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Agroforestry solutions to address food security and climate change challenges in Africa☆

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Trees inside and outside forests contribute to food security in Africa in the face of climate variability and change. They also provide environmental and social benefits as part of farming livelihoods. Varied ecological and socio-economic conditions have given rise to specific forms of agroforestry in different parts of Africa. Policies that institutionally segregate forest from agriculture miss opportunities for synergy at landscape scale. More explicit inclusion of agroforestry and the integration of agriculture and forestry agendas in global initiatives on climate change adaptation and mitigation can increase their effectiveness. We identify research gaps and overarching research questions for the contributions in this special issue that may help shape current opinion in environmental sustainability.

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Introduction

Thirty-five years ago widespread concerns over land degradation and the lack of effective solutions in Africa led to the hope that international agroforestry research could contribute new solutions [1]. Despite local success stories [2••], many parts of Africa have continued to experience food insecurity, declines in per capita farm income, and land and soil degradation, aggravated by biodiversity loss [3,4]. Where climate is highly variable, especially in the drier parts of Africa, many observers have begun attributing recent land degradation to climate change [5]. Indeed, projected future climate change is almost certain to affect negatively the agricultural resource base in many parts of the continent [6••,7•,8,9,10].

Many smallholder farmers in Sub-Saharan Africa practice agroforestry. These systems have prevailed despite persistent attempts to introduce monoculture production of annual crops, which have been much less successful in Africa than elsewhere [11]. Agroforestry has been shown to provide a number of benefits to farmers. For instance, it can enhance soil fertility in many situations and improve farm household resilience through provision of additional products for sale or home consumption [12]. The insight that trees on farms provide livelihood benefits is not new, and diversity-based approaches to agricultural adaptation to climate variability have been adopted by many farmers [13]. In light of recurring food shortages, projected climate change, and rising prices of fossil fuel-based agricultural inputs, agroforestry has recently experienced a surge in interest from the research and development communities, as a cost-effective means to enhance food security, while at the same time contributing to climate change adaptation and mitigation. It has also experienced a recent increase in adoption by farmers in many parts of Africa as demonstrated by Garrity *et al.* [2••].

In spite of these success stories, adoption has not been widespread in many parts of Africa, due to a number of reasons related to the performance of agroforestry practices, the political and socioeconomic environment or simply farmers' disposition towards trees on their farms. An active area of research therefore concerns the preconditions that must be met for successful establishment of agroforestry. For these reasons, major research frontiers in agroforestry science are the identification of appropriate extrapolation domains for locally successful practices, better understanding of barriers to adoption and development of strategies to overcome these barriers.

Major obstacles to the spread of agroforestry strategies are the lack of support for such systems through public policies [14], which often take little notice of tree-based

farming systems. Consequently, agroforestry is often absent from recommendations for ensuring food security under climate change [10], even though many practices have been shown to deliver benefits for rural development, buffer against climate variability, help rural populations adapt to climate change and contribute to climate change mitigation [15•,16]. Many studies have shown that agroforestry practices can slow or reverse land degradation, sequester carbon from the atmosphere and secure rural livelihoods through provision of ecological and economic benefits. In addition to increasing soil fertility, trees managed by farmers can also provide ecosystem services and functions in addition to the products and services that motivated farmers to plant or preserve them [17,18]. These services are of particular importance in many low-income countries in Africa, where large proportions of the populations work in an agricultural sector that does not attract much investment from either government or private investors [19].

This paper introduces a special issue of Current Opinion in Environmental Sustainability (COSUST) that seeks to explore the potential of agroforestry for providing benefits for livelihoods, as well as climate change adaptation and mitigation. The objective of this Special Issue is to take stock of the current state of knowledge and to flag important research avenues on agroforestry's potential to contribute to food security and to meet the challenge of climate change.

Agroforestry systems in Africa

Throughout Africa, agroforestry systems come in a wide variety of shapes and forms. Many of these systems have little more in common than the coincidence of woody perennials with agricultural crops and/or livestock. Basic data collection by the FAO does not clearly stress the segregation between forests and agricultural landscapes with trees. This can be seen as an historical anomaly rather than a reflection of incompatibility between annual and perennial plants within a farming system [20].

Trees or shrubs on farms and in landscapes can occur as solitary individuals, in lines, as woodlots or in the seemingly random constellations that characterized the forest that was present before the establishment of agriculture. Depending on the environmental, climatic, economic and socio-cultural niches they occupy, different types of agroforestry systems have arisen in different places. Some prominent examples that illustrate the diversity of agroforestry are the parkland systems of the Sahel, multistory homegardens on Mt. Kilimanjaro in Tanzania, cocoa systems in Côte d'Ivoire and rotational woodlots in Kenya. A number of approaches have been proposed for defining a typology of agroforestry practices and systems [18,21,22], but inclusion of multiple characteristics is necessary for grasping all major distinctive attributes of agroforestry systems (Table 1).

Several agroforestry practices can be relevant for different agro-ecological zones, and many systems with a range of different compositions can fulfill essentially the same functions for livelihoods and landscapes. There is thus no single classification scheme that can be universally applied [18]. What differentiates agroforestry from other land uses is the deliberate inclusion of woody perennials on farms, which usually leads to significant economic and/or ecological interactions between woody and non-woody system components [22]. In most documented cases of successful agroforestry establishment, tree-based systems are more productive, more sustainable and more attuned to people's cultural or material needs than treeless alternatives. Yet agroforestry is not being adopted everywhere, and better insights are needed into the productive and environmental performance of agroforestry systems,

Table 1

Diversity of agroforestry (AF) classification.

Typology of AF	Key elements	Examples AF practices	References
Ecological	Geographical location (AF system adaptability to particular ecologies)	Lowland humid or sub-humid tropics AF	[18,22]
Physiognomy	Parkland Mosaic Multistoried homegarden	*Faidherbia*, Shea butter parks in West Africa Long term fallows	[2••]
Compositional/structural	Simultaneous or sequential combination of trees, crop, animal	Trees in pasture and rangelands (silvopastoral) and agriculture (agrosilvopastoral)	[13]
Practices (systems)	Management systems, livelihood strategies	Hedgerows, long term fallows, alley cropping, improved fallow, multilayer tree cropping, woodlots	[18,22]
Functional	Erosion control, soil fertility	Wind breaks, shelterbelts, erosion control/soil conservation, scattered nitrogen fixing trees, boundary planting	[8,23]
Socioeconomic	Scale of production and level of technology, input and management (Commercial, subsistence AF)	Low input, high input agroforestry	[15,24,25]