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Use and management of biodiversity by smallholder farmers in semi-arid West Africa

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ABSTRACT

Strategies that strengthen and use biodiversity are crucial for sustained food production and livelihoods in semi-arid West Africa. The objective of this paper was to examine the role of biodiversity in sustaining diverse forms of multifunctional farming practices while at the same time providing ecological services to subsistence-oriented farming families in the region of study through mechanisms as (a) crop species diversification, (b) management of spatial heterogeneity, and (c) diversification of nutrition-sensitive landscapes. Our analysis shows that crop associations between cereals and legumes or between perennials and annuals, have overall positive effects on soil characteristics and often improve crop yields. Soil heterogeneity is produced by woody perennials and termites. Local management provides opportunities to collect a diversity of nutrition-rich species year-round and sustain household nutrition.

1. Introduction

Management of biodiversity is the cornerstone of agriculture. Historically, the perspective of 'ecology in agriculture' was introduced by Hanson (1939), underlining the need for ecologists to broaden the spectrum of study from wild native plants to domesticated, exotic, and cultivated crops. Agroecological 'theory' suggests that the strategic use of locally-available biological diversity (cultivated or wild) is key in supporting ecological functions and maintaining food cultures (Gliessman, 2011). A growing body of knowledge recognizes the importance of anchoring these designs in local food cultures and household objectives (Duru, 2013; Luckett et al., 2015; Bellon et al., 2016; Nicholls et al., 2016), and of integrating scientific and local farmer knowledge in the co-design of more sustainable farming systems (Dogliotti et al., 2014; Speelman et al., 2014; Geertsema et al., 2016; Garibaldi et al., 2017).

Rain-fed agriculture in semi-arid West Africa (SWA) is characterized by soils that are naturally poor in nutrients and organic matter content. Production indices for countries of semi-arid West Africa show increases in total staple food production yet average yields for local consumption remain alarmingly low, below 1 t ha^{-1} (www.faostat.org). While food security assessments and recommendations often focus on increasing production of staple food crops (i.e. cowpea, millet, sorghum, rice), it is unlikely that smallholder farmers in SWA sustain on grains exclusively. The strategic use of locally-available biological diversity (cultivated or autochthonous) is key in the design of agricultural management systems able to (1) produce sufficient food and ecosystem services, (2) diversify diets to meet food security and nutrition, and (3) support and sustain local food systems. In particular, woody perennial vegetation in Sahelian ecosystems provide an array of services to farming families, from the regulation of on-farm and landscape ecological processes to supporting local livelihoods (Sinare and Gordon, 2015). Despite a wide diversity of initiatives to cope with erratic environmental and market conditions (West et al., 2008; Sissoko et al., 2010), financial constraints and low institutional support rarely help in recognizing smallholders as innovators with valuable expertise to share with peers.

Farming practices that include biodiversity make use and simultaneously generate sources of spatial and temporal resource heterogeneity at various scales having consequences for soil functions, food

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production, and habitat provision for wildlife (Tittonell et al., 2015). At regional scales, several environmental characteristics may shape landscapes. These include biophysical aspects, such as heterogeneous soil types and topography (i.e. lowlands and salinization), soil fertility hotspots (i.e. termite nests or presence of woody perennials), and anthropogenic drivers such as accumulation of organic matter around household compounds (i.e. biomass transfers of woody or organic amendments and plant associations) (see Fig. 1).

Moreover, it is common in SWA to encounter different types of actors in farming territories, including pastoralists (nomadic or sedentary), market-oriented farmers (cotton, horticulture), and subsistence-oriented farmers (cereals, legumes, wild edible plants) (Diarisso et al., 2015). These actors use and manage biodiversity following food and livelihood objectives in different ways, but mainly through the combination of plant and animal species, the spatial and temporal management of fields and natural habitats, or through the direct collection of wild foods, medicinal plants and other resources from their landscape.

The objective of this paper is to examine the role of biodiversity in sustaining diverse forms of multifunctional farm and food systems and in providing ecological services. This is done through the analysis of farmer-driven (i) plant species diversification, (ii) management of spatial heterogeneity at field level and (iii) strategic use of nutritional functional diversity at landscape level. Illustrations and quantitative examples are built with own research data from semi-arid Burkina Faso.

2. Management of plant species diversification

2.1. Annual plant associations

Annual plant association or intercropping is an ancient and widespread agricultural practice in semi-arid West Africa (Mbaye et al., 2014). It consists of establishing two or more crops with overlapping development cycles simultaneously on the same plot during the same season (Zongo, 2013), with the objectives of diversifying and/or securing agricultural production and integrated fodder systems, but also for the improvement of soil fertility, weed-growth control, labour reduction, and intensive management of the available land (Essecofy, 2011; Karim et al., 2016). In traditional farming systems, the geometric arrangement of cultural associations may vary widely, from crops grown in different rows, or alternated within the same row, to distributed randomly without a specific geometric arrangement (Table 1). Associated crops can be sown in the same planting hole, as well (Zongo, 2013), or planted at different growth periods according to expected outputs or functions. The most represented combinations were cereals

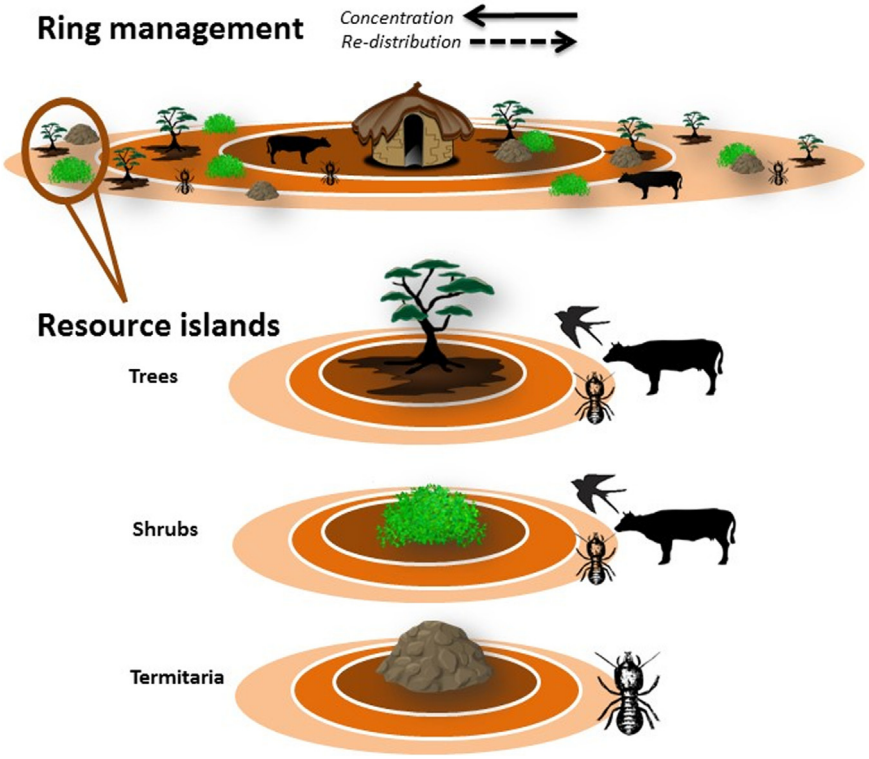

Fig. 1. Ring management results in continuous soil fertility gradients, catalysed by biodiversity management at the landscape level. Nested rings are formed by trees, shrubs, and termite nests constitute 'resource islands' that provide conditions for other organisms to thrive.

Table 1
Examples of spatio-temporal arrangements in intercropping practices of West Africa.

Location	Author	Cereal component	Associated legume component
Sub-humid Senegal	Diangar et al. (2004) ; Mbaye et al. (2014)	Millet (2 rows; 100 x 90 cm)	Cowpea (1 row; 10-15 days after; 100 x 60 cm)
Burkina Faso	Sanou et al. (2016)	Millet (1 row; 80 x 60 cm)	Cowpea (1 row; 80 x 40 cm)
Sahelian zone	Sarr et al. (2009)	Millet (1 row; 150 x 50 cm)	Cowpea (2 rows; 50 x 50 cm)
	Garba (2007)	Millet (1 row; 100 x 80 cm)	Groundnut (1 row; 100 x 30 cm)
		Sorghum (1 row; 100 x 80 cm)	Cowpea (1 row; 10 days after; 100 x 50 cm)
		Maize (2 rows; 80 x 50 cm)	Cowpea (1 row; 10 days after; 80 x 50 cm)
		Maize (2 rows; 120 x 80 cm)	Groundnut (2 rows; 10 days after; 40 x 15 cm)