurity, especially among vulnerable and marginalized groups.

By addressing social justice, food-security policies can strengthen food resilience. Critically, support is required for local governance systems, particularly locally managed resource use and locally controlled production. For example, policies that strengthen the organizations of smallholder producers build local resilience by increasing the ability of farmers to set shared priorities, negotiate fair prices and make decisions on the distribution of resources necessary to increase food production.

Other areas that are critical for food security are building good social relations and tackling inequalities, including widespread discrimination against women. Policies can help remove such discrimination by formally recognizing gender equality and implementing specific policies to improve women's food security and productivity. These policies can be as simple as getting potable water into villages: it has been estimated that, in the United Republic of Tanzania (total population of 46 million people), women collectively spend 8 billion hours of unpaid work per year in water and fuel collection and food preparation, which is equivalent to the hours required for 4.6 million full-time jobs (Fontana and Natali, 2008). Other policies that improve productivity include those that secure tenure, increase knowledge, such as by specifically targeting women in agricultural extension, and improve health (FAO, 2011). Social justice cannot be ignored by food-security policy-makers. It is morally and ethically unacceptable that so many people still lack the opportunity to live free from hunger.

WHAT DO EFFECTIVE FOOD-SECURITY POLICIES LOOK LIKE?

To be effective, food-security policies need to be ecosystem-aware and supportive of food resilience by addressing issues of diversity in multiple systems at different scales, natural infrastructure and social justice. Effective food-security policies will also adhere to the following principles.

Effective policies recognize that the services provided by ecosystems are not limitless. This includes the capacity of ecosystems to absorb waste. Policies should tackle land, water and air pollution to help support human and ecosystem health and wild food supplies (such as fish, fruit and wild meat). For example, municipal and industrial wastewater can be treated effectively with existing technologies, but such treatment requires strong regulatory oversight and significant infrastructure investment and capacity-building, especially in developing countries.

Effective policies link across sectors. Food-security policy-making needs to be based on better integration of the various economic and development sectors. In particular, the environment should be better integrated with the policies of those sectors – such as trade, energy, water, health and tourism – that affect the ecosystem services underpinning food security. Such integration will require giving environmental agencies a more central role in developing strategies for achieving food security.

Effective policies see agricultural systems as agro-ecosystems. Agro-ecosystems provide a wide variety of ecosystem services and are linked to other ecosystems. Taking this broader view of how agricultural systems fit within landscapes enables policies to identify and act on opportunities for synergies between crop and livestock production, fisheries and forestry to achieve food security.

Effective policies value ecosystems as productive assets. Food-security policies should recognize the need to maintain natural assets on the grounds that they provide important safety nets for the food-insecure and form the basis of diversified livelihoods. This recognition does not mean abandoning the total protection of particularly fragile or threatened ecosystems, but it does mean looking at protection as one tool in recovering and maintaining ecosystem services and considering interactions between protected areas, neighbouring agro-ecosystems and other sustainably managed ecosystems.

Effective policies support increased investment in off-farm ecosystem assets.

The rationale for such policies is that off-farm ecosystem assets such as forests can strengthen the resilience of smallholder farmers and pastoralists and support diversified livelihood options, including non-agricultural income sources. This reduces the vulnerability of rural poor people to extreme weather events and price shocks. Ensuring that local people are able to use these off-farm opportunities requires financial and technical support for knowledge exchange and learning, as well as robust local organization.

Effective policies strengthen local organization and amplify the voices of rural communities.

Local communities are often the custodians of ecosystems and the managers of food production from both wild and farmed resources and therefore are critical actors in sustaining natural resources and managing conflict over them. Supporting the inclusion of both women and men in local communities – farmers, pastoralists, forest people, shifting cultivators, fisherfolk and other food harvesters and producers – in decision-making about food security can help ensure more appropriate decisions and policies. Food-security policies need to help rural communities engage with other stakeholders in defining solutions, and they should support the recognition of the rights of rural communities to information, transparency, accountability, participation and recourse to justice. ♦



References

- Anseeuw, W., Alden Wily, L., Cotula, L. & Taylor, M. 2012. *Land rights and the rush for land. Findings of the Global Commercial Pressures on Land Research Project*. Rome, International Land Coalition.
- Boelee, E., Chiramba, T. & Khaka, E. eds. 2011. *An ecosystem services approach to water and food security*. Nairobi, United Nations Environment Programme, and Colombo, International Water Management Institute.
- Bora, S., Ceccacci, I., Delgado, C. & Townsend, R. 2010. *Food security and conflict*. Background paper for the World Development Report. Washington, DC, The World Bank.
- Committee on World Food Security. 2012. *Food security and climate change*. High Level Panel of Experts Report 3. Rome, FAO (available at: www.fao.org/fileadmin/user_upload/hlpe/hlpe_documents/HLPE_Reports/HLPE-Report-3-Food_security_and_climate_change-June_2012.pdf).
- Da Silva, J.G. 2012. The US must take biofuel action to prevent a food crisis. *Financial Times*, 9 August 2012 (available at: www.ft.com/intl/cms/s/0/85a36b26-e22a-11e1-b3ff-00144feab49a.html#axzz2392Moy8Z).
- Deininger, K. 2003. *Land policies for growth and poverty reduction*. World Bank Policy Research Report. Washington, DC, The World Bank.
- FAO. 2008. *An introduction to the basic concepts of food security*. Food Security Information for Action. Practical Guides. Rome (available at: www.fao.org/docrep/013/a1936e/a1936e00.pdf).
- FAO. 2009. *How to feed the world in 2050*. Background paper for the How to Feed the World in 2050 Forum, 12–13 October 2009, Rome (available at: www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf).
- FAO. 2010. *The state of the world's fisheries and aquaculture 2010*. Rome.
- FAO. 2011. *The state of food and agriculture 2011: women in agriculture, closing the gender gap*. Rome.
- Fontana, M. & Natali, L. 2008. *Gendered patterns of time use in Tanzania: public investments in infrastructure can help*. Paper prepared for the IFPRI project “Evaluating the long-term impact of gender-focused policy interventions”. Cited in FAO (2011).
- Gaddis, E., Glennie, P.R., Huang, Y. & Rast, W. 2012. Water. In United Nations Environment Programme, *GEO-5 global environment outlook: environment for the future we want*. Nairobi, United Nations Environment Programme.
- future we want. Nairobi, United Nations Environment Programme.
- Greiber, T. & Schiele, S. eds. 2011. *Governance of ecosystem services*. Gland, Switzerland, IUCN.
- IFRC. 2005. *World disaster report 2005*. Geneva, Switzerland, International Federation of Red Cross and Red Crescent Societies.
- Pimentel, D., McNair, M., Buck, L., Pimentel, M. & Kamil, J. 1997. The value of forests to world food security. *Human Ecology*, 25: 91–120.
- Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin III, F.S., Lambin, E., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H., Nykvist, B., De Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P. & Foley, J. 2009. Planetary boundaries: exploring the safe operating space for humanity. *Ecology and Society*, 14(2): 32 (available at: www.ecologyandsociety.org/vol14/iss2/art32/).
- Sanchez, P., Swaminathan, P.D., Dobie, P. & Yuksel, N. 2005. *Halving hunger: it can be done*. New York, USA, Millennium Project.
- Sayne, A. 2011. *Climate change adaptation and conflict in Nigeria. Special report*. United States Institute of Peace.
- Schöninger, I. ed. 2006. *The challenge of hunger: global hunger index: facts, determinants, and trends*. Washington, DC, International Food Policy Research Institute.
- Sunderland, T.C.H. 2011. Food security: why biodiversity is important. *International Forestry Review*, 13(3): 265–274.
- Teodosijevic, S. 2003. *Armed conflicts and food security*. ESA Working Paper No. 3-11. Rome, FAO.
- UNEP. 2006. *The state of the marine environment: trends and processes*. The Hague, United Nations Environment Programme.
- UNEP. 2012. *GEO-5 global environment outlook: environment for the future we want*. Nairobi, United Nations Environment Programme. ♦