Introduction

The challenge of meeting the food and nutrition requirements of a growing population through sustainable and climate-resilient farming systems is one of the key issues facing African agriculture over the coming decades. This challenge is well recognized by African political leaders. Africa’s Agenda 2063 endorsed by the African Union (AU) Summit of January 2015 and the AU Malabo Summit Declaration of June 2014 on Accelerated Agricultural Growth and Transformation both affirmed African governments’ commitment to eliminate hunger and food insecurity by 2025; and to enable resilience of livelihoods and production systems to climate change and other shocks (AU, 2014, 2015). Meeting these commitments will critically depend, among other things, on how land, soils, water, energy and agroecosystems are managed and sustained in the production of food and other basic human needs. As essential as these resources are, each one is coming under pressure due to demographic, economic and climatic changes.

Africa’s population is projected to increase from 1.1 billion in 2013 to 1.6 billion people by 2030 (UNDESA, 2013). This increase will translate into a need to produce at least 50% more food (AUC-AMCOW, 2016). Urbanization is also growing apace. In 2015, 40% of Africa’s population lived in urban areas and this proportion is projected to rise to 56% by 2050 (UNDESA, 2014), leading not only to an increase in the quantity but also in the variety of food demanded. Water use in the agricultural sector is about 184 km³/year, accounting for about 81% of total water withdrawal (FAO, 2016). The projected increase in population by 2030 is expected to lead to, at least, a tenfold increase in water needs for energy production to support industrial, social and economic growth (AUC-AMCOW, 2016). This points to a greater competition for available water resources in future. At the same time, water and energy resources are at the centre of the recent wave of foreign investments in agricultural land in Africa (Williams et al., 2012; Sidibé and Williams, 2016). Climate variability and climate change also come into play. The projected increase in temperature of up 1.4°C by 2020 in Africa is predicted to result in increased rainfall variability and incidences of extreme weather events.

The mounting pressure on natural resources from various angles and the risks posed to the attainment of the SDGs in Africa point to the need to reexamine, within a nexus perspective, the linkages between natural resources. This reexamination is needed to identify technical, policy and institutional arrangements that will promote resource use efficiency and integrated resource
management approaches to meet future food, human and environmental security objectives in Africa. However, in order to understand how linkages between resources can be better managed, it is necessary to first review the status and characteristics of resources and how they impact on food production and food insecurity on the continent.

Characteristics of the natural resource base, food production and food insecurity in Africa

Land and water

Africa is relatively well endowed in land and water resources. Over the three-year period 2012–2014, average cultivated area was about 271 million hectares (24% of cultivable area and 9% of total land area) compared with 238 million hectares in South Asia (75% of cultivable area and 37% total land area) (FAOSTAT, 2017). Long-term average internal renewable freshwater resources (IRFWR) per capita is about 3,319 m$^3$ in Africa and 1,131 m$^3$ in South Asia. Freshwater withdrawals as a percentage of IRFWR is around 6% in Africa compared with 46% in South Asia (FAO, 2016). The overall land and water endowment statistics for Africa, however, mask significant sub-regional differences between land abundant and land constrained countries (Jayne et al., 2014) and between countries experiencing physical and economic water scarcity (CA, 2007). Furthermore, Chamberlain et al. (2014) and Jayne et al. (2014) have pointed out that Africa’s underutilized arable land is concentrated in a few countries, many of which are fragile states, with the additional problem that most of this land is located far from input and output markets, thus limiting their economic attractiveness in the short term. Irrigation is not yet widespread in Africa. The total area equipped for irrigation in Africa in 2013 was 15.6 million ha (5.8% of cultivated area) and 98.0 million ha in South Asia (45.7% of cultivated area) (FAO, 2016).

Over most of the cultivated and rangeland areas, land degradation is pervasive. A recent study by ELD Initiative and UNEP (2015) reckoned that desertification affects about 45% of Africa’s land area, with 55% of this area at high or very high risk of further degradation. The same study pointed out that an additional 280 million tonnes of cereals per year could be produced if soil erosion is controlled.

Soils

Although Africa has a wide variety of soil types (Figure 26.1), the soils over much of the continent are old and highly weathered, often lacking in essential nutrients and organic matter and thus requiring careful management when used for agricultural purposes.

Arenosols are the most dominant soil type in sub-Saharan Africa (SSA) occupying about 22% of the land area. They are easily erodible sandy soils with low water- and nutrient-holding capacity. Leptosols are the second dominant soils, covering about 17% of the land area. They are shallow soils over hard rock with a weak soil structure and little fine earth. They have low organic carbon and low fertility status which create severe limitations for rooting depth. Next in order of relative share are cambisols covering about 11% of SSA land area. They can have varying characteristics depending on the nature of the parent material, climate and terrain. They have low to medium agricultural potential. In essence, going by the classification in Figure 26.1, up to 50% of SSA soils are of low to medium quality.

On top of the inherent quality problem, continuous cultivation of arable land with little or no nutrient input has led to declining soil fertility. For the period 2010–2012, fertilizer use
intensity, measured as average kilograms of fertilizer nutrients (nitrogen, phosphorus and potassium) per hectare, was 14.9 for SSA, 157.9 for South Asia and 124.0 for the world (FAO, 2015). Other negative consequences include soil acidification and soil erosion.

The conundrum of limited arable land expansion possibility in many African countries coupled with widespread soil and land degradation and the need for irrigation expansion bring to the fore the synergies and trade-offs underlying the resource nexus approach. Under this situation, sustainable agricultural intensification, involving increased fertilizer, organic manure and water use together with high-yielding crop varieties, would seem an appropriate response. Although renewable water resources in Africa are not anywhere near being fully exploited currently, managing trade-offs among competing needs and using water efficiently is critical given climate change and population growth projections.

**Energy**

Primary agricultural production in Africa is still largely driven by human and animal energy. The use of mechanical energy for land preparation, cultivation and harvesting remains low. Energy
input for water lifting and pumping in large-scale irrigation schemes has traditionally been based on electricity generated by hydropower schemes. In 2013, Africa’s installed hydropower capacity was reported at 45,936 MW out of an estimated hydropower potential of 304,335 MW (AU-AMCOW, 2016), indicating room for expansion of hydropower generation in new environmentally and socially acceptable ways. Small-scale irrigation schemes rely mostly on small- to medium-size pumps powered by electricity or fossil fuel (diesel and gasoline). In many countries across Africa where such pumps are commonly used by smallholder farmers, the removal of government subsidy on electricity, diesel and gasoline has sharply increased the cost of running these pumps, prompting a gradual switch to solar-powered pumps. Data on mechanization and energy input into agro-processing, storage and transportation are not routinely collected on a national or regional basis. Indirect energy input into food production in the form of sequestered energy in fertilizers is low.

The recent increase in bioenergy crop production in Africa raises the spectre of a trade-off when biofuel and food production competes for land and water (Harvey and Pilgrim, 2011; Bogardi et al., 2012). In a review of 148 large-scale agricultural land investments across sub-Saharan Africa with a total of 3.4 million ha, 68% of the investments were directed towards bioenergy crops, including *Jatropha* and sugarcane (Williams et al., 2015). Apart from the direct competition, large-scale biofuel plantations have often led to the displacement of poor existing land users and this, in turn, leads to loss of access to land and associated water rights (Williams et al., 2012; Kizito et al., 2013).

**Food production**

With low population pressure in the 1960s, per capita food production in Africa was higher than in Southern Asia and the world (Figure 26.2, based on FAOSTAT database). With increasing population and poor performance of the agricultural sector in Africa in the 1970s and early 1980s, food production failed to keep pace with population growth. Per capita food production for most of the 1980s and 1990s was below the level achieved in the early 1960s in Africa. It is only in the last decade that Africa has witnessed a rapid growth in per capita production but the continent still lags behind the growth achieved in Southern Asia and globally over the same period.

**Cereal yield**

Only modest gains have been recorded over the past 50 years in increasing the yield per hectare of the most important cereals consumed in Africa (Figure 26.3, based on FAOSTAT database). For the period 2010–2014, rice yield per hectare in Africa was only about 70% and 57% of yield levels in Southern Asia and the world. For the same period, maize yield per hectare was about 70% and 38% of Southern Asia and World yield level. The cereal yield gap indicates the potential for improvement in Africa and show that more needs to be done to close the gap. Nonetheless, a recent study by van Ittersum et al. (2016) provided evidence which showed that it will not be feasible to meet future SSA cereal demand on current production area by yield gap closure alone. Additional measures including intensification (i.e. increasing cropping intensity) and sustainable expansion of irrigated production area will be needed, if SSA is to avoid greater dependence on imports of cereals than it does today. For much of the 1990s and up to 2007, cereal import-dependency ratio hovered around 22–30% per year. It jumped to an average of 35% during the three-year period 2010–2012 and 42% over the period 2011–2013 (FAOSTAT database).
Figure 26.2  Net per capita food production index in Africa, South Asia and the world, 1961–2013

Rice:

Figure 26.3  Cereals yield (kg/ha) in Africa, Southern Asia and the world, 1961–2014
Figure 26.3  Continued
The slow progress in increasing yield per hectare and overall production has, in turn, led to unsatisfactory progress in eliminating hunger in Africa. Despite progress achieved over the past 20 years in reducing hunger and undernourishment, one in five people remained undernourished in Africa in 2014 (Table 26.1).


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Source: FAO, IFAD, and WFP (2015)

**Undernourishment**

The slow progress in increasing yield per hectare and overall production has, in turn, led to unsatisfactory progress in eliminating hunger in Africa. Despite progress achieved over the past 20 years in reducing hunger and undernourishment, one in five people remained undernourished in Africa in 2014 (Table 26.1).

### Opportunities and challenges of a resource nexus approach

The current status of natural resources, the magnitude of yield gaps and the level of undernourishment depicted above partly provide a justification for an alternative approach to the utilization and management of natural resources for food production. Figure 26.4 illustrates a conceptual framework that can be used to examine the potential opportunities and challenges entailed in a...
resource nexus pathway to feed Africa. Drivers of change such as population growth, urbanization, climate change, science and technology, income growth and policies will affect the inter-linkages and the way land, soil, water and energy resources within an agroecosystem is managed to produce food and meet development and environmental objectives. Understanding the linkages, trade-offs and synergies between the various resources in an agroecosystem is key to managing them in such a way that they can mutually support food production and allow the critical gains of a nexus approach to be realized while contributing to desirable sustainability outcomes.

There is evidence that the interlocking and reinforcing positive benefits of integrated land, soil, nutrients, water, energy and ecosystem management can bring about increased food production alongside resource use efficiency, resource substitution, climate change mitigation and adaptation. Achieving these objectives will, in turn, lead to positive sustainability outcomes. A few examples will suffice.

Soil and water conservation techniques, including zaïs and rock bunds, in conjunction with tree planting are being used in many countries in West Africa to rehabilitate degraded land and contribute to food security and poverty alleviation (Sawadogo, 2011). Zaïs are traditional constructions of holes about 20 cm across and 15 cm deep used to increase soil moisture and organic matter content. Farmers place organic matter, such as composted manure, in these holes to create a micro environment that allows crops such as sorghum and millet to grow well despite poor soils and dry conditions. Tests of the impact on soil fertility and yields show that zaï can produce significant increase in soil moisture and organic content and can, under certain conditions, double or even quadruple crop yields. However, manual construction of zaï is labour intensive, requiring about 300 man hours per hectare (Barro et al., 2005). Mechanized zaï construction using animal traction has been shown to reduce labour time to about 22–36 hours per hectare and simultaneously increased sorghum yield by 34% compared with manual zaï construction (Fox et al., 2005).

System of Rice Intensification (SRI) is an agroecology-based rice planting method that was developed in Madagascar in the 1980s. It incorporates four synergistic agronomic practices of
improving plant establishment, reducing plant population, improving soil conditions and reducing irrigation water application. In practice, single young rice seedlings are planted at wide spacing and compost, manure and crop residues are applied, supplemented as needed by chemical fertilizer. Weeds are controlled using a mechanical hand-pushed or motorized multi-row weeder and irrigation water is applied using alternate wetting and drying (AWD) method. The technology has been successfully applied in several sub-Saharan Africa countries including Madagascar, Mali, Gambia, Ghana, Kenya and Tanzania. Benefits of SRI per hectare reported in several studies can be summarized as follows: rice yields increased by 25–70%; 30–60% less irrigation water utilized; plots used 85–90% less seeds and 30% less chemical fertilizer and herbicides (Styger et al., 2011; Nyamai et al., 2012; Omwenga et al., 2014; Kahimba et al., 2014). These benefits translated to lower costs and improved revenue for farmers, while simultaneously allowing them to optimize the use of natural resources. In addition to rice, farmers have begun to apply SRI agronomic principles to the cultivation of other crops such as wheat, sugarcane and teff with good yield increases and environmental benefits (SRI-Rice, 2014).

Kizito et al. (2013) provided evidence which showed that when large-scale biofuel plantations on marginal lands are properly managed, they can serve as a positive ecosystem buffer to reduce runoff and pollution of water bodies. Model results indicated that runoff under *Jatropha* was 30% lower than runoff under fallow land. The reduced soil erosion arising from reduced runoff can also help in the reclamation and restoration of such marginal lands for future productive agricultural use. By using marginal lands that are not used for food production, the trade-off between biofuel and food production on prime agricultural land is avoided.

Solar-powered irrigation systems (SPIS) are emerging in Africa as an antidote to the challenges faced in using electricity and fuel-powered pumps for irrigation. Many rural communities are located in out-of-grid connection areas. Even in areas with electricity connection, high tariff and erratic power supply make electric pumps extremely unreliable and expensive to use by small-scale farmers (Giordano and de Fraiture, 2014). Use of fuel-powered pumps (diesel and gasoline) is equally expensive for smallholders due to the increasing cost of fuel, as governments gradually withdraw subsidies, and maintenance costs (Namara et al., 2014). In this situation, solar pumps coupled with drip irrigation kits are seen as a cost-effective and environmentally benign long-term solution to expand irrigation and increase agricultural productivity in Africa. Private sector companies and NGOs are at the forefront of promoting SPIS in East, West and Southern Africa while state agencies are prominent in North Africa. Some of the more advanced private sector companies (e.g. SunCulture in Kenya) provide farmers with soil analysis and on-site training using technicians and agronomists certified by the company, thereby creating service-oriented jobs for other workers. The various benefits associated with SPIS, for example, reliance on renewable energy and emissions-free pumping power, water savings, reduction in fossil-fuel demand and agricultural labour costs are all in consonance with the principles of resource substitution, resource use efficiency and environmental sustainability that are at the heart of the nexus approach. Burney et al. (2010) in a study conducted in Sudano-Sahel zone of West Africa showed that solar-powered drip irrigation can provide significant economic, nutritional and environmental benefits. Income earned by women irrigators from the production of market vegetables enabled them to purchase staples and protein during the dry season and their consumption of vegetables increased to the recommended daily allowance of 500–750 g per person per day. Also, the authors estimated that by using a solar-powered pump instead of a fuel pump, each vegetable garden of about 0.5 ha avoided a minimum of 0.86 t of carbon emissions per year (12.9 t over a 15-year lifetime). Nevertheless, there are cost-related challenges and environmental safeguard measures that need to be put in place to promote adoption and sustainable out-scaling of SPIS in Africa. These measures will be discussed in the following section.
Another promising area in the application of the resource nexus approach that also provides a rural–urban linkage is the work that IWMI and its partners are doing to turn fecal sludge and solid waste that end up polluting water sources and the environment in rapidly urbanizing cities across Africa into safe, pelletized organic manure for agricultural use (Nikiema et al., 2014; Cofie et al., 2016). The objective is not only to improve sanitation in urban areas, but also to recover nutrient and organic matter from waste in a business-oriented manner that is also beneficial to soil fertility improvement and agriculture. The fertilizer produced through the co-composting of solid waste and fecal sludge, called Fortifer, provides organic manure in a form (i.e. pellets) that is cost effective (lower transport cost) and easier to handle for on-farm distribution. In Ghana, the Environmental Protection Agency and the Ministry of Food and Agriculture in 2016 certified Fortifer as an organic fertilizer for commercialization and distribution. As part of this work, IWMI facilitated the establishment of two public–private partnerships (PPPs) for commercialization of Fortifer. A co-composting plant, established through one of these PPPs, that will annually transform 5,000 m³ of fecal sludge and 300 t of organic solid waste into 200 t of Fortifer is due to start production early in 2017. Another strand of this work is investigating energy recovery from waste to provide reliable cooking energy in the form of briquettes to households in Uganda (Gebrezgabher et al., 2016).

**Policy and institutional measures for a resource nexus approach to future food production in Africa**

The interlinked and interdependent nature of the resource nexus makes it imperative to coordinate and integrate policies across sectors. Yet to date in Africa there is a dearth of policy frameworks to explicitly link and coordinate the management, planning and implementation of the nexus. To be sure in some countries, for example, Morocco a single ministry is responsible for energy, mining, water and the environment. Also, several African countries that have signed the Comprehensive African Agriculture Development Program (CAADP) compact have developed a National Agriculture Investment Plan (NAIP) and, with respect to climate change, National Adaptation Plan of Action (NAPA) that include some elements of the resource nexus. A recent review of the NAIPs of countries in West Africa that make up the Economic Community of West African States (ECOWAS) pointed to a missed opportunity to sufficiently integrate energy dimensions into the NAIPs and rural development programmes where agricultural and water management policies and income generation are jointly considered (Bhattacharyya et al., 2015). At the continental level, the African Climate-Smart Agriculture Alliance was launched following the 2014 Malabo Declaration to mainstream climate change into agriculture. Through this alliance, countries and regional economic bodies across the continent are being supported to initiate inter-agency dialogues and cross-sectoral integration of climate-smart agriculture into NAIPs and water management policies. While these efforts are in the right direction, much more still needs to be done to put in place coordination and integration structures across sectoral boundaries. In doing this, thoughtful consideration should be given to what needs to be coordinated at what level and which policy instruments would be appropriate to bring about this coordination (Pahl-Wostl et al., 2014).

The growing importance of SPIS in Africa exemplifies the need for joined-up policies to ensure full realization of the benefits of the resource nexus approach. With increasing cost of fuel and electricity due to withdrawal of government subsidies, farmers are willing to ditch fuel and electric power pumps for solar pumps. But a majority of smallholder farmers cannot afford the initial capital outlay on solar pumps, which are still expensive in many African countries compared to fuel pumps of the same power supply capacity. In this situation, innovative financing arrangements, including credit risk guarantee schemes to lenders by governments, can help to provide loans to farmers to defray the upfront capital outlay on solar pumps and drip irrigation kits. In addition, complementary
energy policies to allow the sale of any excess power generated by farmers using SPIS to public
and/or private sector utility companies will prevent farmers from over irrigating and drawing down
the water table through over pumping of groundwater. IWMI through the TATA Foundation
supported Solar Power as Remunerative Crop (SPaRC) project is exploring coordinated policy
options not only to ensure sustainable SPIS, but also to improve future solar economy of India
(Shah et al., 2015). Similar projects appropriately adapted would be equally useful in African countries.

Policy measures are also needed to effectively bring together various actors (representatives of
farmers, public and private sectors, NGOs and civil society) in the resource nexus value chains. In
many African countries, private sector firms, NGOs and civil society organizations working
-1-

Together with individual farmers and farmer groups are already actively promoting various
aspects of the nexus approach. In addition to the involvement of some of these actors in the SPIS
described above, Syngenta Foundation for Sustainable Agriculture (SFSA), in collaboration with
AfricaRice (a CGIAR centre), has been working since 2010 to support SRI projects in Senegal,
Mali and Burkina Faso. SFSA provides land preparation and grain harvesting and threshing ser-

vices to farmers through its Farmer Equipment Service Centre model. Yields have increased from
6 to 8 t/ha in the river delta of Senegal and from 4 to 6 t/ha in parts of Burkina Faso and Mali
(SFSA, 2016). In addition, farmers are linked to the rice supply chain to improve timely access to
inputs and increase productivity and income. Governments can support these developments by

providing an enabling environment and regulatory framework to provide appropriate incentives.

Governance of natural resources is at the heart of the resource nexus. The range of scales and
institutional settings in which governance decisions are made suggest that flexible but comple-

mentary governance arrangements are needed to ensure resource use efficiency and desirable live-

lihood and environmental outcomes. Such flexibility will allow some decision-making powers to
be devolved to local government level, while others are coordinated at the national level (Bhaduri
et al., 2015). In countries where such devolution of power has been undertaken (e.g. Burkina Faso,
Ghana, Ethiopia, etc.) the problem often is the disconnection between natural resource manage-

ment decisions taken at the two levels. In other cases, the decision-making authority at the lower
tier level lacks the power and resources to put into effect the decisions taken. Establishment of
multi-stakeholder dialogue platforms involving representatives from the different tiers of govern-
ment, resource user groups and civil society is of paramount importance to facilitate the crafting
of new governance arrangements that are in tune with the nexus approach (Karlberg et

al., 2015).

At the same time, the political issues inherent in the nexus approach need to be recognized
and addressed. As pointed out by Woertz (2015), ‘affordable food, water and energy are crucial
for political legitimacy and so is their nexus’. The trade-offs and co-benefits innate in the nexus
will throw up winners and losers and other issues that are best resolved through the political
process. On a different but related note, checks and balances in the political system will be

needed to ensure that nexus narratives are not used to justify rent seeking or disadvantage poor
smallholder farmers while favouring big domestic and foreign investors.

Effective and well-functioning intra-Africa regional trade will be an important adjunct in the
quest to promote resource use efficiency and to ensure that food is produced only in areas with
the requisite comparative advantage. While the volume of food trade within the continent has been
increasing in recent years, removing the remaining bottlenecks that still impede trade will go a long
way to promote future improvement in trade and allow more efficient resource use and food produc-
tion on a regional basis. Furthermore, opportunities to mainstream the basic tenets of the resource
nexus approach into future revisions of the Voluntary Guidelines on Responsible Governance ofTen-
ure and Principles for Responsible Investment in Agriculture and Food Systems should be explored.

One criticism that has been leveled against the nexus approach is that it is long on theory
but short on translating theory into real-world solutions and outcomes at multiple scales and
on demonstrating practical steps of how the nexus approach can be implemented (Leck et al., 2015; Woertz, 2015). Lack of a consensus on what constitutes a successful nexus approach outcome and how it can be achieved, monitored and evaluated poses significant challenge to policymakers (Leck et al., 2015) and puts the onus on the proponents of the approach. This points to the need for investment in research to expand the pool of nexus-related technologies and foster innovation that will allow the processes, solutions and outcomes of the nexus approach to be clearly and practically demonstrated. Equally needed is investment in the development of indicators and methods to monitor and evaluate the outcomes of nexus implementation and provide the evidence base to scale-out successful solutions. In this respect, the SDGs and associated targets and indicators that are now being developed provide a framework to organize and implement the resource nexus approach in many African countries.

Practical utilization of new nexus-related technologies and management practices will necessitate strengthening the capacity of farmers and/or assisting them to develop new competencies to implement approaches they may not yet be familiar with. Yet agricultural extension systems in many African countries are poorly resourced in human-, physical- and financial-capital terms. Non-governmental organizations and international aid agencies have stepped in to provide advice directly to farmers without much coordination among such organizations and with government departments. Policies to foster coordinated public–private sector partnership in advisory services delivery to farmers will need to be implemented to support the resource nexus approach.

Conclusions

Land, water, energy and agroecosystems are the essential pillars of primary food production all over the world. The availability, quality, policies and institutions governing the use and management of these resources impose opportunities and challenges on food security, human well-being and the environment. Linkages between these resources have always been recognized, but often considered in a two- or three-dimensional context that links land and food production; soil fertility and food production; land and water; land, water and ecosystems; or water, energy and food. Recent evolution in nexus thinking, as espoused in the opening chapter of this book and the SDGs, have provided an impetus to look at the linkages through a multidimensional lens in order to identify solutions to improve resource use efficiency and address trade-offs without losing sight of human well-being and environmental outcomes. This task is of special relevance to Africa where increasing population, resource degradation and unsatisfactory progress in reducing malnutrition makes it particularly important to utilize available resources to improve food and nutrition security and enhance livelihoods while simultaneously protecting valuable ecosystems.

This chapter analyzed the characteristics of the natural resource base and the ensuing food insecurity and resource degradation to show that business as usual is no longer tenable. Five promising agricultural initiatives that are in line with the principles of the resource nexus approach were presented, with a discussion of the policy and institutional measures that are needed to further improve them and to ensure that additional similar innovations can be developed and successfully scaled out.

The evidence pieced together in this chapter demonstrates that there is a strong basis for the adoption and implementation of a resource nexus approach to feed Africa over the coming decades. It is both an imperative and a necessity that should be embraced by African governments on the basis of enlightened self-interest. With implementation of appropriate policies and institutional measures progress can be made in the planning and implementation of such an approach to deliver tangible outcomes that will ensure improved resource use efficiency and livelihoods, as well as long-term sustainability of valuable ecosystems.
References


