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Agrobiodiversity performance in contrasting island environments: The case of shifting cultivation in Vanuatu, Pacific

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ABSTRACT

Shifting cultivation is considered to be the most widespread cultivation system in the tropics. However, it remains poorly understood in some countries. The measurement of agrobiodiversity in these systems, which could be used to better understand its sustainability in the face of social, economic and environmental change, has been the focus of little research. This study aimed to measure the agrobiodiversity on small, family-farmed, shifting cultivation fields in Vanuatu and to test the effect of different demographic pressures, locations and cropping systems. A total of 297 fields in 6 villages were measured and a spatial approach was used for comparisons at the field, farmer and village scales. Shifting cultivation in Vanuatu includes three main cropping systems, based on yams, rain-fed taro or irrigated taro, and other subsidiary systems. The configuration of each farm's cropping system depends on each farmer's choices and opportunities. Agrobiodiversity in fields was high with a mean species richness of 10.2 (±4.8 SD) and an intraspecific richness of 8.6 (±7.3 SD). In a crop sequence, agrobiodiversity decreased for yam and rain-fed taro fields but this decrease was faster in yam fields. Cluster analyses showed that the main factor influencing agrobiodiversity at the field and farmer scale was the cropping system. At the village scale, however, the cropping system only appeared to influence intraspecific richness as no difference in species richness was found between villages. Moreover, ANOVA showed no village effect on agrobiodiversity, which raises the question of whether there is an effect of scale affecting biodiversity assessments in landscapes. No correlation was found between agrobiodiversity and demographic pressures or fallow length at any spatial scale. This study showed that the agrobiodiversity is variable at the field and farmer scale but is stable across villages and islands and is influenced only by the dominant cropping system. It suggests that this system is still resilient in the face of recent economic, social and environmental changes, but requires further multiple scale studies for a deeper understanding.

1. Introduction

Shifting cultivation is considered to be the oldest cultivation system in the tropics (Gupta, 2000) and still ensures the subsistence of an estimated 250 million people (Bandy, 1987). Shifting cultivation (also known as swidden or slash-and-burn cultivation) could be defined as, "a natural or improved fallow phase, which is longer than the cultivation phase of annual crops, sufficiently long to be dominated by woody vegetation, and cleared by means of fire" (Mertz et al., 2009). It has long been considered to be a non-efficient system and the main cause of deforestation (Bandy, 1987). All around the world, conservation policies tried to eradicate shifting cultivation systems, e.g. in Southeast Asia (Fox et al., 2009). However, shifting cultivation increasingly appears to be an effective system for faunal and floral biodiversity (Gupta, 2000), crop diversity conservation (Rerkasem et al., 2009) and as a keystone for cultural and livelihood diversity (Shen et al., 2010; Xu et al., 2009). Shifting cultivation is also competitive with other cultivation systems such as intensive monoculture due to its high labor productivity (Nielsen et al., 2006) and the income it generates for farmers (De Jong, 1997). Thus under certain conditions, shifting cultivation could be considered to be a sustainable and productive agricultural system (Padoch and Pinedo-Vasquez, 2010). It remains, however, poorly understood.

Furthermore, relatively few studies have focused on the agrobiodiversity present in shifting cultivation systems. According to

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Qualset et al. (1995), "Agrobiodiversity refers to all crops and livestock, their wild relatives, and the species that interact with and support these species: pollinators, symbionts, pests, parasites, predators and competitors." In this definition, agrobiodiversity is a broad concept focused on crops and livestock (i.e. food production). Vandermeer and Lawrence (2002) propose another approach to agrobiodiversity that focuses on the manager of the resources. These authors consider agrobiodiversity to be, "the variety of biological components chosen by the manager. These may be the crops chosen to be planted [...], the volunteer medicinal plants that are not planted but nevertheless tended [...], the tree species chosen to be planted [...], the trees chosen to be harvested [...]." In this definition, agrobiodiversity includes all crops and plants managed and used by farmers, including food, medicine, timber, etc. This definition is particularly suited to shifting cultivation fields, which often contain multi-use species, and focuses on farmers' choices and management strategies. It consequently was retained for this paper. As biodiversity can be linked to the functioning and resilience of ecosystems (Hooper et al., 2005), agrobiodiversity can be used to better understand the dynamics and resilience of shifting cultivation systems. In shifting cultivation, farmers usually use mixed-cropping systems involving numerous crops and varieties, contributing to potentially high agrobiodiversity (Xu et al., 2009). Many studies have highlighted the impact of environmental, socioeconomic and political changes on agrobiodiversity (e.g. demographic growth, Gupta, 2000). Agrobiodiversity thus could be used (1) to compare different cultivation systems operating under the same conditions, and (2) as a proxy for assessing an agricultural system's resilience to various factors.

In Vanuatu, small-scale family farming plays an important role in the country's economy and involves 76% of the population (VNSO, 2009). In rural areas, each family owns a few fields managed through a shifting cultivation system that contain multiple species and, in some, multiple varieties. The agrobiodiversity on these fields therefore is expected to be high, as was shown by Caillon et al. (2006) at the intraspecific level (i.e. the genetic diversity inside crops) for taro (*Colocasia esculenta* (L.) Schott, Araceae). This mixed cropping system of species and varieties implies that two biological levels have to be considered when studying agrobiodiversity: (1) the species level, which offers a wide range of products (Kumar and Nair, 2004) for food, fuel wood, handicrafts and cash income; and (2) the intraspecific level, which contributes to yield stability (Cleveland et al., 1994), to a form of insurance to respond to future needs and changes (Jarvis et al., 2008) and to cultural diversity through farmers' practices and knowledge (Peroni and Hanazaki, 2002). To our knowledge, no study has focused on both species and intraspecific-level diversity in shifting cultivation fields in Vanuatu.

This study focused on assessing agrobiodiversity in shifting cultivation systems in different environmental contexts in Vanuatu. A hypothesis that agrobiodiversity is influenced by the cropping systems used and recent demographic changes was tested. Three spatial scales were considered: (1) the field scale, referring to the smallest management unit, (2) the farmer scale (or the cropping system scale) that includes all of the fields owned by a farmer of a given cropping system, and (3) the village scale (or the cultivation system scale) that includes all of the shifting cultivation fields in a village. This spatial approach allowed a better understanding of the accuracy of each scale. At the field scale, a temporal approach focused on the evolution of agrobiodiversity in the crop successions of a given cropping system. The main purpose of the study was to quantify intra and inter-specific agrobiodiversity in shifting cultivation systems in Vanuatu in six different situations. An integrated spatial and temporal approach was used to test the particular effect of the cropping system, the age of the field, the fallow length, the demographic pressures and the village location on agrobiodiversity.

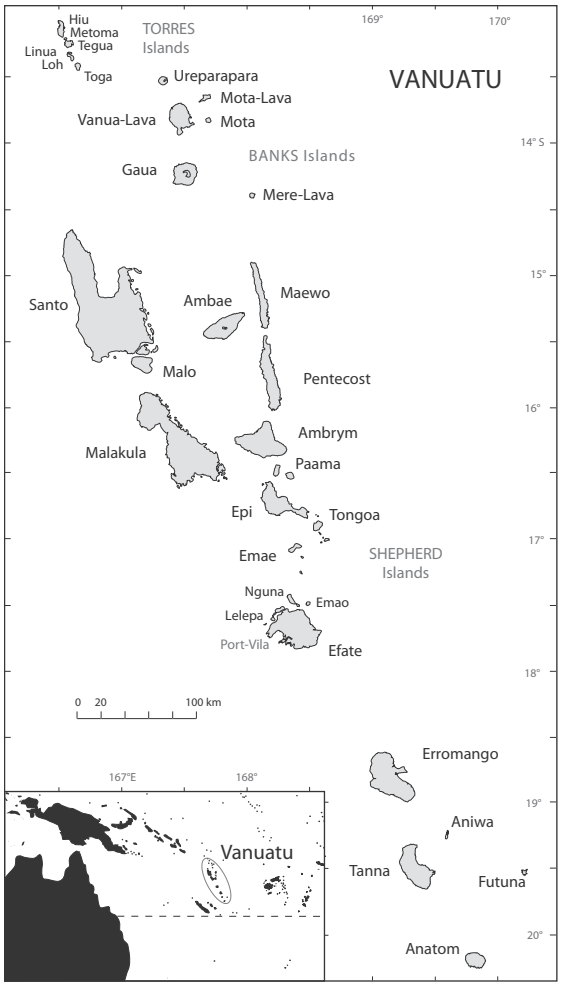

Fig. 1. Map of Vanuatu and island locations.

2. Materials and methods

2.1. Study site

This study took place in Vanuatu, a volcanic archipelago of 65 inhabited islands (out of a total of 83 islands) located in the South Pacific Ocean (Fig. 1), 1750 km east of Australia. From 1906 to 1980, Vanuatu (then known as the New Hebrides) was co-managed through a British-French condominium. In 2009, the population was 234,023 inhabitants, with an annual growth rate of 2.3% (VNSO, 2009). The rural population represented 75.6% of the total. With a total surface area of 12,281 km^2, the population density was about 19 inhabitants/km^2. The climate is subtropical, with a dry and cold season from May to October and a wet and hot season from November to April. Annual mean temperatures range from 23 to 27 °C (Siméoni, 2009). Annual rainfalls are very heterogeneous from North to South and range from 1500 mm in the southern islands to 4000 mm in the northern ones. Soils are dominated by Andosols of volcanic origin (Quantin, 1972).

2.2. Agriculture in Vanuatu

Agriculture dominates the country's economy and 98% of the rural population practice small-scale family farming. Farming systems have three components: a perennial plantation cultivation system, a shifting cultivation system, and a forest and arboricultural system (Fig. 2). The perennial cultivation system constitutes the main source of cash income for families. They usually own and