



Research article

Natural ecosystem mimicry in traditional dryland agroecosystems: Insights from an empirical and holistic approach



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ABSTRACT

While the aim of Ecological Intensification is to enable the design of more sustainable and productive agricultural systems, it is not suited to dryland agroecosystems that are driven by non-equilibrium dynamics and intrinsic variability. Instead, a model based on mobility and variability management has been proposed for these agroecosystems. However, this model remains under-applied in southern Morocco where there have been few studies on the functioning of traditional agroecosystems. This paper focuses on an agroecosystem in the Moroccan Saharan fringe zone that combines agriculture and pastoralism in an acacia parkland. A grounded theory approach was used over a three-year investigation period (i) to highlight how agro-pastoral activities interface with environmental variability, and (ii) to analyze the formal and informal institutions that support these activities. Results show that farmers interface with rainfall variability through (i) an opportunistic agricultural calendar, (ii) a variation of cultivated areas, and (iii) crop diversification. Herders combine macro-mobility (nomads move over long distances to track rainfall) and micro-mobility (nomadic and sedentary herds are driven on a daily basis around settlements) to optimize the exploitation of ecological heterogeneity. During droughts, they also resort to State-subsidized forage supplies. Both cultivation and pastoral activities tend to interface with ecological dynamics and to mimic nature, resulting in a human-modified parkland that could be considered as a 'green agroecosystem'. The sustainability of natural resource use relies on flexible property rights, backed up by a social and cultural norm-based regulation system, that allow crop-livestock integration and landscape collective management. Despite encouraging results, the agroecosystem appears to be threatened by current agricultural policies, rural exodus and the lack of social recognition of nomadism. Nevertheless, because ecosystem mimicry of nature is often considered as a sound agricultural model for drylands, this case study could provide a basis for local development policies, and thus merits further attention from local managers and researchers.

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1. Introduction

Food production systems have to face two apparently contradictory challenges: producing more food and raw materials for a growing population demanding better quality, while contributing to biodiversity and ecosystem conservation. To meet these challenges, the Ecological Intensification paradigm (EI) has progressively emerged with the aim of "producing more output from the

same area of land while reducing the negative environmental impacts and at the same time increasing contributions to natural capital and the flow of environmental services" (Pretty et al., 2011). The conventional wisdom on EI acknowledges that there is not a single universal model to achieve this goal and recommends a site-specific adaptation of EI applications (Tittonell, 2014). Nevertheless, the general recommendations of EI per se – i.e., increasing and stabilizing yields per area, increasing cropping intensity and frequency, and adopting higher value crops (Pretty et al., 2011) – are argued to be incompatible with certain dryland agroecosystems, for which alternative recommendations have been formulated (Adams and Mortimore, 1997; Krätli, 2015).

Drylands encompass arid, semi-arid and dry sub-humid areas, cover more than 40% of the world's terrestrial surface area and host around one third of the human population (MEA, 2005). In contrast

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to more favorable life zones, where agriculture is mainly constrained by biological stress (e.g., interspecific competition, predation), environmental stress (e.g., water deficit) is the main limiting factor for dryland agriculture (Ewel, 1999). A second specificity of drylands is their “non-equilibrium functioning” (Chesson et al., 2004): rare, sporadic and unpredictable rainfall episodes are ‘pulses’ that initiate peaks in primary production and that put an end to longer periods of drought (‘inter-pulses’) characterized by near-zero production. As a consequence, ecosystem dynamics are not based on any equilibrium but are intrinsically driven by stochastic rainfall (in space and time) and variability. This functioning generates, for human livelihoods, a high degree of uncertainty that people have had to adapt to. The most well-known example is pastoral nomadism: herders breed mobile herds in order to track rainfall over an extensive territory (Niamir-Fuller, 2000), so as to maintain animals in the best pastures as long as possible and to stretch the length of the ‘pulse’ (Krätli, 2015). Another common strategy is livelihood diversification through crop-livestock integration or temporary jobs that, among other things, enable people to achieve a variable resource endowment according to climatic and socio-economic conditions (Turner, 1999). These adaptations nevertheless presuppose suitable structural and institutional arrangements. In particular, nomads’ access to a vast rangeland territory depends on collective land tenure systems and agreements between social groups (Salzman, 1967). In addition, being mobile affects every aspect of people’s lifestyle and social and technical organization (Fernandez-Gimenez and Le Febre, 2006).

Given the specificity of dryland functioning, a mobility paradigm emerged in rangeland literature in the 1990s for agroecosystem sustainable development (Niamir-Fuller, 1999). In contrast to EI, that focuses on production increase, the mobility paradigm emphasizes the importance of reproductive capital, safety nets and adaptive planning (Oba et al., 2000). Nevertheless, the pursuit of equilibrium and technocratic visions still influence dryland policies and legislation and undermine people’s ability to benefit from their variable environment (e.g., Hesse and Thébaud, 2006). In addition, dryland societies have been facing major changes over the last decades, including rural exodus, sedentarization, mobility restrictions and the development of the market economy. If certain changes may have been positive for dryland populations – e.g., access to temporary jobs and to new markets to stock and destock livestock have increased people’s ‘portfolio’ of activities –, others have undermined their ability to interface with variability – e.g., development of exclusive land tenure systems and work force erosion.

Southern Morocco, at the Saharan fringe, traditional agroecosystems based on nomadism and opportunistic cultivation have persisted, despite the development of modern, market-oriented and irrigated systems (Royaume du Maroc, 2010), and despite the pervasive impact of the decolonization process (Pons, 1997). Nevertheless these systems are largely overlooked by governmental agro-pastoral development agencies, especially because they are considered as archaic agricultural systems responsible for land degradation and desertification (Davis, 2005). The aim of this paper is to describe the functioning of a traditional agroecosystem (located in an area named Ighuweln) that appears to constitute a sustainable agroforestry parkland combining crop cultivation, pastoralism and acacia tree stands (Blanco et al., 2015). We first focus on the agro-pastoralists’ practices and strategies and describe how people achieve the domestication of a sustainable landscape that mimics natural ecosystem. Secondly, we analyze how institutional and social arrangements enable people to achieve ecological sustainability. Finally, we emphasize potential threats to this agroecosystem and the lessons learned from this holistic analysis regarding dryland traditional agroecosystems and their conservation.

2. Materials & methods

2.1. Study site

2.1.1. Ecological context and land-use system

The studied agroecosystem is located 40 km from the city of Guelmim (Fig. 1) in a place named Ighuweln. The climate is arid, with mild winters due to the proximity of the Atlantic Ocean (average temperature: 19.6 °C). Annual rainfall is particularly low (118 ± 72 mm)¹ and variable (with a coefficient of variation of 60.8%): a minimum of 23 mm was recorded in 2000 and a maximum of 350 mm in 2014. Four land uses dominate in Ighuweln (Fig. 1): (i) rocky terraces superficially covered with sand and gravel and crisscrossed by sandy runnels, used as collective pastoral lands; (ii) a pastoral plain with deep alluvial soils and local sand accumulations from wind erosion, also used as collective pastoral land; (iii) an agro-pastoral plain, occasionally flooded, used for swamp farming or livestock grazing according to rainfall and season; and (iv) steeply sloping unproductive rocky mountains, part of the Anti-Atlas Mountains. The vegetation is typical of the Saharan ecoregion, with *Vachellia tortilis* subsp. *raddiana* as the dominant tree species forming acacia parklands, and *Hammada scoparia* as the dominant shrub (Blanco et al., 2015). Because of the rainfall variability and the occasional presence of ephemeral species that grow and die rapidly after episodic rainfall, vegetation cover and biomass show high inter- and intra-annual variation (Fig. 2).

2.1.2. Populations: tribal vs. modern system

Ighuweln is located in Wadi Nun where the *Tekna* tribal Arab-Berber confederation have lived since the 13th century (La Chapelle, 1934). The *Tekna* is segmented into tribes and, in particular, the *Ait Noss* tribe is recognized as the legitimate owner group of Ighuweln according to traditional custom. This tribe is divided into four branches, each associated with a village: Taidalt and El Borj (Fig. 1) are respectively associated with the *Ouled Bouachra* and the *Ait Zikri* branches.² The modern Moroccan administrative boundaries are superimposed on the tribal boundaries. At the time of the study, Ighuweln was located in the township of Fask, in the province of Guelmim. In 2014, this township extended over 1532 km², and had 3943 inhabitants (2.6 ind./km²), with an annual growth rate of 1.3%. As the tribal and administrative boundaries do not match, only one part of the *Ait Noss* tribe (branches from Taidalt and El Borj) is embedded in the Fask township.

2.1.3. Local livelihoods and political background

Historically, the economy of Wadi Nun essentially relies on *trans*-Saharan trade, husbandry and agriculture (La Chapelle, 1934). Oases were used for date palm cultivation and irrigated gardening, floodplains and main riverbeds for cereal cultivation, and pastoralism occupied the rest of the territory. Wild plants and animals were also used for food, medicines, and raw materials. Nowadays, *trans*-Saharan trade has stopped, the regional economy is dependent on agriculture (irrigated and rain-fed), pastoralism (goats, sheep and camels), fisheries in coastal areas and tourism (Royaume du Maroc, 2010). The market-economy and urban development, along with recurrent droughts and sedentarization policies, has resulted in the widespread sedentarization of families and emigration to urban areas and abroad. Families who settled had to abandon pastoralism, but they still keep few head of livestock (only

¹ As recorded by the Agricultural Technical Center of Guelmim between 1984 and 2014.

² The two other branches, *Ait Bouhou* and *Ait Brahim*, are associated with the villages of Tiglit and Taghijit, both located outside Ighuweln.

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