Biological Conservation 191 (2015) 779–786

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/bioc

Through the eye of a butterfly: Assessing biodiversity impacts of cashew expansion in West Africa

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ARTICLE INFO

Article history:
Received 12 June 2015
Received in revised form 17 August 2015
Accepted 24 August 2015
Available online 14 September 2015

Keywords:
Agricultural expansion
Lepidoptera
Perennial crops
Shifting agriculture
Tropical ecology

ABSTRACT

The cultivation of perennial cash crops is fast expanding in the tropics, but for most crops and regions there is very limited understanding about their biodiversity impacts. This is the case of cashew nut cultivation, which is occupying ever larger areas, particularly in West Africa. Here we investigated the impacts of cashew cultivation on biodiversity using butterfly assemblages sampled across a gradient of cashew expansion in Guinea-Bissau (West Africa). The overall species richness and abundance of butterflies were only slightly lower in cashew orchards than in native woodland habitats, but whereas the former were dominated by generalist species, the latter showed a much higher richness and abundance of trophic and habitat specialists. The landscape context significantly affected butterfly assemblages, with reduced richness and abundance of generalist species recorded within woodland habitats in heterogeneous landscapes with low woodland cover. Increases in land cover by cashew cultivation were associated with reduced abundance of specialist species within woodland habitats, and reduced abundance of generalist species within cashew orchards. Overall, our study provides the first evidence that cashew expansion may have serious negative consequences for biodiversity in West Africa, suggesting that this is an unfolding conservation problem that needs to be fully evaluated. Retaining woodland patches within production landscapes might help reducing the negative impacts of cashew expansion on biodiversity.

1. Introduction

In tropical regions worldwide there is a fast expansion of perennial cash crops (sensu FAO, 2010), particularly in West Africa and tropical Asia, which are occupying land previously devoted to small-scale subsistence farming, as well as forests and other natural vegetation types (Phalan et al., 2013). The biodiversity impacts of this process are generally considered strongly negative, with many studies showing that tropical perennial crops can retain only a small fraction of species from natural habitats (Norris et al., 2010). For instance, only 36% of forest butterflies were found in cocoa and coffee plantations in Cameroon (Bobo et al., 2006), while approximately 24% of forest birds occurred in rubber tree plantations and around 20% in oil palm plantations in Peninsular Malaysia (Peh et al., 2006). In contrast, however, almost 60% of forest birds were reported in Sumatran rubber plantations (Thiollay, 1995), about 45–60% of forest bird specialists occurred in cocoa plantations in Indonesia (Abrahamczyk et al., 2008), and 90% of bird species associated with native forest occurred in arecanut palm (*Areca catechu*) production systems in western India (Ranganathan et al. 2008). It thus seems that the biodiversity retained within tropical farmland may vary widely across regions and crop types, though information is still needed on the underlying processes (but see, e.g., Ranganathan et al., 2008; Clough et al., 2011).

Variation in tropical farmland biodiversity may be due at least partly to the relative amount of cropland versus natural habitats represented in different landscapes, because natural habitats may serve as population sources (Lucey and Hill, 2012) or complementary habitats (Dunning et al., 1992) for species in adjacent cropland. As the amount of natural habitats declines and their fragmentation increases, fewer species can be retained within the natural vegetation patches (Benedick et al., 2006; Daily et al., 2001), contributing less to the biodiversity of surrounding farmland (Faria et al., 2007). The loss of natural vegetation within farmland may be particularly negative for trophic and habitat specialists, which may be unable to persist within cropland habitats (Steffan-Dewenter et al., 2007; Koh and Wilcove, 2008). Landscape heterogeneity may also be influential, because different land cover types may provide conditions for more species with contrasting habitat requirements (Fahrig et al., 2011). For instance, it is possible that a landscape with various crop

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http://dx.doi.org/10.1016/j.biocon.2015.08.032

types may have higher biodiversity levels than those dominated by a single monoculture (Tscharntke et al., 2005; Fahrig et al., 2011). Despite the importance of these ideas for designing conservation management strategies, they remain largely untested for most tropical perennial crops (but see, e.g., Ranganathan et al., 2008; Clough et al., 2011).

In this paper we address these issues, assessing the biodiversity impacts of cashew nut (*Anacardium occidentale* L.) cultivation in West Africa, and how these impacts vary in relation to landscape context. The cashew nut is one of the fast expanding perennial crops in the tropics (Phalan et al., 2013), particularly in West Africa, where it is replacing native forests and shifting cultivation systems (Norris et al., 2010; Temudo and Abrantes, 2012, 2014). Commercial cultivation started in the 1950s in Nigeria (Asogwa et al., 2008), and the harvested area currently occupies about 22,600 km^2 across 11 West African countries, of which Ivory Coast, Benin, Nigeria and Guinea-Bissau account for most of the area (FAOSTAT, 2015). To the best of our knowledge, no study has yet evaluated the consequences of cashew expansion for biodiversity, though it was suggested that they may be negative due to the loss of rich mosaic-like landscapes that existed under shifting cultivation practices (Temudo and Abrantes, 2014). The study focused on butterfly assemblages across a regional gradient of cashew expansion, testing the following hypotheses: (i) species richness and abundance should be lower in cashew orchards than in natural woodland habitats; (ii) assemblage structure should differ between the two habitats, with relatively more trophic and habitat specialists in natural than in production habitats; and (iii) species richness and abundance should decline with increasing cashew cover and increase with increasing landscape heterogeneity, particularly in the case of habitat and trophic specialists, both in cashew orchards and in natural woodlands. Results were then used to discuss possible strategies to counteract negative biodiversity effects of cashew expansion in West Africa.

2. Methods

2.1. Study area

The study was conducted in eastern Guinea-Bissau (West Africa), within an area of about 360,000 ha located in the administrative regions of Bafatá and Gabu (Fig. 1). Climate is tropical, with marked wet (June to November) and dry (December to May) seasons, and annual rainfall ranging from 1200 to 1400 mm (Machado, 1972). Native vegetation is dominated by open forest and savanna woodland (hereafter woodlands), but at present they are mostly secondary formations resulting from human activities such as fire and shifting agriculture (Catarino et al., 2008). The main ethnic groups are the Fula and Mandinga, cattle herders that traditionally practise shifting cultivation of upland rice, sorghum, millet, maize and peanuts (Temudo and Abrantes, 2014). Crop rotations typically start with the removal of woody vegetation from native woodlands or long-term fallows, through slashing of bushes and killing of trees using fire (Temudo and Abrantes, 2014). Land is then cultivated for 3–4 years, followed by a period of fallowing that lasts for about 8 years, during which there is a quick regeneration of woody vegetation (Temudo and Abrantes, 2014). Another common production system is associated with wet lowlands and inland valleys, where there is a mixture of riparian forests, palm groves and agricultural fields (locally called 'bolanha'), where freshwater swamp rice is cultivated during the rainy season and sweet potatoes and cassava during the dry season (Temudo, 2011). These traditional systems have changed in recent years along with the rapid expansion of cashew cultivation, which currently represents the primary source of income for villagers and more than 90% of the country's exports (Temudo and Abrantes, 2014). In general, cashew starts to be planted close to villages, and then expands to surrounding unfarmed land, typically fallow and native woodlands. Production is undertaken mainly by small-scale farmers and involves about 85% of the population to some degree (Kyle, 2009). At present there is little or no input of chemical pesticides (P. Santos, personal communication), and orchards possess varying amounts of undergrowth, depending on their age and degree of maintenance.

2.2. Study design

The study was based on comparisons of butterfly assemblages between cashew orchards and native woodlands, sampled around small rural settlements (hereafter, villages) selected across a regional gradient of cashew expansion. First, we mapped in a Geographic Information System the location of the ≈700 villages located within the study area. Second, we estimated a virtual area of influence of each village (i.e., potential farming area available to villagers) using Voronoi polygons, drawn from the centre of each village and with a maximum buffer of 2 km. Third, we selected a subsample of 70 villages based on the following conditions: (i) medium-sized (100–500 inhabitants; INEC, 2009); (ii) with sufficient cover by cashew orchards and woodlands within the area of influence to survey three sampling points in each habitat at a minimum distance of 100 m from each other; (iii) ease of access; and (iv) representing the northern, central and southern thirds of the study area, which roughly matched the gradient of cashew expansion. Finally, we sampled a subset of 21 of these villages, alternating the three regions in consecutive sampling dates to avoid space × time interactions. Although a larger sample size was initially envisaged, this was unfeasible during the time frame available due to logistical difficulties of conducting field work in rural areas of Guinea-Bissau.

2.3. Butterfly sampling

Butterflies were sampled during the dry season, from late January to early May 2013. Sampling was carried out around each village, within six fixed-radius (50 m) circular plots, half of which in cashew orchards and another half in woodland habitats (21 villages × 2 habitats × 3 plots per habitat = 126 plots). Plots were placed within the area of influence of each village, preferentially in different habitat patches of each habitat type, and spaced a minimum of 100 m from each other. Each plot was sampled once for butterfly activity, through visual surveys carried out from the central point to the 50-m limit in a spiral pattern, and in adequate weather conditions ($T > 17$ °C, little or no cloud cover and wind speed <5 Beaufort scale). Prospections at each plot were carried out until no new species or individuals could be detected, which took between 20 and 72 min; structurally more complex and speciose plots were prospected for longer periods, which was expected to minimize bias in sampling completeness (Phalan et al., 2011). The number of individuals of each *taxon* was recorded, with care taken to avoid double counting. Butterflies that could not be identified on the wing were netted and, when necessary, collected for subsequent identification. Congeneric species which were neither reliably identified in flight, nor captured, were grouped at the genus level. Records from the *Lycaenidae* family were excluded, as these butterflies are difficult to identify and capture in the field (Ghazoul, 2002), leading to a large number of non-identified records.

Butterfly species (or genus) were categorised according to their trophic and habitat specialization, as these ecological traits are often good predictors of butterfly responses to habitat modification and fragmentation (Koh et al., 2004; Barbaro and van Halder, 2008), and there was sufficient information to characterize all *taxa* recorded (Larsen, 2005; Bívar-de-Sousa et al., 2008; Robinson et al., 2010). Trophic specialization was categorised considering the number of larval host plants: monophagous — feeding on one host plant genus; oligophagous — feeding on various genera within one host plant family; or polyphagous — feeding on more than one host plant family (Verdasca et al., 2012). Habitat specialization was categorised considering the main habitat type of each species: forest, savanna or ubiquitous (Belcastro and Larsen, 2006). Due to a small number of monophagous species, they were combined with the oligophagous species in a single category of trophic specialists. Likewise, the forest and savanna species were categorised together as woodland specialists.