Food and Agriculture Organization of the United Nations

FAO Inclusive Agrifood Systems Working Papers 25-03

Natural resources for resilient, inclusive rural transformation

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FAO Inclusive Agrifood Systems Working Papers No. 3

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Rome, 2025

Required citation:
Meybeck, A., Opio, C., Gitz, V., Gordes, A., Cintori, L., Albinelli, I., Boscolo, M., Bahri, T., Berrahmouni, N., Cavatassi, R. and Li. Y. 2025. *Natural resources for resilient, inclusive rural transformation.* FAO Inclusive Agrifood Systems Working Papers, No. 3. Rome, FAO. https://doi.org/10.4060/cd5784en

ISBN 978-92-5-139900-2

Abstract

The purpose of this paper is to consider the role of natural resources in resilient and inclusive rural transformation. It starts by reviewing the availability of land and water for future agricultural development. Then, it recalls the specific dependence of poor and vulnerable groups on natural resources. Finally, the paper explores means to improve natural resources management to ensure contribution to resilient and inclusive rural transformation.

FAO projects that 165 million additional hectares (ha) of arable land will be needed by 2050, while urban expansion, land degradation and climate change will reduce highly suitable land for rainfed crops by 250 million ha. Rural communities, and especially the most vulnerable groups, strongly rely for their livelihoods, food security, and income on natural resources, including ecosystem services and wild resources. Increasing scarcity, unequal distribution of and competition over resource use, exacerbated by climate change, question the capacity of current models of agriculture growth to sustain inclusive and resilient rural development.

This paper identifies four pathways for natural resource management to support resilient and inclusive agricultural development: resource use efficiency; diversification; sustainable bioeconomy; and landscape approaches. Combining these pathways can help address trade-offs, such as that between maximizing economic benefits from resource extraction and optimizing employment and food production. Inclusive governance and strong stakeholder engagement are needed to address challenges related to wealth and power imbalances among stakeholders, as well as unclear property and use rights. Policies and investments should support improved efficiency in the use of natural resources at all scales, including through development of the bioeconomy; and ensure integrated adaptive natural resources management through inclusive institutions, policies, better governance and integrated planning.

Keywords: natural resources, sustainability, land and water, bioeconomy

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Acknowledgements

Two convenings supported the development of this manuscript and were funded in part by the Bill & Melinda Gates Foundation (Gates Foundation). Paolo d'Odorico (University of California, Berkeley) and Paxina Chileshe (IFAD) provided very valuable comments on the working paper during the expert consultation. Thanks are extended to all the experts who participated in the "Expert consultation on Shaping priorities for investment in resilient, inclusive rural transformation (RITI)", held from 14 to 16 June 2023 and organized by FAO Rural Transformation and Gender Equality Division, which helped sharpen the paper. Garima Bhalla (FAO), Benjamin Davis (FAO), Leslie Lipper (Independent consultant) and Nicholas Sitko (FAO) provided valuable comments on a previous version.

Finally, we are grateful for the editorial support provided by Sarah Pasetto and layout design provided by Virginie Matterne.

Abbreviations

BAU	business as usual
BECCS	bioenergy with carbon capture and storage
CCS	carbon capture and storage
CDR	carbon dioxide removal
CIFOR	Center for International Forestry Research
CSA	Climate-Smart Agriculture
EAP	East Asia and the Pacific
FSN	Food Security and Nutrition
GAEZ	Global Agro-Ecological Zones
GHG	greenhouse gases
GDP	gross domestic product
Gt	giga tonnes
IIASA	International Institute for Applied Systems Analysis
INBAR	International Bamboo and Rattan Organization
IPCC	Intergovernmental Panel on Climate Change
HLPE	High Level Panel of Experts on Food Security and Nutrition
LAC	Latin America and the Caribbean
LIFDCs	low-income food deficit countries
LMICs	low- and middle-income countries
Mha	million hectares
Mt	million tonnes
NDC	Nationally Determined Contribution
NNA	Near East and North Africa
PES	payment for ecosystem services
RITI	resilient, inclusive rural transformation
SAS	South Asia
SSA	sub-Saharan Africa
SSP	shared socioeconomic pathways
SIDS	Small Island Developing States
USD	United States Dollars

Introduction

Agriculture, including crops and livestock production, forestry, fisheries and aquaculture, is totally dependent on natural resources. The availability and accessibility of natural resources thus condition agricultural development and its contribution to resilient and inclusive rural development. Globally, agricultural production more than tripled between 1960 and 2015, thanks to technological improvements and a significant expansion in the use of land, water and other natural resources for agricultural purposes (FAO, 2017). The sustainability of economic development is strictly dependent on protecting and sustainably managing natural resources. This is even more true with regard to low-income countries and rural dwellers, who are among the poorest segments of the population and whose livelihoods depend directly on natural resources (Masiero *et al.,* 2019). In low- and middle-income countries, almost 3.4 billion people live in rural areas (UNDESA, 2019); most of these people still depend, albeit to varying degrees, on agriculture and food systems for their livelihoods. Critically, this rural population includes a large majority of those who are extremely and moderately poor (UNDESA, 2021). Addressing persistent poverty, climate change, and evolving nutritional challenges demands comprehensive re-evaluation of rural development approaches.

Many of the natural resources on which agriculture production depends – including land, water, energy, nutrients, biodiversity – are being depleted and degraded at alarming rates. The sustained availability and quality of land, water and other natural resources for further agricultural development as well as their accessibility for the most vulnerable who depend on them for their food security and livelihoods are also compromised by competing demands for economic and environmental objectives, including carbon sequestration and biodiversity conservation. Moreover, growing demand and increasing global population put additional pressure on increasingly scarce land (IFAD, 2021; Lipper *et al.*, 2022). Competition for land, water and nutrients shapes the evolution of landscapes and land uses. Concerns about the capacity of nature to further withstand population growth and economic development have been strongly articulated by Thomas Malthus in the end of the eighteenth century (Malthus, 1798). While technological innovations have enabled productivity increases, growing understanding of planetary limits and tipping points is drawing renewed attention to the mounting pressures on natural resources (Lambin, 2012). Together with more acute awareness of persisting shortfalls in human well-being and growing inequalities, this leads to question traditional approaches to economic development. In a powerful figure Kate Raworth has represented the “safe and just space for humanity” as a doughnut, between the social foundation of human well- being and the ecological ceiling of planetary boundaries (Raworth, 2017).

Rural communities, Indigenous Peoples, women and vulnerable groups often depend on multiple sources for their food security and livelihoods, combining cultivation, livestock, forestry and agroforestry, fisheries, all of which depend on the availability, accessibility and sustainable management of natural resources. This has been gradually acknowledged over the last decades in discussions around the notion of food security and nutrition (FSN) and the sustainability of food systems. The High Level Panel of Experts on Food Security and Nutrition (HLPE-FSN) has explicitly defined the sustainability of food systems according to their capacity to provide FSN to all, now and in the future. "A sustainable food system is a food system that ensures food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition of future generations are not compromised" (HLPE, 2014, p. 31). There can be no food security without sustainability (Berry *et al.*, 2015). These reflections led the High Level Panel of Experts on Food Security and Nutrition (HLPE-FSN) to consider sustainability[1] as a dimension of food security, adding also "agency"[2] and to propose a six-dimensional framework for food security in its 15th report: *Building a Global Narrative Towards 2030* (HLPE, 2020).

This paper aims to understand how the availability, distribution and management of natural resources (land, water, genetic resources, harvested wild species, forests and trees, fish and aquatic foods) affect the inclusivity and resilience of agrifood systems. The paper also seeks to explore possible pathways for resilient and inclusive rural transformations. It gives particular attention to livestock, forestry and fisheries, which often receive less attention than crops in the literature on agriculture development.

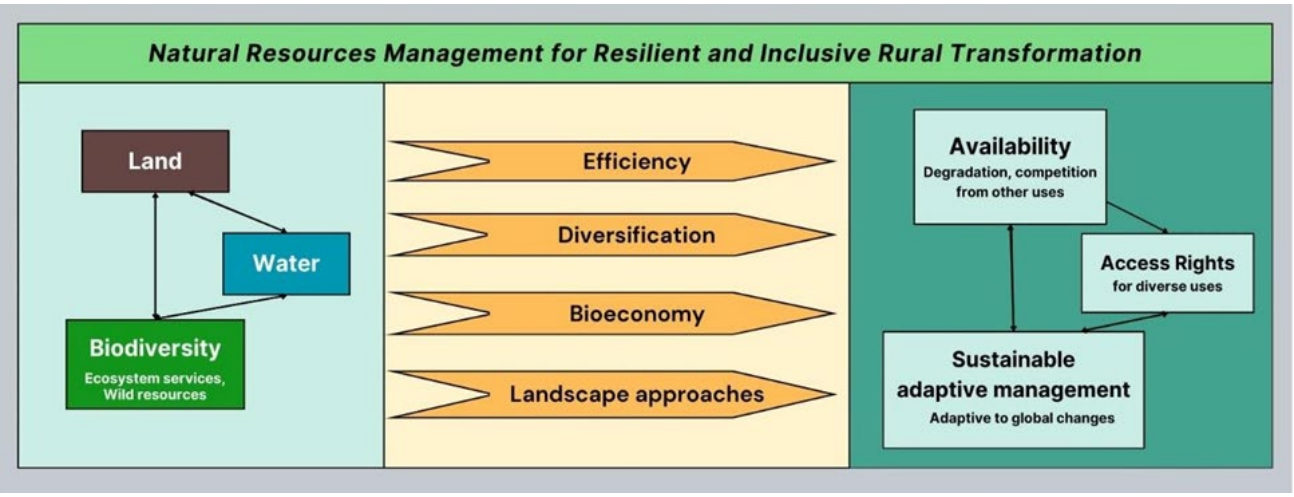
Section 1 of this paper considers the contribution of natural resources to rural transformation, focusing on land availability, on the role of irrigation and livestock for intensification, the contributions of fisheries and aquaculture and the impacts of agriculture development on natural resources. Section 2 considers natural resources for rural development in the context of poverty eradication, improved nutrition and climate change. Section 3 considers four pathways to maximize sustainable natural resources management for resilient and inclusive transformation in rural areas: better use for efficiency and resilience, diversification, the development of bioeconomy, and landscape approaches that aim to reconcile different land and water uses and objectives. Section 4 analyses constraints and trade-offs in order to make recommendations for supportive policies and investments to

[1] Sustainability refers to the long-term ability of food systems to provide food security and nutrition in a way that does not compromise the economic, social and environmental bases that generate food security and nutrition for future generations. (HLPE, 2020, p. XV)

2 Agency refers to the capacity of individuals and groups to exercise voice and make decisions about their food systems; sustainability refers to the long-term viability of the ecological and social bases of food systems (Clapp *et al.,* 2022, p.4).

optimize natural resources management for resilient, inclusive rural transformation (RITI). Section 5 draws conclusions.

Figure 1. Natural resources management for resilient and inclusive rural development



Source: Authors' own elaboration.

1. Natural resources: the basis for rural transformation

Globally, agricultural production more than tripled between 1960 and 2015, thanks to technological improvements and a significant expansion in the use of land, water and other natural resources for agricultural purposes (FAO, 2017). However, the sustained availability of land and water and other natural resources for further agriculture development now seems increasingly uncertain, given the effects of climate change. Additionally, other economic sectors and environmental objectives – particularly carbon sequestration and biodiversity conservation – exert competing pressures and demands on natural resources.

1.1 Availability of land for rural transformation

Worldwide, between 1961 and 2019, agricultural land[3] has increased to reach 4.75 billion hectares (ha) today, or around 37 percent of total land area. Cropland has grown by 15 percent, reaching 1.56 billion ha. Since 1950, about 700 million ha of forest have been lost to crops and pastures.

The Global Agro-Ecological Zones (GAEZ) analysis combines soil, terrain and climate characteristics with crop production requirements to estimate land suitability for crop production. Data from FAO-IIASA (International Institute for Applied Systems Analysis) GAEZ v4 (2021) enables estimation of available land with high potential for crop production. Globally, the area of suitable land for irrigated and rainfed agricultural systems amounts to 2.7 million ha and 2.1 million ha, respectively. Deducting areas already under agriculture use, urban use or forest cover and excluding protected areas (615 million ha today globally, according to FAO-IIASA GAEZ v4), around 400 million ha of highly suitable land remain for rainfed agriculture expansion, or around 26 percent of the arable area in use today. More

[3] **Agricultural land** is defined as “land used for cultivation of crops and animal husbandry. The total of areas under ''Cropland'' and Permanent meadows and pastures.” **Cropland** is defined as “land used for cultivation of crops. The total of areas under arable land and permanent crops.” **Arable land** is defined as “the total of areas under temporary crops, temporary meadows and pastures, and land with temporary fallow. Arable land does not include land that is potentially cultivable but is not normally cultivated.” **Land under permanent crops** is defined as “land cultivated with long-term crops which do not have to be replanted for several years (such as cocoa and coffee), land under trees and shrubs producing flowers (such as roses and jasmine), and nurseries (except those for forest trees, which should be classified under "Forestry"). **Permanent meadows and pastures** are used permanently (five years or more) to grow herbaceous forage crops through cultivation or naturally (wild prairie or grazing land). (FAO, 2022d).

than two-thirds of this land is located in low- and middle- income countries, 29 percent in sub-Saharan Africa (SSA) and 21 percent in Latin America and the Caribbean (FAO, 2018a).[4]

FAO (2018a) projects that under its business as usual (BAU) scenario, 165 million ha of additional arable land will be needed by 2050. Over the same period, urban expansion, land degradation and climate change will further reduce highly suitable land for rainfed crops by 250 million ha. Due to rapid urbanization trends, urban land area could triple by mid-century (Lwasa *et al.*, 2022) and consume up to 5 percent of current cultivated land (Jia *et al.,* 2019). Urban sprawl also puts a high pressure on peri-urban farms, often among the most productive (FAO and ITPS 2015, Jia *et al.* 2019, UNEP 2019). It is estimated that urban expansion will result in a loss of cropland of between 1.8 percent and 2.4 percent, mostly in Asia and Africa (Bren d'Amour *et al.*, 2016), which corresponds to a loss of 1.6 million to 3.3 million ha per year (Lambin and Meyfroidt, 2011). Bren d'Amour *et al.* (2016) estimate that 80 percent of cropland loss due to urbanization will occur in Asia and Africa, moreover, involving highly fertile cropland that is more than twice as productive as the global average.

Estimations of "available land" generally do not take into account extensive and informal uses, nor ecosystem services provided. Yet, any change of use is likely to modify ecosystem services and to exclude informal users, who are often among the most vulnerable and marginalized people (Place *et al.,* 2013). In this regard the term of "marginal land" deserves specific consideration. The notion and scope are not well defined, giving rise to various estimations of surface (Lewandowski, 2015). Three important caveats to their use need to be highlighted. First, such land is often economically marginal, meaning that its exploitation would give low economic returns. Second, often it is already used, at least partially, by smallholder farmers or pastoralists who generally hold traditional or informal rights. Third, their transformation might result in significant biodiversity loss and environmental degradation.

The global scarcity of suitable land for rainfed crop expansion is exacerbated by its highly unequal distribution. Even without taking into account urbanization and land degradation, in Near East and North Africa (NENA) and East Asia and the Pacific (EAP) (excluding China) the area of exploited arable land is already close to the existing total area of very suitable unprotected available land. Under BAU, arable land might become scarce by 2050 in sub-Saharan Africa (SSA) and South Asia (SAS) (FAO, 2018a). Moreover, this maldistribution does not favor the countries that need the most to produce more in the future (Alexandratos, 2005). The average per capita availability of cultivated land in low-income countries is less

[4] This estimate, however, includes areas that are no longer cultivated because their productivity has decreased due to land degradation.

than half that of high-income countries. The suitability of land for cropping is also generally lower. There tends to be a strong link between poverty and lack of access to land and water (FAO, 2011). This is likely to be exacerbated by population growth particularly in some countries. Additionally, average farm size has declined in many places, often widening land inequality and impeding the adoption of more sustainable land use practices, such as land fallowing.

1.2 Intensification of natural resources use for rural transformation

This section considers three specific modes of intensification of the use of natural resources. The first one is irrigation that allows to produce more products and value on the same land area. The second is livestock that allows to use land improper for crop cultivation, to give value to biomass otherwise not consumed and to increase economic return through transformation of plants in animal products. The third one uses the example of fisheries and aquaculture to illustrate the increase of production harvested from the wild as well as through domestication.

1.2.1 Irrigation

Irrigation allows producers greater liberty in the choice of species, varieties and agronomic practices in their climatic conditions even with low and irregular precipitation. It allows for higher yields and, in many cases multiple harvests, acting in a way as a "land multiplier". Well-managed irrigation systems can also buffer seasonal gaps in diets (Ringler *et al.*, 2022). Finally, irrigation ensures more stable yields, in spite of climate variability, particularly rainfall pattern changes.

The global area equipped for irrigation more than doubled between 1961 and 2022, from 161 million hectares (Mha) to 353 million ha (FAO, 2022d). While representing only about 20 percent of total cropland, irrigated areas account for 40 percent of global food production, 47 percent of all crop production and almost 60 percent of cereal production (FAO and ITPS, 2015; IPBES, 2018). However, this masks discrepancies between regions. In Asia, 39 percent of the cultivated area is irrigated, or about 70 percent of the world area equipped for irrigation, with India and China together accounting for 40 percent. The region with the least irrigation is SSA, where only 3 percent of cultivated land is irrigated.

According to FAO's BAU scenario (FAO, 2018a), globally, irrigated areas are projected to grow slightly faster (13 percent) than rainfed areas (10 percent) by 2050, with irrigation partly expanding into new areas but mostly through the conversion of rainfed ones. This expansion is forecast mainly in regions where arable land is expected to expand and sufficient water resources are available, such as East Asia and the Pacific (EAP) (excluding China) and some countries in Latin America and the Caribbean and SSA. However, in regions where water

resources are already under stress, such as South Asia, NENA and parts of East and Central Africa, there is no margin for expansion and irrigated areas may even contract.

Water scarcity and growing competition from other economic activities are constraining the current availability of water for irrigation and further expansion of irrigated areas. It is estimated that, on average, a withdrawal rate from all sectors above 20 percent of renewable water resources represents substantial pressure on water resources – and that more than 40 percent is "critical" (FAO, 2012). In some cases, when extracting from non-renewable aquifers, withdrawals can exceed 100 percent of total renewable resources. The intensive agricultural economies of Asia already withdraw 20 percent of their internal renewable resources, of which more than 80 percent goes to irrigation. In many low-rainfall regions of NENA and Central Asia, most of the exploitable water is already withdrawn, with 80–90 percent going to agriculture; rivers and aquifers being depleted beyond sustainable levels (FAO, 2011). Certain regions already experience severe water scarcity, such as Western, Central and South Asia, which use half or more of their water resources for irrigation, and in Northern Africa, where withdrawals for irrigation can exceed renewable resources through use of groundwater and recycling treated water for agriculture. In other areas, particularly in sub-Saharan Africa, there is still an important potential for developing irrigation with appropriate investments for both large- and small-scale irrigation, but economic viability depends on containing costs (You *et al.*, 2010). Lack of available water can be aggravated by issues of water quality. In China, 21 percent of available surface water resources are too polluted to be used for agriculture (2030 Water Resources Group, 2009). Water scarcity worsens land scarcity, and it has been noted that international investments in land are often in fact focusing on water resources (HLPE, 2011).

1.2.2 Livestock systems

Along with technological improvements in crop farming systems, livestock systems play a considerable role in agriculture development, as a very effective way of intensifying production by increasing the produce value of the same amount of land. Livestock systems currently represent an average of 40 percent of agricultural gross domestic product globally, (50 percent in high-income countries, 25 percent in low and middle-income countries (LMICs); with substantial growth expected in developing countries. Livestock-keeping is a pathway out of poverty, particularly for women and vulnerable groups, increasing income on small farms (poultry, pigs, dairy) and allowing smallholders to transition out of poverty. In some places, including semi-arid areas, mountains and wetlands, it is the only form of agriculture that can be practiced. Livestock can create value by utilizing feedstock that cannot be used as human food, such as crop residues and by-products. Currently, 86 percent of global livestock feed is non-edible to humans of which 46 percent stems from grass and leaves, 19 percent from crop residues, 8 percent from fodder crops, 5 percent from oilseed cakes, 5 percent from by-products and 3 percent from other non-edibles (Mottet *et al.,* 2017). In many Asian countries, for example in India, Bangladesh, Pakistan, Myanmar and

Indonesia, ruminant production is largely based on crop residues and agro-industrial by-products. To address the feed deficit in India the Government provides incentives to promote technologies that utilize crop residues. Under the National Livestock Mission Scheme, the Government of India provides a 50 percent capital subsidy for setting up fodder block production units. The subsidy provides an incentive for cattle feed entrepreneurs and dairy cooperatives to take up the commercial manufacture of densified complete feed blocks on a large scale (Government of India, 2021).

The progress of the livestock sector was largely based on productivity increases brought about by a broad application of science and advanced technology in feeding and nutrition, genetics and reproduction, and animal health control as well as general improvements in animal husbandry. However, livestock systems draw heavily on natural resources, emit greenhouse gases (GHGs) and, if not managed in a sustainable way, can contribute to detrimental land-use change, land degradation and pollution (Section 1.3).

1.2.3 Fisheries and aquaculture

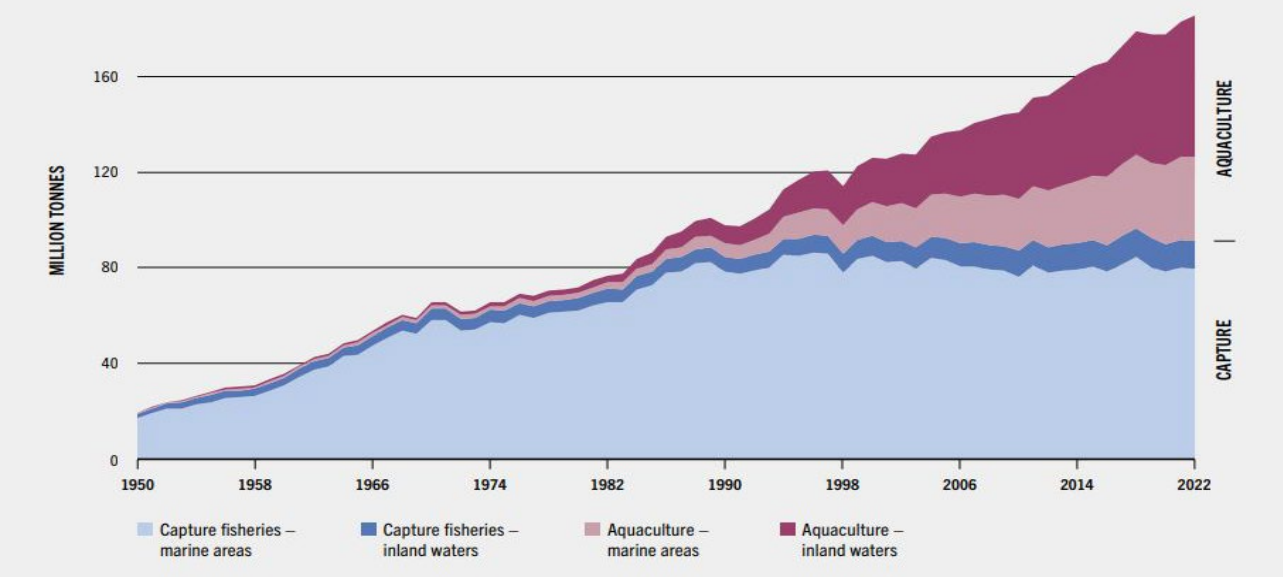
Fisheries and aquaculture provide income and nutrition to many people, including vulnerable populations, particularly in coastal areas and Small Island Developing States. Globally, in 2022, fisheries and aquaculture systems produced 223.2 million tonnes (live weight equivalent) of food, an all-time record (FAO, 2024). Aquatic systems are increasingly recognized for the environmentally sound solutions they offer to sustain food security, poverty alleviation and socioeconomic development (FAO, 2024). Aquaculture enables increasing production of aquatic foods above levels that can be sustainably harvested in the wild. It is the fastest-growing food production system, with production multiplied more than fourfold between 1990 and 2020 (FAO, 2022a), contributing significantly to rural development. In 2022, an estimated 61.8 million people globally were employed in the primary sector, across both marine and inland operations (FAO, 2024). The industry furthermore contributes to employment in processing, transportation, marketing and distribution, fostering economic growth and reducing poverty. Sex-disaggregated data indicate that 24 percent of fishers and fish farmers, and 62 percent of processing workers, were women (FAO, 2024). Taking into account subsistence and secondary-sector workers and their families, it is estimated that the livelihoods of around 600 million people depend at least partially on fisheries and aquaculture (FAO, 2022a). In 2022, international trade of fisheries and aquaculture products generated around 195 billion United States Dollars (USD) (FAO, 2024). Total net trade of aquatic animal products reached USD 45 billion in LMICs, exceeding that of all other agricultural products combined (FAO, 2024).

Assessments have been made of the extent to which fisheries contribute to national gross domestic product (GDP) in various countries. For Malawi, Mozambique and Sierra Leone, data collected for small-scale fisheries was compared to published figures on total capture fisheries contribution to national GDP. It shows the importance of small- scale fisheries,

probably often underreported as shown by numbers that in some cases exceed the total contribution of fisheries to GDP. In Malawi for instance, estimates for fisheries contribution to GDP range from 1.2 and 7.2 percent between 2017 and 2018, with the value added by small-scale fisheries as a percentage of fisheries GDP within a range of 30 to 180 percent (FAO, Duke University and WorldFish, 2023; Torell *et al.*, 2020; Government of Malawi, 2019). In Sierra Leone, fisheries were found to contribute 9.1 percent of the national GDP in 2010 and 10.2 percent in 2013, and the value added by small-scale fisheries as a percentage of fisheries GDP was estimated to be between 45 and 50 percent (FAO, Duke University and WorldFish, 2023; FAO, 2010; Neiland *et al.*, 2016). Mozambique's case indicates that fisheries contribute approximately 3 to 4 percent of the national GDP, while the value added by small-scale fisheries as a percentage of fisheries GDP falls within the range of 135 to 180 percent (FAO, Duke University and WorldFish, 2023; Benkenstein, 2013).

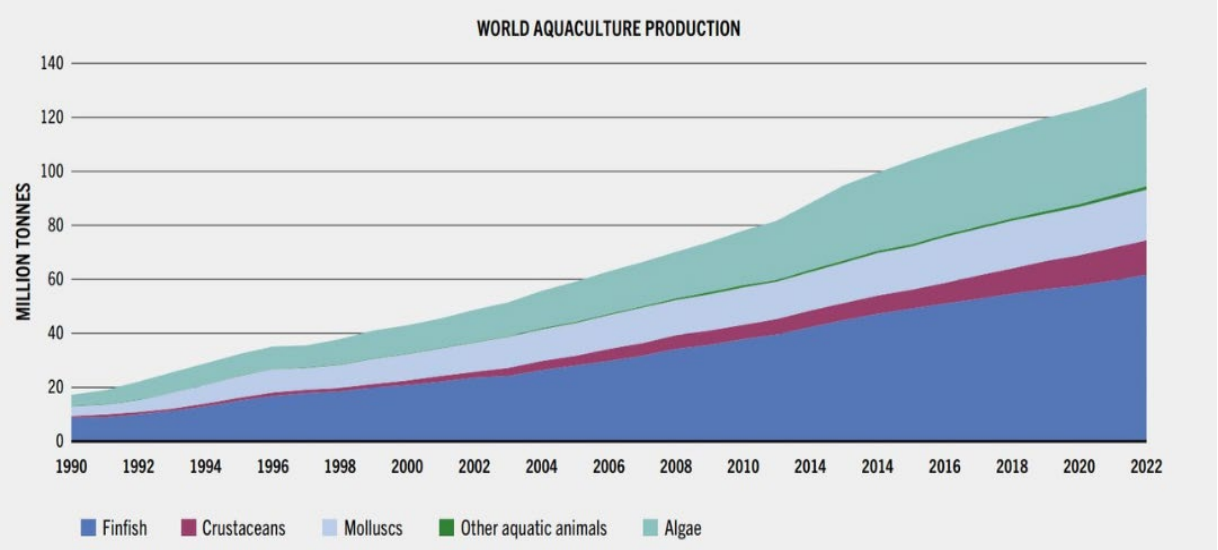
Small-scale fisheries and aquaculture systems make direct and indirect contributions to food security. They make affordable fish accessible to marginalized and vulnerable populations in developing countries, sustaining their livelihoods (HLPE, 2014a). A substantial proportion of small-scale fisheries' landings is directed to consumers in local or regional markets. This is especially true for inland fisheries, as 94 percent of the small-scale inland production is consumed within the country of origin (HLPE, 2014a, Mills *et al.*, 2011). FAO reported an inland fisheries catch of 11.3 million tonnes in 2022 (FAO, 2024). Almost 95 percent of the world's inland fisheries are caught and consumed in developing countries (Ainsworth, Cowx and Funge-Smith, 2021; Bartley *et al.*, 2015; FAO and WorldFish, 2008).

Figure 2. Global fisheries and aquaculture production



Source: ***FAO.*** *2024. The State of World Fisheries and Aquaculture, Blue Transformation in Action. Rome. https://openknowledge.fao.org/items/06690fd0-d133-424c-9673-1849e414543d*

Figure 3. World aquaculture production from 1990 to 2022



Source: ***FAO. 2024.*** *The State of World Fisheries and Aquaculture: Blue Transformation in Action. Rome. https://openknowledge.fao.org/items/06690fd0-d133-424c-9673-1849e414543d*

On a global scale, the contribution of aquaculture to total aquatic food production (excluding algae) has climbed steadily (Figure 3). In 2022, for the first time, production of animal species from aquaculture surpassed that from capture fisheries, with 130.9 million tonnes of food (live weight equivalent) produced (FAO, 2024). Of these, 94.4 million tonnes were aquatic animals and 36.5 million tonnes algae (wet weight) (FAO, 2024). Aquaculture has significantly boosted fish availability worldwide, according to FAO (2022e), the global annual growth rate of 4.3 percent between 2011 and 2020, and created a more competitive market, generally offering fish at lower prices compared to wild-caught fish. The pace of growth, for some developing countries, had been incredibly high, with Tanzania, Kenya and Ghana experiencing an annual growth rate of approximately 35 to 40 percent (FAO, 2022e). Aquaculture products help people in developing countries exit poverty and afford nutritional diets. In Africa, the renewed focus on local trade of products could provide a further stimulus for aquaculture, which has been contending with production challenges. Increased demand for fish by the growing population could also boost investments in peri-urban aquaculture (HLPE, 2014a). Aquatic animal production is forecast to grow another 14 percent by 2030, mainly driven by the growth of aquaculture.

1.3 Agricultural development has often degraded the natural resources base for future development

The significant achievements of the last century – during which per capita food supply increased around the world – came at a cost. The agricultural sector uses a significant amount of natural resources and emits a considerable quantity of GHGs. Many natural resources on which agriculture production depends (including land, water, energy, nutrients

and biodiversity) are being depleted and degraded at growing rates, effectively "borrowing" against their future integrity.

Many studies have tried to assess the global extent and severity of land degradation (IPBES 2018; Olsson *et al.* 2019). According to FAO, human-induced degradation affects 35 percent (1,660 million ha) of agricultural land (FAO, 2021a). Inappropriate tillage practices can lead to soil erosion or compaction. Poor irrigation practices generate soil salinization. Overfertilization and inefficient fertilization adversely affect the environment, including soil acidification, accumulation of heavy metals, increased GHG emissions and air pollution, nutrient leaching and eutrophication of water bodies (FAO and ITPS, 2015; IPBES, 2018; Olsson *et al.*, 2019). Up to 1.5 billion people worldwide rely on degraded lands for their subsistence and livelihood, and over 40 percent of the world's poor people live within degraded areas (IPBES, 2018). Land degradation could cost up to USD 10.6 trillion annually (ELD Initiative, 2015).

Around 420 million ha of forest have been lost worldwide through deforestation since 1990. Over the same time, afforestation, landscape restoration and natural forest expansion have reduced the net loss of forest area to 178 million ha. More than 90 percent of deforestation is taking place in the tropics. There is an apparent correlation between net forest change and national income, with poorest countries suffering from net forest loss, many middle-income countries transitioning from net forest loss to net forest gain, and high-income countries generally experiencing net forest gains. Beyond income, other factors such as land use and forest management policies or market opportunities, also play an important role in the evolution of forest area (Keenan *et al.*, 2015; Sloan and Sayer, 2015; HLPE, 2017). Agricultural expansion has been identified as a major, if not the main, driver of deforestation, especially in Latin America and the Caribbean (IPBES, 2018). Almost 90 percent of deforestation between 2000 and 2018 was related to agriculture (FAO, 2022b). Further, grasslands may be converted into croplands, explaining the global decrease in rangeland area observed since the early 2000s (FAO, 2021b). In turn, degradation of grasslands and croplands drives further deforestation.

Cropland expansion has been accompanied by a continuing decline in crop diversity and a dramatic simplification of cropping systems (IPBES, 2018). There are at least 12 650 edible plant species, of which 7 000 have already been harvested or cultivated by humans to a significant extent over the past millennia (Kahane *et al.* 2013). Yet, in 2020, the top 20 crops covered 74 percent of global cropland area, while the top 4 crops – wheat, maize, rice and soybean – covered 45 percent, compared with only 55 percent and 33 percent respectively in 1961 (FAO, 2021b). Simplification and specialization contribute to homogenizing world diets, reducing dietary quality and diversity and also reduce farms' resilience to economic and ecological shocks and challenges, including climate change. This trend is self-reinforcing as public and private investments in agricultural research, development and commercial plant breeding privilege the most cultivated staple crops and oilseeds at the expense of

other crops, often called “orphan crops”, many of which are of particular nutritional and economic importance for smallholders and marginalized groups (HLPE, 2016; HLPE, 2017).

Agriculture has been identified as a major cause of biodiversity loss and ecosystem degradation with accompanying reduction of all ecosystem services on which agriculture is depending. For instance, forests and trees play a crucial role in water availability; they stimulate rainfall, contribute to water infiltration in the soil and to retrieve it during the dry season, with regulating effects from the field to local, regional and even continental levels, through atmospheric fluxes of water (Ellison *et al.*, 2017). Deforestation has thus major effects on water availability and regulation. Animal pollination is essential for the reproduction of more than three-quarters of flowering plants including many culturally and economically important plants (IPBES, 2016), such that the decline of pollinators is of concern for the cultivation of numerous crops, including many that are important for a diversified and balanced diet. Land use change, land management and pesticides are considered very important drivers of pollinators decline in most regions of the world (Dicks *et al.*, 2021). Landscape simplification affects ecosystem services by reducing the abundance and diversity of service-providing organisms for both pollination and pest control, resulting in lower crop production (Dainese *et al.* ,2019). Overall, this loss of diversity, including genetic diversity, undermines the resilience of many agricultural systems to climate change, pests and diseases, as well as to economic shocks on specific value chains.

Harvesting of wild resources requires careful management to be sustainable. Globally, populations of many terrestrial animals are declining because of unsustainable practices. Approximately 34 percent of marine wild fish stocks are overfished, and an estimated 12 percent of wild tree species are threatened by unsustainable logging (Barron *et al.,* 2022). Pollution and ocean acidification may deteriorate tropical and subtropical reefs and reduce fish availability. Combined with the poleward migration of many fish stocks due to warming waters, this can result in severe detrimental impacts on nutritionally vulnerable populations in low-income food deficit countries (LIFDCs), who rely on fish for micronutrients, animal protein and livelihoods (UN Nutrition, 2021; Golden *et al.,* 2016; Landrigan *et al.,* 2020).

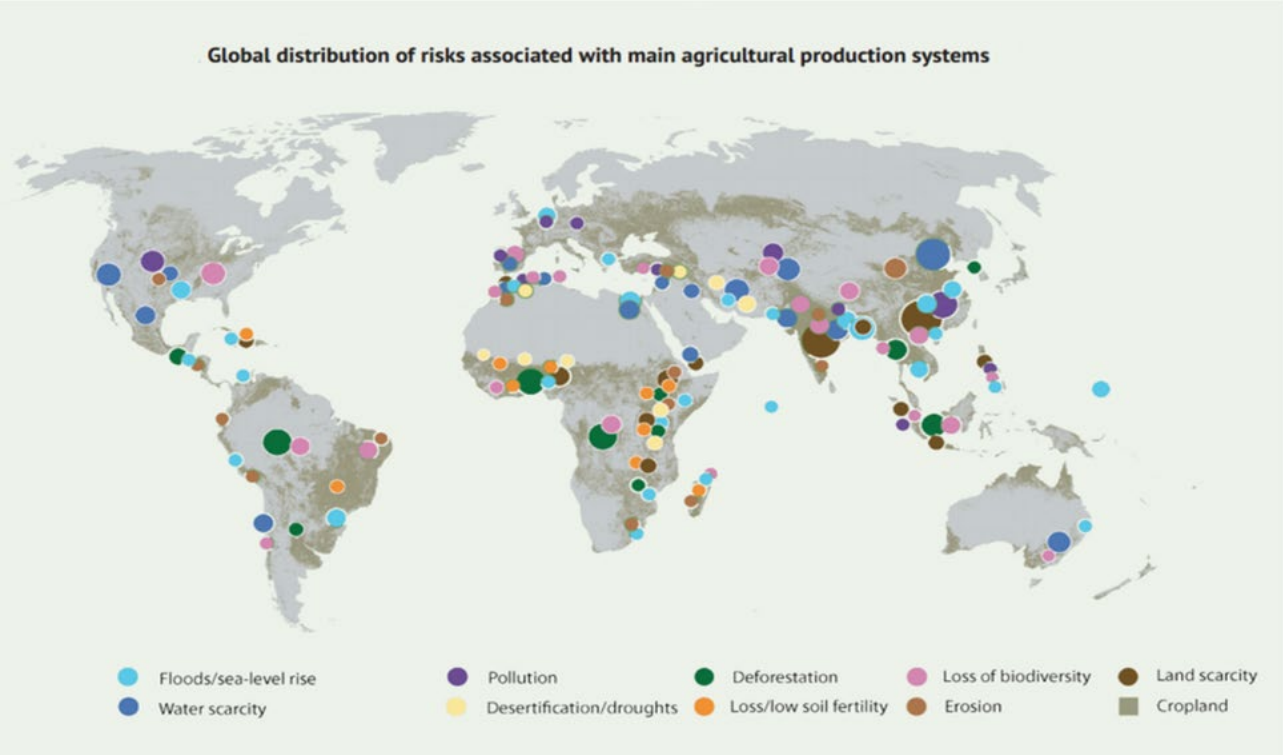
Livestock development has a considerable impact on the environment, biodiversity and ecosystems. Livestock systems are the biggest users of agricultural land. While a large proportion of grasslands cannot be cropped (1.3 billion ha), poor grazing management causes land degradation and biodiversity loss. Many of the world's grasslands are in poor condition and showing signs of degradation caused by a variety of reasons, mostly related to overgrazing and the resulting soil erosion and weed encroachment. The impacts are particularly pronounced in drylands, where 69 percent of global livestock production occurs and where it is often the only viable agricultural activity (Mottet *et al.*, 2017). Livestock consume approximately one-third of global cereal production (Mottet *et al.*, 2017). Animal feed crops now account globally for 33–39 percent of all croplands and explain half of the additional cropland production since 1963 (HLPE 2016; IPBES 2018). The sector contributes

significantly to total anthropogenic GHG emissions (Gerber *et al.*, 2013), uses significant amounts of the world's freshwater, emits around one-third of human-induced nitrogen emissions (Uwizeye *et al.,* 2020) and contributes to phosphorus losses, which can have significant negative impacts on water quality. While intensive livestock systems often reduce GHG emissions per unit of protein produced (Gerber *et al.*, 2013), the waste streams from intensive production systems can result in air pollution, water contamination, human health impacts and water eutrophication.

The question is to what extent and how the natural resources base will be able to continue sustaining the growth of agriculture and its contribution to economic development and poverty eradication, also given competing demands by other economic sectors and nature conservation, in a context of climate change. The State of the World's land and water resources for food and agriculture (FAO, 2011) has identified a range of systems where natural resources are at risk (Figure 4).

A long-term, inclusive rural transformation plan needs to have a strong environmental component that explicitly takes planetary boundaries and future systems' integrity into account. Another critical issue is the way agricultural development may modify the distribution of natural resources and how different categories of actors, including the most vulnerable, benefit from their uses.

Figure 4. Global distribution of risks associated with main agricultural production systems.



Note: Refer to the disclaimer on page ii for the names and boundaries used in this map.

Source: ***FAO.*** *2011. The state of the world's land and water resources for food and agriculture (SOLAW) – Managing systems at risk. Rome, FAO; London, Earthscan. http://www.fao.org/3/i1688e/i1688e.pdf*

2. Stagnating poverty and inequality, climate change and nutrition

Poor and vulnerable populations are directly dependent for their livelihoods on natural resources and ecosystems. These are, in turn, profoundly affected by climate change. Food insecurity and malnutrition are persisting and evolving challenges that call to recognize nutrition explicitly as an objective of natural resources management.

2.1 Poor and vulnerable populations are directly dependent on natural resources for their livelihoods and FSN

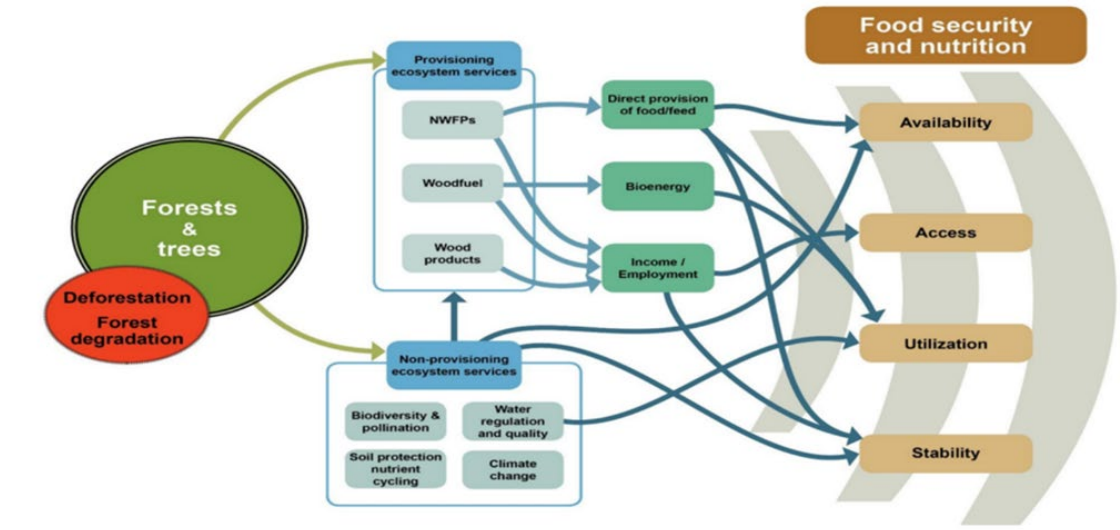
“Natural resources are a major, and may be the major, asset of the poor” (OECD, 2008, p72). The livelihoods of poor and vulnerable communities are tied to natural resources, which are increasingly affected by climate change (OECD, 2008). The concept of “GDP of the poor” emphasizes the significant ecosystems’ contribution to rural livelihoods — typically 50–90 percent — contrasting starkly with their modest contribution to national GDP — 6–17 percent (TEEB, 2010). 80 percent of the world's extremely poor reside in rural areas. More than 500 million farmers work less than 2 ha of land on about 11 percent of the total land farmed worldwide, producing about 31 percent of the food calories produced (IFAD 2021). Poor and vulnerable groups often rely on multiple sources of food and income and are highly dependent for their livelihoods on “natural ecosystems” and “common property” natural resources, which include fallow fields, forests, coastal and riparian ecosystems, fishing grounds, pastureland and wetlands. These provide a variety of goods including food, fodder, building materials, fuel and medicinal plants among others, which are important sources of sustenance or income for many rural populations. Mining, both formal and informal, provide additional sources of income to poor populations, and often conflict with other users of land and water.

Even though they are not reflected in official statistics evidence shows that sustainable use of wild species is central to the livelihoods and resilience of billions of people, particularly for people in vulnerable situations, Indigenous Peoples and women (Fromentin *et al.*, 2022). Environmental resources are renewable, widely dispersed, and often found in common property areas where poor and vulnerable groups can access them without owning the land. Ecosystem goods and services can act as community assets, with benefits beyond household cash incomes. For rural poor people, natural resources foster cohesion and strengthen the safety net for the whole community. Agricultural development, often modifying land and

waterways, the way they are managed and the distribution of use rights (formal and informal) risks pushing these populations further into poverty, forcing them to find other means of subsistence including by migrating. This is especially significant for Indigenous Peoples, given the deep interrelations their way of living has with the natural environment, as well as people residing in marginalized lands, including women, who often are part of the informal economy and therefore left behind.

Approximately 4.17 billion people–95 percent of all people outside urban areas, live within 5 km of a forest, and 3.27 billion live within 1 km (Newton *et al.*, 2022). People who live in and around natural forests, or on the forest frontier, often live as hunter-gatherers, shifting cultivators or are involved in agricultural practices either within or outside the forest, and regularly use forest products (timber, fuelwood, bush foods, medicinal plants, etc.), for their own subsistence purposes, as well as for income generation (FAO, 2019). In many tropical countries, forest-adjacent people earn about one-quarter of their income from forests (FAO, 2022b). Globally, an estimated 1.6 billion people fully or partly depend on forests for their income and livelihoods (FAO, 2019).

Figure 5. Forest functions and their link to food security and nutrition



Source: ***HLPE.*** *2017. Sustainable forestry for food security and nutrition. A report by the High-Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, June 2017. Rome, FAO.* https://openknowledge.fao.org/handle/20.500.14283/i7395e

Forest's benefits can be very wide and diverse (HLPE, 2017; Gitz *et al.*, 2021) as shown in figure 5. Besides the direct provision of food, forests offer an indispensable source of energy, on which about 2.4 billion people, one-third of the global population, rely as their main source of energy for cooking. (HLPE, 2017). Wood energy often represents the only available and accessible source of energy in rural areas and is especially important for poor people in

developing countries, particularly in Africa where it accounts for 27 percent of the total primary energy supply. Wood fuel is also used by 764 million people to boil and sterilize water, with a positive impact on health (HLPE, 2017). A significant proportion of the population in tropical Asia, Africa and Latin America relies on medicinal plants as an integral part of their primary health care systems. (Miller *et al.*, 2020; Colfer *et al*., 2006). As revealed by a study conducted by the Center for International Forestry Research (CIFOR) in more than 60 countries, forests provide a great variety of contributions to income and livelihoods, differing by ethnic groups and gender (FAO, 2019; Rowland *et al.*, 2016). The Poverty and Environment Network (PEN) data (PEN, 2016) also showed that lower-income classes are proportionally more dependent on non-wood forest products (NWFP) collection (Angelsen *et al.*, 2014; Wunder *et al.*, 2014). Forests and trees also improve agricultural resilience, supporting the capacity of agricultural systems and households to prevent, mitigate or cope with risk, and recover from shocks, making a significant contribution to the stability dimension of food security (HLPE, 2017). Forests are often of particular importance for livelihoods and food security in times of crisis, allowing rural populations to address occasional income needs, particularly during (and in response to) conflicts, natural disasters and economic crises (FAO, 2019). In times of drought or food insecurity greater reliance on wild foods has been observed (HLPE, 2017; Powell *et al.*, 2013). In times of crises, artisanal fisheries and aquaculture systems can provide alternative and vital sources of livelihood to rural households (FAO, 2021c; Nieland and Béné, 2004). The livelihood safety role is particularly evident in the case of inland fisheries (Virdin *et al.*, 2023). For example, in the Lake Chad Basin, fisheries contributed to the food and nutritional security of over 10 million people during the crop failure crisis (FAO, 2021c) while in the Lake Tanganyika region, fish provided critical nutritional welfare after the disruptions of crops and livestock production due to civil war and displacement in the United Republic of Tanzania and the Democratic Republic of Congo (FAO, 2021c). In Malawi, Uganda and Tanzania households located close to small scale fisheries were 13 percent more likely to be food secure and 15 percent less likely to be income poor (Virdin *et al.*, 2023).

Livestock is catalytic in helping rural households achieve their livelihood objectives. Globally, more than 1 billion people depend on livestock value chains. Small-scale livestock keepers and pastoralists represent a large proportion of the livestock producers (FAO, 2023a). Animals have many different functions: they produce important food products, fertilizer, alternative energy; they are a source of income; they provide draught power; they fulfill banking and insurance functions; and they act as an important resilience and consumption smoothing strategy in the face of external shocks. Small livestock in particular require minimal investment. They can be kept in the vicinity of the household or on common land and fed with “residue” from agricultural production. Several nomadic societies, on the other hand, devote themselves exclusively to livestock production, which is an integral part of their culture, heritage and traditions. Pastoralism is practiced in more than 75 percent of countries by between 200 million and 500 million people, including nomadic communities,

transhumant herders and agropastoralists (McGahey *et al.*, 2014). For most of these people, livestock are often one of the main assets of rural households and are an important part of their livelihood.

Women's access to land, water, inputs and resources continues to lag behind men's. In 40 out of 46 countries with accessible data, men possess stronger ownership or secure tenure rights to agricultural land compared to women. A more inclusive and resilient use of natural resources, and equal access to their ownership and use, can have significant benefits for gender equality and women's empowerment, and also for the environment. Evidence suggests that when women have secure rights and access to land, they use resources sustainably, and indicates a correlation between women's inclusion in leadership and decision-making structures and sustainable natural resources and adaptation outcomes (IFAD, 2023). Research also shows that women's ownership of land and access to clean water significantly reduces gender-based violence (FAO, 2023b). Beyond ownership rights, it is important to consider natural resources use rights, especially as many vulnerable communities depend on natural resources for their food security and livelihoods. Changes in land use, such as conversion to large-scale plantations for biofuel production, often lead to land takeover by investors through state-issued permits. This shift, reducing forest or food crop agriculture land in favour of cash crops, significantly affects communities reliant on small-scale agriculture and sustainable informal use of forests, disproportionately affecting women and vulnerable populations (White and White, 2012). The repercussions of such land-use changes are evident in instances like the expansion of oil palm in West Kalimantan, Indonesia, where the development of plantations on customary lands has seriously undermined women's land rights, also excluding them from the political process, and reduced their income derived by gathering forest products and raw materials for crafting (White and White, 2012).

2.2 Climate change, a game changer for natural resources and ecosystem services for agriculture.

Agriculture is among the sectors most directly affected by climate change (FAO, 2015a and 2016; IPCC, 2022; Lipper and Cavatassi, 2024). This has a direct impact on the food security, nutrition and income of rural households. Additionally, climate change exacerbates the threats of weather-related disasters, drought, floods, increasing wildfires, biodiversity loss, as well as land and water scarcity, increasing uncertainty and poverty. The purpose of this section is to briefly review the impacts of climate change and related policies on natural resources – land, water and biodiversity – ecosystem services, and their role for adaptation of systems and people in the perspective of resilient and inclusive rural development.

2.2.1 Impacts of climate change on natural resources and people depending on them

Climate change exacerbates the vulnerabilities associated with natural resources scarcity and degradation. It aggravates land and water scarcity, affecting land suitability for agriculture (IPCC, 2022; FAO, 2018a). It heightens competition for irrigation, exacerbating groundwater depletion (IPCC, 2022; FAO, 2015a), and intensifies threats of weather-related disasters, droughts and biodiversity loss. Globally, climate change is projected to render 10 percent of suitable areas for major crops and livestock unsuitable by 2050, and up to 34 percent by 2 100 (IPCC, 2022). FAO projects that under its BAU scenario climate change will bring about a net loss of around 6 percent of suitable land by 2050 compared with 2012, particularly in East Asia and the Pacific and NENA. The stratified societies scenario[5], with very little mitigation, would lead to a loss of around 14 percent of highly suitable land, particularly in EAP, SSA and NNA (FAO, 2018a). In addition, climate change impacts might exacerbate losses in land productivity through degradation and other mechanisms. For example, a sizeable fraction of cropland (12 percent) is currently located within 100 km of the coastline (Kummu *et al.*, 2016). The productivity of those areas might be affected by sea level rises. Besides the immediate impacts on coastal areas (submergence, increased flooding, saltwater intrusion), longer-term effects of this phenomenon include increased erosion and saltwater intrusion into groundwater; effects that are more apparent in densely populated coastal areas in Africa, and South, Southeast and East Asia, and for small island states (Nicholls and Cazenave, 2010) but are not considered in the aforementioned FAO estimates.

Increased water needs of plants and animals due to rises in temperatures, combined with changes in precipitation regimes, will increase the need for irrigation and the competition with other water uses for which demand is also increasing. Changes in precipitation, runoff and snow/ice melt have effects on hydrological systems, water quality, water temperature and groundwater recharge (FAO, 2015a; IPCC, 2022). Worldwide, depletion of non-renewable groundwater storage is expected to continue due to increased groundwater demand. By 2050, environmentally critical streamflow is projected to be affected in 42 percent to 79 percent of the world's watersheds, with negative impacts on freshwater ecosystems and inland fisheries (IPCC, 2022).

[5] "In this scenario, societies are structured in separate layers. Self-protected elite classes, such as groups of people who have decisional power and use it primarily to protect their position and interests, do not feel the urgency to conserve natural resources or mitigate climate change. At the same time, increased poverty, food insecurity and poor nutrition leads to the over-exploitation of natural resources and unmanaged agglomerations." (FAO, 2018a)

Climate change has multiple impacts on biodiversity and ecosystems. It affects production through changes in species distribution, abundance and relations, for both harvested wild species and species crucial to farming systems as pollinators, pests, disease vectors and invasive species. Such systemic effects are difficult to assess and project, given the multiple interacting parameters and links, many of which are still unknown (FAO, 2015a). Risks to ecosystems' integrity, functioning and resilience are projected to escalate with every increase in global warming. Climate change will reduce the effectiveness of pollination as some species are lost from certain areas, or the coordination of pollinator activity and flower receptiveness will be disrupted in some regions (IPCC, 2022). Climate change will significantly alter aquatic ecosystems and their food provisioning services. Marine catch will change regionally. Inland aquatic systems will be negatively affected by changes in precipitation, sea level rise, temperature and extreme events (IPCC, 2022). Genetic resources for food and agriculture can play a central role in meeting the challenges of climate change to FSN, and in maintaining and improving agricultural productivity, rural livelihoods, sustainability and resilience (FAO, 2015b; Asfaw and Lipper, 2011). However, climate change is also threatening the strategic reservoir of crop and livestock genetic resources from which to breed the varieties that will be needed to adapt production systems to future challenges (FAO, 2015a). Climate change also aggravates poverty and food insecurity (Lipper and Cavatassi, 2024; FAO, 2018a). The combined effects of resource degradation and climate change can potentially force over 100 million people into poverty by 2030 (World Bank, 2021).

2.2.2 Climate change adaptation

The importance of natural resources for adaptation is well recognized in the nationally determined contributions (NDCs) prepared by countries as part of their commitments under the Paris Agreement on climate change. Most adaptation components of the NDCs refer to observed or projected climate-related impacts on ecosystems and natural resources. Almost all adaptation components of the NDCs include priority areas or actions in the agricultural sector, while most of them include priority areas related to ecosystems and natural resources (Crumpler *et al.*, 2021).

Adaptation measures focusing on natural resources conservation and sustainable use can have multiple co-benefits, for the adaptation of other sectors, mitigation of climate change and sustainable development (Crumpler and Meybeck, 2020). Prioritizing adaptation measures that generate co-benefits for sustainable development can contribute to development while also meeting long-term sustainable development and resilience objectives (IPCC, 2014a). Evidence suggests that, overall, the impacts of adaptation on sustainable development, poverty eradication and reducing inequalities are expected to be largely positive, given that the inherent purpose of adaptation is to lower risks (IPCC, 2018). However, redistributive measures need to be put in place to facilitate equitable development, including the poor and most vulnerable, so that adaptation strategies do not

risk impeding or reducing progress on poverty reduction nor exacerbate existing inequalities (IPCC, 2014b).

Natural resources degradation increases susceptibility and exposure to climate shocks and further strains the adaptive capacity of resource-dependent communities. Restoring natural resources and healthy ecosystems is an important adaptation pathway for both agrifood systems and the people depending on them. Healthy ecosystems can support social adaptation, as recognized through the concepts of ecosystem-based adaptation (EbA) and ecosystem-based disaster risk reduction, by regulating risks from climate change and natural hazards, and by providing options for sustaining material and non-material benefits (FAO, 2015a; Meybeck *et al.,* 2021). Forests and trees contribute to local climate regulation by supporting water provision and providing shade; protect coastal areas from storms and sea level rise; protect watersheds; supporting the resilience of farming systems and households. Vulnerabilities of forests and forest-dependent people have many dimensions (environmental, economic, social, political and geographic) that interact in specific locations and contexts (Meybeck *et al.,* 2019). Households that rely most on wild resources in times of crisis could be constrained in their adaptive capacities if their rights to collect food are not recognized. Sustainable management of natural resources, encompassing land, water, and biodiversity, including genetic resources, as well as access and use rights for local communities, are crucial for enhancing adaptive capacities (Meybeck *et al.*, 2019).

2.2.3 Impact of climate change mitigation response measures and policies on land available for agriculture

Climate change mitigation policies will have contrasting effects on agricultural development and on vulnerable populations. The protection of forests reduces the scope for agriculture expansion and, depending on modalities, may have exclusionary effects on Indigenous Peoples and local populations. However, a growing literature supports the notion that forest protection measures that recognize traditional livelihoods and the rights of Indigenous People and local communities are among the most effective measures to combat deforestation and reduce GHG emissions (FAO and FILAC, 2021). Mitigation policies could also affect livestock development, with potential negative economic and social consequences for those employed or living from the sector, but with positive environmental consequences. Policies in favour of renewable energy and of the replacement of non-renewable materials by wood and similar materials (bamboo, rattan, latex, gums…) create new opportunities for rural development (see Section 3.3). However, they may also cause additional pressure on land and water and need to be appropriately designed not to exclude smallholders, Indigenous Peoples and vulnerable groups.

Demand for land for climate change mitigation measures add to and combine with pressures resulting from population and income growth, fueling multiple and often competing needs for: food, feed, fiber, bioenergy, carbon capture and storage (CCS), protection of biodiversity

and other ecosystem services, as well as space for human settlements and infrastructures (Pingault *et al.*, 2024). The shared socioeconomic pathways (SSP) storylines, developed for the Intergovernmental Panel on Climate Change (IPCC) sixth assessment report, make assumptions about the evolution of the three key drivers of land demand — population, economic growth and urbanization — and assess their impacts in terms of land-use changes and patterns, depending on the climate target. All pathways consistent with a limitation of temperature to 1.5°C rely on a large use of bioenergy, which might impact food security and biodiversity, depending on how much bioenergy is generated and how (Rogelj *et al.,* 2018). Bioenergy with carbon capture and storage (BECCS) and large-scale afforestation and reforestation are expected to take the lion's share in the total carbon dioxide removal (CDR) effort, especially in the first half of the century when other CDR technologies will still not be implemented at scale. In all 1.5°C consistent pathways, land dedicated to energy crops and forest areas is generally expected to increase during the 21st century, albeit with large variations across models. Hence, the evolution of arable land will depend heavily on the underlying SSP narrative. Pastures, generally used as the adjustment variable despite their high potential for soil carbon sequestration, are expected to decrease slightly during the twenty-first century. A robust finding is that by 2050, stringent climate mitigation policy, if implemented evenly across all sectors and regions, would have a greater negative impact on global hunger and food consumption than the direct impacts of climate change (Lipper and Cavatassi, 2024). The negative impacts would be most prevalent in vulnerable, low-income regions such as SSA and South Asia, where food security problems are already acute (Lipper and Cavatassi, 2024). There is thus a critical need to carefully contextualize climate change mitigation policies and programmes, taking into account their potential impacts on all dimensions of sustainability.

2.3 Mainstreaming nutrition objectives in natural resources management

There is increasing recognition of the importance of nutrition for development. However, the world is not on track to achieve any of the seven global nutrition targets by 2030 (FAO et al., 2024). Micronutrient deficiencies have been extensively documented in populations experiencing food insecurity (FAO, 2018b; Arimond and Ruel, 2004; Roos, 2016). More than 2 billion people, particularly in developing countries, are affected by micronutrient deficiencies, with vitamin A, iron, and iodine being the most notable (FAO, 2018b; Allen *et al.,* 2006). Current global estimates show that 40 percent in children under 5 years and 30 percent of women aged 15 to 49 years have anaemia, primarily caused by iron and vitamin B12 deficiency (Stevens *et al.,* 2022). At the same time, the prevalence of adult obesity (in individuals aged 18 years and above) has steadily increased over the last decade, from 12.1 percent (591 million) in 2012 to 15.8 percent (881 million) in 2022. This figure is projected to reach 19.8 percent (1.2 billion) in 2030 (FAO *et al.,* 2024). There is increasing recognition

that agricultural interventions should become nutrition-sensitive, to improve food access and attain global nutrition targets. The concept of nutrition-sensitive agriculture (NSA) aims to go beyond increasing food production by incorporating nutrition objectives and actions in the design and implementation of agriculture interventions (Sharma *et al.,* 2021). It requires to acknowledge the diverse contributions to nutrition of different uses of natural resources and food production systems in order to appropriately take them into account in assessing nutritional outcomes of options for natural resources management.

Wild species often play a substantial role in providing nutritious foods for poor people. The contributions of wild species to FSN need to be recognized and taken into account in agriculture development policies, to avoid that short-term economic gains threaten their key role as source of nutrition and safety net in times of crisis. The sustainability of their use also depends on the relationship between commercial and subsistence harvesting, and whether local communities receive an equitable sharing of the benefits from harvests (Fromentin *et al.*, 2022). Studies found that forests food represents 36 percent of total vitamin A and 20 percent of iron in Gabon (FAO, 2020a; HLPE, 2017; Blaney, Beaudry and Latham, 2009); 31 percent of vitamin A intake and 19 percent of iron in the United Republic of Tanzania (HLPE, 2017; Powell *et al.*, 2013); 42 percent of calcium, 17 percent of vitamin A and 13 percent of iron in a traditional swidden agricultural community in the Philippines (HLPE, 2017; Schlegel and Guthrie, 1973).

Fish and seafood can contribute to the alleviation of nutritional deficiencies, being excellent sources of protein, essential fatty acids, vitamins, and minerals, accounting for 16.6 percent of the world population's intake of animal protein and 6.5 percent of total protein consumed. Approximately 3 billion people receive almost 20 percent of their animal protein intake from fish, and 4.3 billion people receive about 15 percent (HLPE, 2014b). The amount of aquatic products destined for human consumption in 2020 (excluding algae) was 20.2 kg per capita, more than double the average of 9.9 kg per capita in the 1960s (FAO, 2022a), and it is expected to rise to 21.4 kg by 2030 (FAO, 2022e). In many developing countries, such as Cambodia, Sierra Leone, Bangladesh, Indonesia, Ghana, Mozambique and some Small Island Developing States (SIDS), aquatic foods contributed 50 percent or more of total animal protein intake in 2022 (FAO, 2022a). For many poor rural populations in low-income food-deficit countries, fish (particularly small fish) can be the most accessible or preferred animal-source food, contributing to the diversification of diets dominated by staple crops and enhancing nutrient absorption from plant-source foods when consumed together, addressing malnutrition, especially in communities with limited access to alternative protein sources (UN Nutrition, 2021; Thilsted *et al*., 2014; Bogard *et al*., 2015; Barré *et al.*, 2018). The consumption of freshwater fish is increasingly reported to provide beneficial human health impacts with respect to micronutrients and to be essential for physical and cognitive development (UN Nutrition, 2021). Fish consumption helped reduce infections and promote chronic wound healing in vulnerable populations living with HIV/AIDS in Zambia (FAO, 2018b, Kaunda, Chizyuka and Phiri, 2008), while in parts of Bangladesh and sub-Saharan Africa,

calcium intake from freshwater fish contributed to the prevention of rickets in children (FAO, 2018b; Craviari *et al*., 2008) and provided health benefits to lactating women and newborns (FAO, 2018b; Longley *et al.,* 2014).

Globally, livestock products contribute 34 percent of protein and 17 percent of calorie intake of diets. However, this contribution is not evenly distributed among regions (FAO, 2020b). Demand for animal source foods in low- and middle-income countries has quadrupled in the past decades and is predicted to increase by 35 percent between 2012 and 2030, and by up to 50 percent by 2050, with great variability among countries (FAO, 2018a). For instance, in SSA, under FAO's BAU scenario, with the assumption that increasing domestic demand will be met by domestic production, poultry units would more than quintuple, pigs triple, and both large and small ruminants double (FAO, 2018a). At the same time, there are increasing concerns about the impacts of livestock development on natural resources (see Section 1.3) that could induce a decrease of consumption in developed countries.

Studies have highlighted a gap in the global supply of fruits and vegetables in regard of established dietary recommendations, particularly in low-income countries (McMullin *et al.*, 2019; Siegel *et al.*, 2014). Among the reasons that limit fruit and vegetable intake are supply-side limitations, including seasonal unavailability, and difficulties of transport and conservation for perishable foods (Siegel *et al.,* 2014). Efforts to increase and diversify production and consumption of nutrient-rich fruits and vegetables can build upon a range of species and varieties, many of which are still underutilized and neglected (Harris *et al.*, 2022; McMullin *et al.*, 2019). They include fruit and vegetable species of considerable nutritional value, such as micronutrient-rich African leafy vegetables adapted to rainfed conditions (Maundu Achigan-Dako and Morimoto, 2009). Many of these species and varieties are still maintained by farmers and local communities and could gain importance through local markets and in urban areas (Harris *et al.*, 2022).

Agricultural policies have traditionally focused on staple foods. There is a need to reorient them towards nutrition objectives. These include nutrition-sensitive agriculture programmes that promote diversified food production and consumption, particularly among poor households living in remote areas with little access to markets, support to urban and peri-urban agriculture and facilitating access to nutritious foods through actions along value chains (Hawkes *et al.*, 2020). Such policies in favor of more nutritious foods (Ambikapathi *et al.*, 2024), as well as increasing demand from urban areas, can provide opportunities for the production of more nutritious foods, including fruits, nuts and vegetables as well as livestock and aquaculture, which generally create greater value added per ha of land or litre of water, thus using these resources more efficiently and providing livelihood opportunities for smallholders while also improving their nutrition. Improving nutrition through agriculture can be at the same time an objective and driver of inclusive rural development.

3. Sustainable natural resources management for resilient, inclusive rural transformation: Pathways and trade-offs

The increasing scarcity and degradation of natural resources, as well as increasing competing demands, call for conserving and sustainably managing all resources, optimizing their use, improving resource efficiency, and facilitating access for diverse uses by various categories of actors. This section outlines four pathways for natural resources management to support resilient and inclusive agricultural development: resource efficiency, diversification, sustainable bioeconomy, and landscape approaches.

3.1 Optimizing efficiency and resilience in natural resources use

Given the competing demands on natural resources, maximizing efficiency of their use is key. This requires restoring degraded resources and enhancing efficient use in production systems managing different resources and objectives to maximize benefits while reducing negative externalities.

Globally, approximately 1.5 billion ha of degraded land could be restored, and an additional 1 billion ha could witness increased tree cover. It is estimated that the restoration of 350 million ha of deforested and degraded lands by 2030 could deliver a net benefit of USD 0.7–9 trillion and USD 7–30 for every USD 1 invested (FAO, 2022b). An assessment in 42 African countries showed that the benefit of land restoration and conservation for agricultural productivity is 3–26 times greater than the cost of inaction, (FAO, 2022b). The restoration of 4 million ha of degraded land in the Sahara and the Sahel area has created more than 335 000 jobs (FAO, 2022b). Restoring degraded land not only helps sequester carbon and enhance biodiversity, but also provides opportunities for economic growth, sustainable agriculture and income generation for some of the most vulnerable populations of the planet (FAO, 2022b). The same approach needs to be applied to water resources, in particular to the potential for irrigation through new investments, especially in Africa. However, particular care should be given to the distribution of water, to avoid exclusion of downstream populations and to preserve the functioning of aquatic ecosystems on which inland fisheries depend. Conserving and sustainably managing agrobiodiversity, including pollinators, natural enemies of pests as well as soil biodiversity, contributes to the

preservation of natural capital and ecosystem services and produces income through agricultural activities.

The increasing scarcity of natural resources also invites to optimize their use, deriving more benefits from the same amount of resource or the same amount of benefit from a reduced amount of resource, summarized as resource efficiency. This can be expressed in various ways, depending on the resources and benefits of interest. The most commonly used for plant production is the yield, which measures the production per hectare. Increasing yield is essential to increase production when land gets scarce. The notion of yield gap, defined as the difference between actual farm yield and the yield potential in a specific context with good agricultural practices, allows to determine a potential for increased production without land variation. However, the yield is focused on the ratio land/physical production. Ideally, an assessment of resource efficiency should be able to focus on the most important resource in the area (generally the scarcest, often land but it could also be water) and on the most important objective (which may not always be yield, but could also be income or jobs), allowing for a suitable assessment of synergies and trade-offs with secondary resources and objectives. The definition of a metric encompassing a set of several resource uses would be challenging given the difficulty of calculating relative weights to the different inputs. A first approach could be to use relative prices, leading to the notion of strict economic efficiency. This would require integrating all externalities (including local ones). However, this is hardly the case. It is not easier on the other side of the equation as output could and should be measured not only in terms of physical production but of nutrition, income, provision of ecosystem services, and even jobs (both directly and indirectly in transformation and distribution). Labour is particularly tricky as it is generally analyzed as a cost for production while, in the perspective of inclusive rural development, it is often a desired result. For all these reasons it is often more efficient, and more transparent, to adopt more focused perspectives, prioritizing the scarcest or most limiting resource in a given context and the priority objective. It should also be noted that increased resource efficiency can also drive increased consumption (the rebound effect) which can result in increased scarcity (Berkhout, Muskens and Velthuijsen, 2000).

A global study of the value of water used in agriculture (D'Odorico *et al*., 2020), based on the added production in irrigated agriculture as compared to rainfed, notes that the value of water, in USD per m^3, is consistently higher producing maize, soybean and rice than for wheat and that from the 16 crops analysed, the highest is potatoes in many regions of the world because of their yield per unit of water and higher price, and sugar cane in South and Southeast Asia. The study notes that the crops that maximize value per unit of water are not necessarily those that maximize value per unit of land. The water footprint of a product is the total volume of freshwater that is used directly or indirectly for it, including water consumption and pollution in all steps of the production chain (Hoekstra *et al.*, 2011). It was originally conceived to inform consumers but can also be used to assess the water use efficiency of different systems, at various scales and for various outputs. A study used the

blue water footprint, which accounts for irrigation water, to compare the income and employment "produced" per litre of water in different systems in Campania, Italy (Altobelli *et al.*, 2018). It showed considerable differences between products and between farms for a determined product. This enabled identification of two main pathways to improve resource efficiency for a specific objective: generalizing best practices within a specific system. or changing the system. Tomatoes can be produced in greenhouses in a much more water efficient way than in the field. Depending on context and techniques, the production of 1 kg of tomatoes can require from 60 litres of water in the field to 12.5 litres in a greenhouse, and even 4 litres in closed hydroponic systems (Nederhoff and Stanghellini, 2010).

Eco-efficiency is increasingly recognized as a business strategy that allows to simultaneously reduce costs and environmental impacts (Korhonen and Seager, 2008). However, it risks decreasing some system characteristics, such as spare capacity or reserve resource stocks and redundancy, that are key to the systems' adaptability and resilience. It is thus important to invest in diversity, adaptability flexibility and reserve capacity to preserve resilience (Korhonen and Seager, 2008; FAO, 2023c). An analysis of farm economic efficiency in Finland has shown that there are no trade-offs between land use diversity and economic efficiency (Kahiluoto and Kaseva, 2016). The authors conclude that diversification can be a strategy to increase resilience without constraining resource-use efficiency. The importance of ecosystem services for the resilience of agricultural landscapes is now well recognized (Bennet *et al.*, 2021). Coomes *et al.* (2019), recognizing that sustained gains in agricultural productivity depend fundamentally on inputs of natural capital and ecosystem services, propose to leverage total factor productivity growth for sustainable and resilient farming. They distinguish two pathways for growth: technology-based and ecosystem-based. The two pathways are complementary and intervene to different degrees, depending on context. Such a perspective allows for a broad understanding of the interrelations between inputs, including natural capital and ecosystem services, and potential combinations in specific contexts to achieve productivity and resilience outcomes. It would also allow, for instance, to consider options giving greater weight to labour when the latter is abundant, which could contribute to more inclusive development. However, to fully exploit the potential of such a model, it is necessary to have appropriate data measuring natural capital and ecosystem services, as well as agreed methodologies to measure resilience. In particular, it appears that resilience results, and especially correlation with efficiency, are highly dependent on indicators or proxies used to measure them, which might in turn depend on specific contextual perspectives. For instance, a study aiming to identify sustainable development options in ecologically fragile areas of China with low levels of natural capital concludes that resilience and efficiency gains are the most promising in areas with the biggest natural endowments or the closest to cities, where technological innovations and new markets provide alternative development pathways delinked from weather and natural resources dependent traditional systems (Tao *et al.*, 2023).

Pathways to increase resource efficiency sustainably can mobilize various approaches, including technological innovations, sustainable intensification, agroecology, sustainable bioeconomy, etc. These pathways are often synergetic with objectives related to climate change adaptation and mitigation, such as in the Climate-Smart Agriculture (CSA) approach (FAO, 2013). Systems that use resources efficiently have significant advantages, generating higher value per ha and litre of water or more efficient use of labour, fertilizers and pesticides like in the case of potato value chain to conserve biodiversity in Ecuador or in the High-Value Production Project supported by IFAD in Nepal (Cavatassi *et al*., 2011; Neubauer *et al*., 2022; González-Flores *et al*., 2014). It should be noted that the lack of a specific resource or of specific knowledge and technologies can reduce the efficiency of resource use. Often these scarcities and imbalances compound their effects: the poorest countries and people often lack the means or inputs needed to make the best use of scarce resources. The development of intensive (high value per ha and litre of water), resource efficient systems, producing fruits and vegetables, fish and aquaculture products as well as livestock products can benefit from their proximity or accessibility to urban markets. Such systems can be particularly efficient in the reuse of wastewater and nutrients coming from cities (e.g. compost). They produce more value per hectare and litre of water and also more jobs, both on farm and along value chains, and more nutrients.

3.2 Diversified and integrated systems for resilient and inclusive rural development

Diversified and integrated systems can increase resource efficiency, providing more products, income, jobs per ha and/or per litre of water, and build resilience as the different products can be susceptible to different risks (both biophysical and economic) that are therefore unlikely to be fully correlated. They also contribute to more diverse and balanced diets and to the development of diversified value chains and local markets (Meybeck and Gitz, 2012). Importantly, they can provide more labour opportunities all along the year, allowing to reduce the deficit in work opportunities that is a main cause of the income gap between agricultural and non-agricultural workers (De Janvry and Sadoulet, 2020). Diversified systems have also been shown to be more inclusive, providing opportunities to a broader range of actors, particularly women and vulnerable groups. For example, in semi-arid West Africa, it has been shown that the use and management of biodiversity enables exploitation of heterogenous territories, management of temporal fluctuations of resource availability and pursuit of multiple production objectives including nutrition diversity, through different combinations of plant and animal species, spatial and temporal management of fields and natural habitats, and direct collection of wild foods, medicinal plants and other resources (Félix *et al*., 2018). A coastal community development project in Indonesia successfully replanted mangroves to protect the coastline and support fish stock reproduction. The project also boosted the local economy through ecotourism, and created

microbusiness opportunities for women in fish processing and sales. As a result, it achieved notable environmental and resilience benefits, increased income, and empowered women (Cavatassi, Mabiso and Brueckmann, 2019). Home gardens and fruit tree portfolios can very efficiently use a range of species and varieties on a small surface to improve nutrition. Home gardens refer to the cultivation of a small portion of land around the household or within walking distance with a high diversity of plants. Fruit tree portfolios are combinations of indigenous and exotic fruit tree species that can provide year-round harvests of fresh fruits and fill the food insecure period, or "hunger gap" and specific nutrient gaps (McMullin *et al.*, 2019).

Agroforestry is a collective name for land-use systems and technologies whereby woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. Agroforestry systems entail both ecological and economic interactions between their different components (Lundgren and Raintree, 1982). Depending on the system and local conditions, agroforestry can achieve 50 to 80 percent of the biodiversity of natural forests, increase FSN by serving as a safety net, and increase crop productivity, (FAO, 2022b) provide improved soil fertility, fodder for livestock, fuelwood, and improved household resilience through the provision of additional products for sale or home consumption (HLPE, 2017). Smallholders have developed various associations of rubber trees with other crops, such as rice, tuber, chili, pineapple, sesame, cocoa, coffee, fruit trees and even livestock (Gitz *et al*., 2020). Such associations enable better use of natural and human resources and build resilience to fluctuating rubber prices. Rubber brings cash with labor requirements that are compatible with rice production. It is associated with fruits that have a local or international market in Colombia, India, Indonesia, Nigeria or Thailand (durian for instance). Combination of rubber with other trees can bring multiple benefits: quick growth trees can help control through shade the invasive *Imperata* in Indonesia; high values low growth trees or combining rubber trees with rattan at the end of the production cycle bring additional value at the end of the cycle which can support investment in replantation. In a project in Mexico to strengthen agroforestry while promoting small and micro enterprises for women, positive benefits have been observed in terms of sustainable use of forest resources and related income (Cavatassi *et al.*, 2019). Additionally, agroforestry systems tend to be more resilient than conventional agricultural systems to environmental shocks and climate change effects. The area of land used for agroforestry increased by 4.21 million ha between 1990 and 2020, to 43.3 million ha.[6]

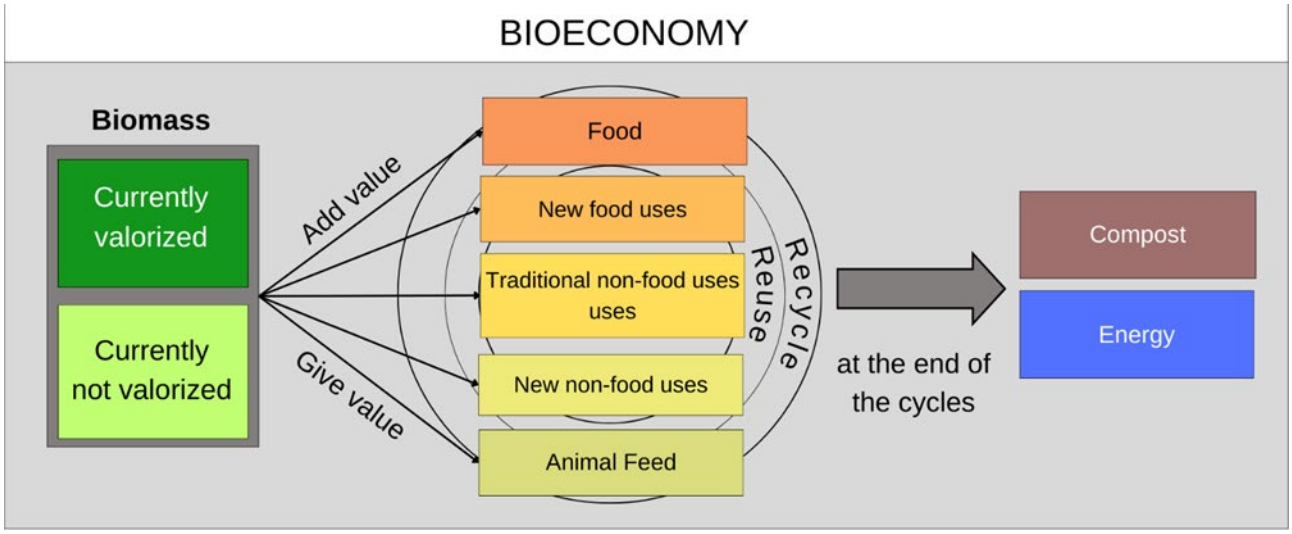
[6] For 54 countries that reported trend data to FRA 2020.

Integrating fish production with irrigation systems holds potential for boosting local economies, food security, household incomes, and livelihood diversity. Integrating fish farming into irrigation systems can increase rice yields by 5 to 30 percent, in addition to providing a second source of income from fisheries (FAO, WorldFish and IWMI, 2020). In rice–fish farming systems, the economic value of fish often exceeds that of the rice grown. However, careful consideration is needed to assess the net impact, especially concerning potential losses in riverine fisheries due to dam construction, and the negative effects of altering natural river flows. The effective use of fishways is crucial in maintaining migratory fish pathways and preventing resource declines, with evidence supporting substantial fisheries productivity returns (Gregory, Funge-Smith and Baumgartner, 2018). Several tools and approaches have been developed to achieve a balance between crop production and water use in fisheries management. For example, the Essential Ecosystem Approach to Fisheries Management (E-EAFm) provides a practical method for managing fisheries, moving away from the single-species focus to a systems-based approach guided by seven principles: good governance; appropriate scale; increased participation; multiple objectives; coordination and cooperation; adaptive management; and the precautionary approach (Gregory, Funge-Smith and Baumgartner, 2018).

3.3 Develop a sustainable and inclusive bioeconomy

Bioeconomy is often defined as “the production, utilization, conservation, and regeneration of biological resources, including related knowledge, science, technology, and innovation, to provide sustainable solutions (information, products, processes and services) within and across all economic sectors and enable a transformation to a sustainable economy” (GBS, 2020). A sustainable bioeconomy promotes the sustainable use and management of biological resources to substitute non-renewable ones, moving away from a fossil-based economy towards a bio-based economy. Given the abundance of biological resources in rural areas, bioeconomy holds considerable potential for rural development, seeking to make efficient and comprehensive use of locally available bioresources, minimizing waste while maximizing their value. It gives value to biomass currently not used and adds value to biomass already used through transformation, reuse and recycling including for coproducts and by-products (Figure 6). At the end of all processes, the same biomass can be used to create energy and compost.

Figure 6. Bioeconomy



Source: ***Meybeck, A., Cintori, L., Cavatassi, R., Gitz, V., Gordes, A., Albinelli, I., Opio, C. et al. 2024****. Natural resources management for resilient inclusive rural transformation. Global Food Security, 42: 100794. https://doi.org/10.1016/j.gfs.2024.100794*

Figure 6 illustrates various means by which bioeconomy can create additional value: give value to non-exploited species or parts of exploited species that are currently not used, (which increases the harvested Index and thus material resource efficiency), add value through transformation and new uses; add value by reuse, recycle and final valorization as energy and compost returning to the soil. The concept of bioeconomy does not only relate to plant and animal biomass but also includes microbes, fungi, and other resources. Natural resource sectors and the primary sector, based on large-scale raw commodities, are often considered to have a comparatively lower growth potential than the industry and services sectors (OECD, 2008). The bioeconomy can drastically reshape this perspective, by diversifying the production of higher-value primary sector products and increasing their use in other sectors.

The consumption of raw materials, driven by population and economic growth, has surged dramatically over the past 50 years, with a near-doubling in the absolute extraction of biomass (UNEP, 2024). This trend is projected to continue, increasing from 89 gigatonnes (Gt) in 2017 to 167 Gt in 2060 with biomass use growing from 22 to 37 Gt, more for wood than for food and feed (OECD, 2019). By using more biomass and giving it more value, bioeconomy is a very powerful pathway to increase resource efficiency, better use natural resources to reduce environmental impacts, create more value and jobs (Gomez San Juan, Harnett and Albinelli, 2022). It can increase economic value of products but also incomes and create jobs at local levels even when market growth is predominantly external to the production area. For example, in Brazil's Amazon only 30 percent of the 13 non-timber forest products forming the category of "Amazonian bioeconomy" are consumed locally, but the production involves close to 350 000 jobs from the total of 4.25 million formal jobs overall in

the region (Fernandes *et al.,* 2022). Bioeconomy can also offer an opportunity for developing countries to participate in global value creation.

Forests and trees have immense potential for development in addition to their already sizeable economic value today. The (formal) forest sector's total contribution to the global economy increased by 17 percent nominally between 2011 and 2015, and directly contributed more than USD 663 billion in 2015 (FAO, 2022b). Taking into account total economic effects (that is, direct, indirect and induced economic contributions), including demand in other sectors and expenditure on labour income, the forest sector contributed more than USD 1.52 trillion to national economies in 2015, directly employing more than 19.2 million people (approximately 1 percent of global employment) (FAO, 2022b). Smallholders, local communities and Indigenous Peoples own or manage nearly half, 4.35 billion ha, of the world's forest and farm landscapes, generating an esteemed gross annual income of up to USD 1.29 trillion (FAO, 2022b). Forests managed for various productive benefits play a critical role in biodiversity conservation and also provide essential ecosystem services (Harrison *et al.*, 2022).

On-farm timber production can be an important subsistence and economic activity of smallholder farmers around the world. The *bolaina* (*Guazuma crinita*) wood value chain in Peru is an interesting example of the coordinated package of actions that is required to develop bio-based value chains that benefit local producers, especially smallholders. This fast-growing species sprouts naturally on fallow land, a simple and economical way of producing timber that can be integrated in agricultural activities. The value chain developed endogenously; however, Bolaina timber, a forest product, falls under conventional forestry regulations that are less adapted to smallholders (Sears *et al*., 2021). The challenge is the formalization of the sector while remaining fully inclusive of smallholders. A way forward is the creation of a network of small producers together with so-called medium to large size "anchor companies" with modern plantation management technologies, allowing the generation of products for the national market and the creation of jobs with quality working conditions (Guariguata *et al*., 2017).

Bamboo is an emblematic crop for bioeconomy, and one able to trigger profound rural transformations. Bamboo forests cover around 35 million ha, with 1642 documented bamboo species that are native to many countries in tropical, subtropical and temperate regions. With over 10 000 documented applications for food, fodder, fuel and as a renewable material, bamboo value chains contribute USD 70 billion to the global economy (FAO and INBAR, 2018). In Chishui, Southwest China, bamboos were used for converting sloping farming land into forests for soil erosion control, resulting in a growing bamboo resource of over 87 thousand hectares. Chishui City has made great efforts to develop the bamboo industry. By the end of 2019, the city had nearly 400 bamboo processing companies, creating an output value of 6.19 billion yuan (about USD 872 million) benefitting over ten thousand local farmers (FAO and INBAR, 2018). Harvested bamboo culms are

mainly used for furniture production and paper pulp making, while the branches and the culm tips are used for creating bamboo brooms and for bamboo charcoal. The bamboo sawdust left behind from making furniture is used for making charcoal, incense sticks and as a substrate for fungus and mushroom growth, while the other unutilized bamboo left behind from making furniture such as culm base parts are used to power the boilers for production. This ensures that 100 percent of the bamboo is utilized and there is no wastage (FAO and INBAR, 2018). In addition, harvested bamboo shoots are consumed fresh or processed into instant food.

Bioeconomy includes the development of value chains for specific products derived from wild or underutilized and neglected species, benefiting from interest for more nutritious foods. An example, among others, is the remarkable development of açaí production and the associated value chain in Brazil. Until 1995, açaí was consumed mostly in the North Region of Brazil. However, in the last 20 years, it has conquered the rest of Brazil and global markets, particularly the United States, Europe, and Japan. It is now considered a commodity, meaning that for local producers, demand is no longer a constraining variable: the national and international market can absorb all production. Açaí pulp production now exceeds 250 000 tons per year, benefits more than 300 000 producers and adds at least 1 billion USD to the Amazon economy each year. Net income from acai production ranges from USD 200 per hectare per year in unmanaged systems and to up to USD 1 500 per hectare per year in managed agroforestry systems (figures for the state of Pará) (MAPA, 2022).

Micro- and macroalgae play an increasingly important role in bioeconomy. Global algae production (including cultivation and wild collection) has increased over 60 times, from 0.56 million (wet) tonnes in 1950 to 35.82 million tonnes in 2019 (FAO, 2021d). In 2020, 36 million tonnes of algae were produced, with a value of USD 16.5 billion (FAO, 2022a). This was largely due to the growth of aquaculture (specifically, marine aquaculture), which accounts for 95 percent of total algae production. Asian countries represent 97 percent of the total algae production (FAO, 2022a). Seaweed cultivation, often labour-intensive, contributes significantly to coastal communities' incomes, with a substantial portion of first-sale value going towards wages. Downstream activities generate even more income and jobs (FAO, 2021e). In the Philippines alone, the industry involves 100 000–150 000 seaweed farmers, 30 000–50 000 local consolidators, and over 20 000 small traders. Seaweed farming in Zanzibar is an important foreign exchange earner, generating up to USD 8 million a year and employing around 25 000 people, the majority of whom are women (Virgin *et al.*, 2022). Trade in algae increased from USD 65 million in 1976 to USD 1.1 billion in 2020, with China, Indonesia and the Republic of Korea the main exporters, and China, Japan and the United States of America the major importers (FAO, 2022a). In 2019, 98 countries earned USD 2.65 billion from seaweed exports, including USD 909 million from seaweeds and USD 1.74 billion from seaweed-based hydrocolloids, according to UN Comtrade statistics (FAO, 2021e). Seaweeds present an opportunity for food security, serving as both food and feed, including for aquaculture (FAO, 2022a). Algae have multiple non-food uses: biofertilizers in coastal

regions and can be used to produce biofuels and bio-packaging, as well as pharmaceuticals and nutraceuticals. Algae-based fabrics are naturally fire-resistant and biodegradable (Arunkumar *et al*., 2023). Various strains of microalgae are also used for the treatment of textile industry wastewater for their ability to remove hazardous materials, such as *Scenedesmus obliquus* (to remove benzophenone in water), Oscillatoria sp., and Chlorella sp. (to remove dyes from wastewater through biosorption) (Khan *et al.,* 2022). The use of microalgal species, especially *Arthrospira* and *Chlorella*, is also well established in the skin care market. Their extracts are found in anti-aging creams, refreshing or regenerating care products, emollient and as an anti-irritant in peelers and also in sun protection and hair care products (FAO, 2021e).

Circular bioeconomy closes the biological resources loop and maximizes the use of residual streams from agriculture, food processing and biobased industries, by reusing, recycling or composting waste materials and converting them into useful products. There is for instance growing interest in insect farming, including in the black soldier fly (*Hermetia illucens*), to effectively bioconvert organic waste materials into resources like food, feed, and plant nutrients (Wang and Shelomi, 2017).

Bioeconomy frequently relies on the dynamism of emerging markets, with demand and market development often driven by actors outside the regions where resources are extracted. Key market participants in the bioeconomy are often located outside the production areas. This creates a potential risk that development initiatives may unintentionally exclude traditional users of these resources – particularly women, Indigenous Peoples, and other vulnerable groups – from both actual use rights and intellectual rights. For bioeconomy to be successful and fully contribute to inclusive and sustainable rural development, accompanying measures need to be put in place to avoid unintentional negative effects on local populations, including proper safeguards and policies that incubate local enterprises and give ownership to local actors, assessing trade-offs in biomass use, prioritizing higher value uses and re-uses over lower value ones, developing related value chains of higher aggregate value, and collectively managing wild resources stock or moving towards domestication when appropriate and feasible. For example, Brazil's Minimum Price Policy Warranty for Socio-Biodiversity Products (PGPM-Bio) offers subsidies to small-scale producers when their products are sold below the minimum price set by the Federal Government. This policy generates income for families whose livelihoods depend on natural resources and contributes to the preservation of local ecosystems and the maintenance of forests (Brazil, 2023). The aspirational principles and criteria for a sustainable bioeconomy, developed by FAO-led International Sustainable Bioeconomy Working Group (ISBWG), cover the three dimensions of sustainability and provide a framework for assessing and managing trade-offs associated with the implementation of bioeconomy (FAO, 2021f).

3.4 Landscape approaches for inclusive resilient rural development

Inclusive and resilient rural development requires sustainable management of natural resources, providing benefits and development opportunities to various categories of actors, including disadvantaged and marginalized people that most depend on them, for diverse activities, while ensuring resilience of socioecosystems and households, and preserving resources for future generations. Often, interventions and changes in agricultural sectors are focused on a single objective or, especially when driven by the private sector, on a commodity and its value chain. Private value chain actors generally focus on increasing production of a single product, to benefit from economies of scale, and to improve and standardize its quality. They have generally neither interest nor adequate means to support farmers' diversification. However, when designing policies and measures that can affect the uses of natural resources, it is imperative to take into account, protect and compensate for effects on existing agrifood systems, Indigenous and traditional uses and use rights, effects on biodiversity and ecosystem services. Valuing natural resources and the services they deliver is crucial for informed decision making and for driving sustainable investment choices (Masiero *et al.,* 2019). This calls for a holistic, systemic approach to the use of natural resources. The difficulty is to determine the appropriate scale and, consequently, appropriate governance modalities.

Many ecosystem services that are relevant to agricultural production, such as pollination, pest and disease resistance, watershed protection and erosion control, occur on a landscape scale. These services are directly related to the resilience of agricultural systems and livelihoods, reducing environmental risks and improving coping capacities (FAO, 2007). Working at the landscape level is conducive to building resilience of land-use systems, natural resources and people's livelihoods in a cohesive way, if supported by effective institutional and governance mechanisms (FAO, 2015a). Understanding the dynamics between the different landscape elements (biophysical, social, economic and institutional) and engaging local stakeholders in decisions will help in the development of strategies and actions to increase resilience (Braatz, 2012).

The concept of an integrated landscape approach to land use management has received growing interest since the 1980s in the scientific literature as a way to reconcile multiple and often competing objectives: nature conservation, food production, poverty alleviation, climate change mitigation, sustainable management of natural resources, and sustainable development (Sayer *et al.*, 2013; Reed *et al*., 2016; Minang *et al.*, 2015; Arts *et al.*, 2017). From a natural resources perspective, a landscape approach enables better understanding of the relationship (in terms of competition, synergies, complementarities, spatial organization, effects on populations etc..) between different land uses within a determined landscape. Landscape approaches have to consider multiple socioecological phenomena that often require different scales of analysis as well as institutional levels of decision-making that can

be described as multiple nested scales and levels (Minang *et al.*, 2015; Reed *et al.,* 2015). The CGIAR programme on Forests, Trees and Agroforestry (FTA) adopted a broad perspective, characterizing landscape approaches in the following way: "As it relates to agriculture, forestry and other land uses, and to the livelihoods they sustain, the landscape approach transcends traditional management and governance boundaries, seeking to provide tools and concepts to identify, understand and address a complex set of environmental, social and political challenges, and to enable evidence-based and inclusive prioritization, decision-making and implementation" (FTA, 2017). Governance is becoming central in most recent analyses of the notion, like for instance, in the ten principles proposed to "reconcile agriculture, conservation, and other competing land uses" (Sayer *et al.*, 2013). The ability to effectively engage multiple stakeholders in decision-making processes not only elicits empathy and trust among participants, but also empowers previously marginalized or disadvantaged actors. Various studies have found stakeholder engagement to be crucial to the success of landscape approaches (Reed *et al.,* 2017), to the extent that such collaboration has been used to define "integrated landscape management" (Denier *et al.*, 2015).

Recent developments about landscape approaches are the result of an evolution of prior attempts to reconcile conservation and development and share characteristics of the ecosystem approach and watershed management. The CBD (2000) defines the ecosystem approach as "a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way". It introduced later the notion of landscape for large areas and to highlight the need to place greater emphasis on "the interactions between forests and other biome/habitat types within a landscape" as a way to go beyond a specific ecosystem (CBD, 2004). Apart from the question of scale the main difference between the two types of approaches (landscape versus ecosystem approach) centers on the place given to humans, who within an ecosystem approach are considered merely a component of the ecosystem, while a landscape approach adopts a more anthropocentric perspective to social-ecological challenges. Watershed management is a type of landscape approach (Scheyvens *et al*., 2017), but with a more specialized focus than other, more integrative, landscape management processes. However, given the importance of water for human activities, including for agriculture and human settlement—it is no surprise that they share a lot of characteristics. Indeed, resource management can be a viable entry point for a broader landscape approach (Foli *et al.*, 2018). The watershed is often a good way to delimit a landscape, and in many cases has a dedicated governance system. It is also a good example of an approach that can be applied at different scales, from small-scale watersheds to extended river basins. Using water as a way to delineate an area of intervention has two advantages: it shows how all economic activities, including agricultural ones, interact with water, both depending on it and impacting water quantity and quality; it can help integrate all activities in water management, including distribution of water use rights. It is at this level that the rules and mechanisms to attribute water use rights

can be determined, including ways to restrict water use and adapt its distribution in times of scarcity. Such choices are crucial to enable inclusive access to water. For instance, in areas where water rights are the object of a market it has been observed that in periods of water scarcity when there is competition with other sectors generating more revenue per unit of water – such as the oil industry – prices increase considerably and farmers are often outbid (D'Odorico *et al.*, 2020).

Landscape approaches can benefit from the recognition and integration of traditional and cultural knowledge and religious values of the landscape, and ought to incorporate such knowledge systems and values within their design, implementation and governance (Djenontin and Meadow, 2018). In the Solomon Islands, coastal communities have adopted conservation programs that are based on cultural landscape models recognizing indigenous values (Walter and Hamilton, 2014). As defined by FAO, Globally Important Agricultural Heritage Systems (GIAHS) are outstanding landscapes of aesthetic beauty that combine agricultural biodiversity, resilient ecosystems and a valuable cultural heritage. The GIAHS Programme, launched by FAO in 2002, aims to strike a balance between conservation, sustainable adaptation and socioeconomic development. It helps identify ways to mitigate the threats faced by GIAHS and to enhance the benefits they provide. Through multistakeholder support, the GIAHS approach aims to: provide technical assistance; support the conservation of traditional knowledge; and promote agricultural products, agrotourism and other market opportunities and incentives (FAO, 2018c). Another emblematic example is the Kailash sacred landscape conservation and development initiative. In 2005, China, India and Nepal agreed to take an integrated approach to the management of Mount Kailash landscape, an area defined through ecological criteria, watershed boundaries, livelihoods and administrative units, leading to a cooperation framework, a conservation and development strategy, and a knowledge management strategy (Deneir *et al*., 2015).

Landscape approaches have to address major challenges. A first challenge is the sheer complexity of landscapes, which requires navigating conflicting objectives and fast and slow drivers of change, such as population growth, migration, policy reform, market fluctuations, climatic events etc. (Fischer *et al*., 2017; Bürgi *et al*., 2017). A second one is the disproportion in terms of wealth, power and capacity to be heard between local actors and big international actors (Sayer *et al.*, 2017). The difficulty to align external and internal objectives has often been noted (Reed J. *et al.*, 2016). Traditional and local institutions cannot deal with such external pressures and need to be supported with strong national policies and institutions. Sayer *et al.* (2017), having reviewed experiences from seven landscapes in three regions, note that landscape approaches cannot overcome disparities of power or entrenched interests. One way to address some of these difficulties is to embed landscape approaches in existing local institutions. In the Philippines the national government is encouraging local authorities to carry out integrated comprehensive land use planning. With the support of GIZ, local authorities have developed an approach to manage landscapes from "ridge to reef", from the central forest areas to coastal and marine zones,

recognizing the inter-dependencies of these areas (Deneir *et al*., 2015). This has given way to jurisdictional approaches. Broadly speaking, jurisdictional approaches are integrated landscape planning initiatives aligned with sub-national or national political jurisdictions to facilitate government leadership. Such approaches can, for instance, aim for jurisdiction-wide "certification" of one or more commodities, or implementation of the Reducing Emissions from Deforestation and Forest Degradation (REDD+) approach.

Climate change creates an additional push towards landscape approaches, both directly and through additional demands for bioenergy and carbon sequestration as well as to support adaptation of human settlements, activities and livelihoods. Climate change strategies and plans can create new opportunities to develop and sustain landscape approaches. There is increasing recognition of the need to consider landscapes as a level of implementation for climate mitigation policies (Bernard *et al.*, 2013), with examples of jurisdictional approaches to REDD+ in particular (Boyd *et al.,* 2018). However, such jurisdictional approaches have not escaped criticism, as they face vulnerability due to political turnover and uncertainty as to how to account for potential leakage effects. Solutions can be sought in regular engagement with policymakers on socioecological challenges at landscape (or jurisdictional) scale. Meanwhile, an emerging field is increasingly concerned with the issue of leakage effects, both in proximate regions and distant teleconnected landscapes (Liu *et al*., 2013; Carrasco *et al.*, 2017; Fischer *et al*., 2017). Furthermore, tools to engage stakeholders in scenario-building and simulation modelling can be used to enhance the anticipation of future threats and opportunities – particularly in the context of a changing climate. It is also at landscape level that the various contributions of ecosystems to the resilience of human settlements and livelihoods to disasters and to climate change can be best assessed and improved. National planning approaches, such as National Adaptation Plans, offer new opportunities for integrated approaches. As an example, Fiji's national plan of adaptation recommends prioritizing ecosystem-based adaptation, for instance to reduce shoreline erosion or provide storm protection.

Particularly promising in terms of governance for inclusive and resilient rural development are the systems grounded in collective management of a territory or resource, such as community forestry (Box 1) and other decentralized collective forms of management of natural resources, including inland and marine fisheries.

Box 1. Community forest management – case studies from Asia

In the Greater Mekong subregion, almost all countries have adopted policies supporting sustainable forest management, with multiple objectives. The development of participatory forestry, local forest management and land allocation helped reduce deforestation and forest degradation (Yasmi Y. *et al*., 2017). In Viet Nam, by 2015, about 1.1 million hectares (ha) of forest were under community forest management. Land laws in Viet Nam regulate the conversion of land, including agricultural and forest land, to other uses. Viet Nam has a system of land-use master plans that must be followed when allocating land uses. The country also introduced a Payment for Ecosystem Services (PES) scheme in 2010 to support sustainable forest management, improve livelihoods and protect the environment.

The Viet Nam case study shows that a shift from state forestry to multistakeholder forestry with the active participation of the local population was a key factor in achieving positive trends. Forest protection contracts with households are being used to involve local people in forest-related activities and to develop community-based forest management (FAO, 2016). The new law, entered into force in 2019, includes provisions on "forest environmental service", a type of non-forestry product arising from the demand for economic development and the realities of people's daily lives. The policy is based on the principle that beneficiaries of forest environmental services must pay their service providers, creating a new financial source to reinvest into the forest.

In Indonesia, Community Plantation Forests (*Hutan Tanaman Rakyat*), introduced in 2007, provide communities with the possibility to develop timber plantation businesses on state forest lands. The scheme was designed to achieve multiple objectives, including to: improve income for communities surrounding forests; increase timber supply for the wood industry; and rehabilitate degraded forest areas. By end 2013, 700 000 ha of state production forests were allocated across 113 districts, with 6 000 cooperative and individual licence holders (Rohadi *et al.,* 2017).

In the 1970s, Nepal's forests were severely degrading due to grazing and fuelwood harvesting (Cassidy, 2021). From 1993, the Government's Forest Act No. 2049 enabled handing over the management of almost 50 percent of Nepal's forests (around 1.8 million ha) to around 18 000 Community Forest User Groups, allowing them to extract resources from the forests (fruits, fodder, medicine) and sell forest products (Libois *et al.,* 2021). Groups often restricted grazing and tree cutting, limited fuelwood harvests, actively patrolled forests to ensure their protection, and developed planting and harvesting programmes. Conferring legal rights to utilize and oversee forest resources, the Forest Act created opportunities for communities to generate income through sustainable forest-based enterprises, ecotourism and agroforestry. It also mitigated conflicts over forest resources. User fees and income generated by sales of forest products are reinvested in the forest and used for collective village-level projects and public infrastructure (Libois *et al.,* 2021). The Act helped double Nepal's forest extension in a few decades. Community forests now cover around 2.3 million ha, one-third of Nepal's total forest area. They are managed by over 22 000 groups comprising 3 million households (NASA, 2021). More than one-third of the Nepalese population is directly involved in forest management (Libois *et al.,* 2021).

Sources: ***Yasmi, Y., Durst, P., Haq, R.U. & Broadhead, J.*** *2017. Forest change in the Greater Mekong Subregion (GMS): An overview of negative and positive drivers. Bangkok, FAO.* ***FAO.*** *2016. State of the World's Forests. Rome.* ***Rohadi, D., Dunggio, I., Herawati, T., Wau, D. & Laode, Y.*** *2017. Promoting the development of community plantation forests in Boalemo, Indonesia. Policy Brief no 73. Bogor, Indonesia, ICRAF. https://worldagroforestry.org/publication/promoting-development-community-plantation-forests-boalemo-indonesia* ***Libois, F., Baland, J.M., Delbart, N. & Pattanayak S.*** *2021. Community Forest Management: The story behind a success story in Nepal. DeFiPP Working Paper 2021-06.* ***Cassidy, E.*** *2021. How Nepal Regenerated Its Forests. In: NASA Earth Observatory.*

Another example of decentralized management of resources is territorial use rights in fisheries (TURFs), an area-based fishery management approach in which the state grants groups, or sometimes individuals, exclusive and secure access to fish in a specified area, with the responsibility to manage the stock (HLPE, 2014b). Well-designed TURF systems include controls and hold fishers accountable. They generally do not grant ownership, but rather harvesting privileges, on some species in a given area. Therefore, TURFs function as forms of community-based management, enabling implementation of ecosystem approaches. They can also trigger fishers to organize, to bring about transformation and marketing of their products.

There is considerable potential for landscape approaches to improve natural resources management for inclusive and resilient rural development. It requires, however, attention to governance; recognizing, giving voice to and managing the diversity of perspectives and interests; and long-term cross-sectoral land use planning, supported by appropriate policies at nested scales, including links with sustainable value chains (van Oosten *et al*., 2018). It also requires facilitating access of small producers to finance for a diversity of activities. This will require concerted efforts and financial innovations as current financial mechanisms and actors are favoring biggest actors and single activities with a risk of further homogenizing landscapes and excluding disadvantaged and marginalized groups (Louman *et al.*, 2020 and 2022). Unlocking investment for a more sustainable use of natural resources means not only looking at how much is being directly invested in conservation, restoration, or sustainable use of natural resources, but also the financial flows diverted away from projects and investments that are harmful to ecosystems and natural resources. There are two complementary approaches to mobilizing finance for nature, including forests, at scale: financing green, and greening finance (World Bank, 2020). Financing green seeks to unlock investment (particularly, private investment) for nature-based solutions and projects that contribute to the conservation, restoration, and sustainable use of biodiversity and ecosystem services. Greening finance aims to redirect broader financial flows away from projects with a negative impact on biodiversity and ecosystems.

3.5 Managing trade-offs and implementation challenges

The multiple potential uses of natural resources, for diverse agricultural activities (crops, livestock, forestry, fisheries and aquaculture) and other economic or environmental purposes give rise to multiple trade-offs, competing objectives and interests. Each of the four pathways depicted above will need to navigate such trade-offs. There may also be trade-offs between maximizing economic benefits from resource extraction and maximizing social benefits such as associated employment opportunities, or maximizing food production, or other ecosystem services (OECD, 2008). Unclear property and use rights, power imbalances between categories of actors and weak institutions, may hinder inclusive

governance and distribution of benefits from rural development. This would push poor, vulnerable and marginalized communities further into marginalization and poverty. The political and governance dimensions are thus key in ensuring pro-poor natural resource management for inclusive rural transformation (OECD, 2008).

Conventional rural transformation models are contributing to changing patterns of settlement and land use, thus exerting varying degrees of pressure on natural resources. Analyses of the effects of rural transformation have generally focused on effects at farm level, size of farms, rural income, labor and capital including their movement between agriculture and other sectors, as well as between rural areas and cities (Wang *et al*., 2023). The effects of land-use change, especially deforestation, on rural transformations also need to be considered. Land use change alters the structure of natural capital and impacts the distribution and amount of ecosystem services it provides. According to economic theory there is scope for converting one form of capital into another. Wild and unmanaged natural capital can be transformed in managed natural capital, or into other forms of capital (including for industry and services). However, for such a conversion to be overall economically beneficial in the long run certain conditions need to be met. A "weak sustainability" approach requires that the combined value of all forms of capital remains constant or increases. In such a perspective the decrease of natural capital due to land degradation for instance could be compensated by an increase of other forms of capital resulting from the accumulation of income produced. Such a condition can only be fulfilled if there is effectively a mechanism for such an accumulation of capital. "Strong sustainability" is grounded on the principle that wild natural capital is complementary to managed capital and cannot be substituted by it. For the conversion to be beneficial overall, the sum of the goods and services provided by the new system must be greater than the sum of those provided by the previous one, including ecosystem services. Moreover, any change in land use is likely to modify not only the amount of natural capital and ecosystem services but also their relative distribution among stakeholders, with perceptions of trade-offs that will be different between categories of actors and often between regional, national and local levels. Decision should thus be informed by a comprehensive assessment of benefits and costs, taking into account the wide range of ecosystems services as well as the various categories that benefit from each of them. This is made difficult by the absence, for many ecosystem services, to the notable exception of CO2 sequestration, of a market value. The loss of ecosystem services can have far ranging impacts when the services are difficult or impossible to substitute or when it will lead to the loss of the human capital (specialized knowledge and skills) associated to previous use. Ideally, the benefits to the very poor should be weighted higher than those to richer categories, leading to a modified benefit-cost ratio or rate of return (Pearce, 2005).

Particular attention should also be given to the way collective resources are managed. Management of common pool resources, public good resources and club resources, for which market mechanisms are absent or highly imperfect totally depend on the rules and

institutions, formal or informal, that govern their use (OECD, 2008). Development of large-scale farms or plantations often leads to privatization of land and water restricting access rights. Rural transformation and growth that is accompanied by the conversion of natural capital to the exclusion of rural poor that depend on it for their livelihoods, is not socially inclusive and exacerbates unequal access to resources and imbalances of power. The imbalance in influence and advocacy capabilities between small and big actors, local stakeholders and international players (Sayer *et al.*, 2017), as well as between different actors at the local level, generally disadvantages small-scale producers, who often lack bargaining power in both inputs and outputs markets, and have limited access to capital, financial and technological resources. This also presents issues for the diversification of production systems, which is often impeded by the prevailing tendency among big actors to favour monocultural production due to its perceived ease and cost–effectiveness, relying on economies of scale. To achieve resilient and diversified agrifood systems it is important to provide technical support and extension services that can support diversification, and develop value chains for different products, supporting strategic planning of value chain development, particularly on production lines downstream and markets, through reducing transaction costs and strengthening market linkages (Cavatassi *et al.*, 2011) as well as using public procurement to create a sustainable demand for emerging value chains.

Conversion of natural forests to crop, livestock, or to tree plantations can bring benefits to rural populations (and has often resulted in migrations into the converted areas). However, populations (including Indigenous Peoples) that were living in these forests, or close to forests were often negatively impacted (in terms of livelihoods, and FSN) by deforestation and land-use change. For example, the conversion of open access natural forests into privately held plantations remains a controversial element of rural development, as it can have positive or negative outcomes for different groups of rural dwellers. Van der Meer Simo reported negative impacts in the Greater Mekong associated with the loss of local access to forest and/or grazing lands, loss of grazing areas contributing to the abandonment of buffalo rearing, which led to lower productivity in rice paddies with impacts on nutrition, and the loss of access to forestlands was associated with loss of areas important for refuge from natural hazards or for the preservation of cultural values (Van der Meer Simo, 2020).

Similarly, pastoralism faces increasing pressure due to sedentarization policies, often harming pastoral livelihoods. Unsustainable pastoral land management is often linked to structural changes and rural transformation policies that are affecting resource governance or land rights, which constrain the way pastoralists use their knowledge of the environment. Sedentary livestock production systems in rangelands are often associated with a series of environmental problems including soil erosion, degradation of vegetation and encroachment by unpalatable shrubs, carbon release from soil organic matter decomposition, loss of biodiversity due to habitat changes, and adverse impacts on soil hydrological function and water cycles. For example, in southern Africa, the establishment of sedentary livestock ranching schemes resulted in vast areas of rangeland becoming encroached by unpalatable

shrubs, which in South Africa alone is estimated to affect over 13 million hectares of rangeland (Behnke, Scoones and Kerven, 1993). In Ethiopia, it is reported that the conversion of critical dry season pastures into irrigated farmland has restricted the mobility of livestock, one of the key factors for the high resilience and sustainable resource management of pastoralism (Centre for Rural Development (SLE), 2017). The loss of mobility is linked to overstocking, environmental degradation and declining livestock productivity and production resulting in a broad-based impoverishment as livestock is the key economic asset among pastoralists. An analysis of the opportunity costs of irrigation in the Awash valley of Ethiopia comparing the economic benefits of three alternative agricultural systems, pastoral livestock production versus cotton and sugar estates, concluded that pastoralism was consistently more profitable than either cotton or sugar-cane farming, while avoiding many environmental costs (Behnke and Kerven, 2013). Such analysis should be conducted before any rural development project resulting in land use change. It should take into account all previous uses, including informal and temporary so that the disaggregated effects of land-use change on poverty and rural development can be assessed, for various categories of populations and types of activities.

Given the increasing scarcity of land, water and other natural resources, both globally and especially in some regions, it is imperative to preserve, restore and sustainably manage these resources. This might in turn add new constraints, some of which could be temporary; examples are exclosures that allow for vegetation to regrow while being protected from livestock. However, such measures, as well as conservation measures like the establishment of protected areas, might increase poverty, reduce resilience of households and also increase pressure in neighboring areas. All these potential effects need to be assessed and addressed to avoid negative impacts that can de facto annihilate the benefits of the measure.

Use and management of natural resources for rural development also depends on the underlying biodiversity (including agrobiodiversity) and will have to integrate the need to reduce biodiversity loss and related policies and plans. The Kunming-Montreal Global Biodiversity Framework (CBD, 2022) includes a range of targets that are relevant to the agricultural sectors. In many countries, as requested by the CBD, these targets are now being inserted into national plans (NBSAPs) and the priority actions further specified at subnational level. Restricting the access and use of natural resources for rural communities, local and Indigenous Peoples, can cause displacement, and worsen the conditions of already vulnerable populations that rely on those resources for income and livelihoods (West, Igoe and Brockington, 2006).

Communal resource management is often an effective conservation tool. Conservation targets can be achieved for example through “other effective area-based conservation measures”’ (OECMs): areas, distinct from protected areas, which are governed and managed to achieve long-term biodiversity conservation, maintain ecosystem functions, and protect

local values. OECMs could recognize productive lands under special conditions such as agroforestry. Effective and sustainable management systems, supported by land tenure and access rights policies contribute to ecosystem conservation, alongside customary provisions that promote wild species' sustainable use, including rest periods, spatial and temporal prohibitions on use, and designation of areas and species for exclusive use by kinship groups (IPBES, 2022). Revenues from the extractive use of wild animals, including hunting and fishing licenses and concession fees can provide an important and substantial income stream for conservation agencies and local communities (IPBES, 2022).

When environmental and social safeguards are fully implemented, the sustainable use of wild species can boost economic and social development, especially through high-added value uses (Fromentin *et al.*, 2022). Non-extractive practices can have significant benefits for local economies and populations. Nature-based tourism is one of the fastest growing segments of the global tourism industry (OECD, 2008). Besides having positive effects on mental and physical wellbeing, this form of tourism supports local economies, contributes to public infrastructure, generates income for local communities and, in protected areas, can alleviate funding shortages by directing revenue to support their management (IPBES, 2022). However, ecotourism can also oversimplify local life, alter people's perception of their surroundings, and lead to resource pressure and increase in waste due to increasing tourist numbers and activities (West, Igoe, and Brockington, 2006). It is therefore important to establish standards for community-based and nature-based tourism that incorporate legal, regulatory, social, and information-based approaches, capable of ensuring the provision of livelihood benefits while safeguarding local cultures and environments. Context-based understanding, best practices in observation, communication, education, and heightened public awareness among tourists and tour operators, as well as implementing sector-specific regulations can, though, alleviate many of the unsustainable impacts associated with this form of tourism (IPBES, 2022).

Any additional challenge to be addressed and any new opportunity for development creates additional risks of exclusion. Poor and marginalized rural people have more difficulties to seize opportunities and may face additional risks as agrifood systems change. Growing demand for food in general and for higher value and more nutritious food products, as well as for other bioproducts, can be a substantial driver of rural economic development. On the other hand, there is the risk that these economic opportunities will not be captured by local populations and/or smallholders. The ability to take advantage of opportunities is not equal. Small-scale producers in rural areas have little bargaining power in either input or output markets. Many smallholders are women, who often have less access to production resources, credit, knowledge and information, and markets. The involvement of youth in farming is also decreasing. Pastoralists continue to be marginalized and not considered by national policies and programmes. New standards will often be more difficult to meet and certify for smaller producers for various reasons.

Additional opportunities also increase competition for resources with additional risks of these resources, whether land, water, or biomass, being captured by more privileged actors, displacing or excluding other actors that were previously using the resource, often in an informal way. The development of bioeconomy and of new uses for discarded food and other poorly valued biomass is for instance likely to reduce the amount easily available as a cheap feed source for livestock. For all these reasons, some countries have developed policies that aim to address trade-offs and more specifically to protect and support the most vulnerable. The example of the Brazilian policies for biofuel production has given way to various analysis (HLPE, 2013a). The National Program of Biodiesel Production and Use (PNPB) was explicitly oriented to social inclusion and regional development, particularly for Brazil's most impoverished Northeastern region, with choice of oil crops being guided by their regional suitability (palm oil in the North, castor oil in the Northeast, soybean in the South and Centre-West), with, in each region, a minimum percentage of feedstock sourced from family farmers being a pre-condition for biodiesel firms to obtain access to the market. Even with such conditions the participation of family farmers remains difficult, showing the importance of access to land and associated assets (HLPE, 2013a).

The four pathways can mutually reinforce each other, reinforce synergies for multiple benefits and help address trade-offs such as between maximizing economic benefits from resource extraction and optimizing employment and food production. They need to be supported by inclusive governance and strong stakeholder engagement to address challenges related to wealth and power imbalances among stakeholders as well as unclear property and use rights. Their implementation also requires supportive policies and investments.

4. Supportive policies and investments

Natural resources availability, accessibility and sustainable management is a prerequisite for resilient and inclusive rural transformations. Optimizing natural resources for resilient and inclusive transformation requires supportive policies and investments that pursue two objectives: Improve efficiency in the use of natural resources at all scales, including through the development of bioeconomy and ensure integrated adaptive natural resources management through inclusive institutions, policies, better governance and integrated planning.

4.1 Improve prioritization and efficiency at all scales

Well-planned and targeted policies and investments are essential for the implementation of pathways towards the sustainable management of natural resources for resilient and inclusive rural transformations. A first step is to identify priorities and constraints in terms of natural resources availability, accessibility and management that should guide the selection of interventions. The conservation and restoration of natural resources can include land restoration, sustainable use of water resources, improvement of irrigation systems and the characterization and sustainable use of agrobiodiversity. Regulations can also seek to optimize the overall productivity of natural capital through adequate prioritization of uses, or to develop complementary public investments, for instance on irrigation and transport infrastructures. To facilitate innovation and increase resource efficiency, it is recommended to make data and knowledge available and accessible to local actors; facilitate the coordination of all involved stakeholders at different levels; and promote innovative practices in value chains and landscapes.

The promotion and development of a sustainable and inclusive bioeconomy can be achieved through existing frameworks or the development of novel approaches. Such approaches may aim to analyze and manage trade-offs associated with biomass use; support research and innovation in novel products and processes; or promote renewable materials as substitute to non-renewable ones. They may also serve to support strategic planning of value chain development, particularly downstream production lines and markets. Such policies can use public procurement and other incentives to create a sustainable demand for emerging value chains, support the creation of transformation industries in rural areas, provide technical support and extension services that can support diversification and facilitate transfer of technologies. To incentivize sustainable consumption, and therefore production, it is also important to foster market signals and incentives that help promote products and services

resulting from and contributing to sustainable, resilient and inclusive agrifood systems. Likewise, it is necessary to address any policies, market and governance distortions that may incentivize unsustainable and inefficient use of natural resources, or otherwise act as barriers to investments in sustainable solutions.

A key area of intervention is data and knowledge generation and sharing. Policies and investments need to be grounded on a clear view of the current situation, and on potential improvements or deteriorations. This requires periodic checks on the status of natural resources and ecosystem services (at various scales and in diverse contexts). It also calls for understanding local use of natural resources, including informal ones, gathering data on wild products, and identifying best practices to increase resource efficiency. This, in turn, may vary depending on contexts and objectives, as well as on the indicators and methodologies applied to monitor and assess resource use and resource use efficiency.

4.2 Ensuring integrated adaptive natural resources management

Governments should recognize that natural resources management is political in nature. As such, it needs to be based on a clear understanding of the interests and perspectives of the various actors, and on the disaggregated impacts of management options. The Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security, officially endorsed by the Committee on World Food Security on 11 May 2012, promote secure tenure rights and equitable access to land, fisheries and forests as a means of eradicating hunger and poverty, supporting sustainable development and enhancing the environment (FAO, 2022c). Together with the Principles for Responsible Investment in Agriculture and Food Systems (FAO, 2014) adopted by the Committee on World Food Security on 15 October 2014, they should inspire all actors' interventions.

Policies should be implemented to establish or improve institutions that enable integrated adaptive natural resource management at various nested levels. Such policies should extend to integrated land use planning (the assessment and allocation of land-based resources across a landscape, accounting for differing uses and demands from different users), collective natural resources management, integrated water management and irrigation, and equitable distribution of benefits and rights. Policies should also aim at promoting inclusive and participatory planning processes on the use of natural resources, particularly land and water, creating the conditions (rules, institutions and incentives) for integrated and adaptive management of resources. This would serve to prioritize the use of such resources, in order to increase resilience of systems, communities and households during crises. An example would be the redistribution of water rights to preserve the livelihoods and capital most at risk of suffering from the long-term consequences of drought. The reallocation should

protect and expand poor and marginalized peoples' access to natural resources, avoiding natural resource capture by elites. The policies should balance the objectives of maximizing production, economic return and job creation.

Policies can be crucial to improve assessment of the economic and social impacts of different natural resources management options. This includes gathering data in a transparent way, with appropriate gender and social group differentiation, ensuring that the assessments and data are available and accessible to all relevant stakeholders. When assessing the benefits and rate of return on investments, giving additional weight to the benefits for the most vulnerable can have significant effects on inclusiveness.

Developing sound regulations and effective institutions is essential to guarantee land and water use rights for all groups, including all disadvantaged categories. In this regard, clear ownership and use rights, including customary tenure and resource use rights, are important. Supporting the capacity of local organizations and collective management by user groups can also significantly reduce inequalities and enhance resilience. Building the capacity of community-based cooperatives and organizations to manage natural resources involves developing skills in accounting, monitoring, planning, and dispute resolution, as well as building upon traditional knowledge.

The preparation and implementation of national plans, such as National Adaptation Plans (NAPs), National Biodiversity Strategies and Action Plans (NBSAPs), and measures for implementing Nationally Determined Contributions (NDCs), offer opportunities to improve the resilience and inclusiveness of rural development.

5. Transforming natural resources management and uses to transform rural economies

Agriculture and rural development depend on the availability of natural resources (natural capital) which is increasingly constrained and degrading, particularly in some regions, and submitted to competition of other activities. Natural resources are the main asset of rural communities, particularly of poor people, Indigenous Peoples and other marginalized categories. For these groups, the ecosystem services provided by nature are particularly important. How natural resources are managed ultimately determines the resilience of agrifood systems and households, particularly against the impacts of climate change. It is therefore more urgent than ever to conserve natural capital, and the ecosystem services it provides, and to ensure that the related benefits go to those who need them most and act as their stewards, so that rural development can be resilient and inclusive. The increasing scarcity and degradation of natural resources, as well as increasing competing demands and uses for diverse agricultural activities or other economic or environmental purposes, call for conserving and sustainably managing all resources, prioritizing and optimizing their uses, improving resource efficiency, and facilitating access.

The growth of different high-value uses of natural resources is an opportunity for rural economies. It also gives rise to multiple trade-offs, competing objectives and interests. Potential conflicts are likely to be exacerbated by development and the increased income and profits expected. This reinforces the need for strong governance to protect and prioritize the rights and voices of the less advantaged. Landscape approaches, where priorities for uses and management of land and natural resources are discussed among the full set of local stakeholders in an inclusive way, are key to making natural resource management work for inclusive and resilient rural development. Considerable attention needs to be given to governance, recognizing, giving voice to and managing the diversity of perspectives and interests, and to long term cross-sectoral land use planning. These efforts should be supported by appropriate policies at nested scales and including links with sustainable value chains.

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Food and Agriculture Organization of the United Nations

Rome, Italy

ISBN 978-92-5-139900-2

CD5784EN/1/06.25