Agriculture, Ecosystems and Environment 265 (2018) 236–243

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

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

Improving cocoa harvest can mitigate for crop damage by wildlife in a forest-agriculture matrix

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ARTICLE INFO

Keywords:
Cocoa
Crop raiding
Conservation
Primate
Development
REDD+

ABSTRACT

Shade-grown cocoa has been suggested as a more carbon and biodiversity friendly land use around protected forests compared with slash-and-burn farmland, and may be particularly suitable for achieving livelihood, biodiversity and forest protection goals of REDD+ projects. However, loss of cocoa to wildlife perceived to come from forest protected areas can result in lower profits for local people, reduced livelihood benefits from development projects and negative perceptions of conservation leading to reduced conservation impacts. We collected and analysed data on cocoa pod numbers and damage by animals over 2 months of the cocoa growing season, coinciding with peak harvesting season, from 39 plots at 3 forest edge communities around Gola Rainforest National Park, Sierra Leone. We estimate that 20% of pods across the cocoa plantations studied were damaged by wildlife, though there was high spatial variation. Of damaged pods where the animal group responsible could be identified, 87.2% of the damage was by monkeys, 11.1% by rats or squirrels and 1.7% by chimpanzees. Binomial mixed modelling of the proportion of pods damaged by wildlife indicated that this was higher closer to settlements and where pod density was lower. This indicates that the species causing the most damage in this system are disturbance-tolerant generalists which are not dependent on the protected forest, that mitigation measures should be concentrated where damage is highest, particularly close to settlements, and that increasing cocoa yield in these communities could offset damage by wildlife and therefore still be a viable option for, for example, REDD+ projects, even where crop raiding is common.

1. Introduction

Cocoa (*Theobroma cacao*) is one of the main cash crops in the tropical forest zone, with the primary producing countries being Ivory Coast, Ghana, Indonesia, Nigeria, Cameroon and Brazil (FAO, 2016). Global demand and production of cocoa have been increasing steadily over recent years (Gilbert, 2016). It is a perennial crop, with shade growth a requirement for many strains. Although cocoa production itself may represent a deforestation threat where virgin forest is cleared to plant cocoa trees (Ruf et al., 2015; Ordway et al., 2017), the forest-like structure of cocoa plantations and the income potential of the crop has led cocoa production to be proposed as an alternative land use to slash-and-burn farming, potentially leading to lower deforestation, less carbon loss to the atmosphere, less damage to forest biodiversity and provision of connective habitat for wildlife between forest patches (Asare et al., 2014; Jezeer et al., 2017).

Because the forest-like structure of shade cocoa supports arboreal wildlife, this inevitably includes species capable of using cocoa as a food source. This can result in financial loss to the farmer, which may motivate him or her to adopt alternative, more profitable land uses, depending on local circumstances and market conditions, potentially reducing the effectiveness of cocoa as a development and conservation tool. Where crop raiding of this type is common, it can lead to negative perceptions of forest wildlife and forest conservation and retaliatory killing of wildlife (Meijaard et al., 2011; Nyirenda et al., 2015). Even if the species causing the damage mainly reside in the agricultural matrix rather than inside the high forest, forest wildlife might still be blamed (Kerr, 2013). Several studies also indicate that farmers perceive a

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https://doi.org/10.1016/j.agee.2018.06.019
Received 19 December 2017; Received in revised form 4 April 2018; Accepted 19 June 2018

greater magnitude of damage to crops caused by wildlife than is actually the case (e.g. Riley, 2007; Arlet and Molleman, 2010). It is therefore important to try and make an accurate assessment of the damage caused at a site to determine the magnitude of the problem, the actual rather than perceived taxa involved (so that mitigation can be correctly targeted), and any temporal and spatial patterns in the damage that might help in finding mitigation techniques to minimise damage. Current mitigation techniques for cocoa focus on time and labour-intensive guarding by humans, with no robust studies yet carried out on the effectiveness of such methods for cocoa, though Wiafe and Sam (2014) found chilli-grease fences to be partly effective in deterring elephants from cocoa plantations.

Whilst crop raiding is a major source of human-wildlife conflict in many agricultural systems across the tropics, with a wide range of mammalian taxa shown to be responsible (Bhat et al., 1981; Riley, 2007; Dakwa et al., 2016), the taxa causing greatest damage, the proportion of production lost and the environmental factors that meditate losses are poorly known. A number of factors are likely to affect crop and therefore economic loss to the farmer. These include field or plantation structure; distance to human settlement (both Songhurst and Coulson, 2014); and proximity to natural habitat such as protected forest areas which can act as a source of raider species. Additionally, the type of adjacent habitat may affect the ease of access to the crop and the availability of alternative food sources for wildlife, which may in turn affect raiding frequency (e.g. Hockings and Humle, 2009; Marchal and Hill, 2009; Addo-Boadu, 2010; Riley et al., 2013), with generalists responding more positively to degraded habitat than forest specialists (e.g. Devictor et al., 2008; Gibson et al., 2011). As many of these factors can be manipulated through changes in agricultural and landscape management or improved landuse planning for agricultural expansion, better understanding of such factors helps identify how losses to wildlife might be reduced, in order both to improve livelihoods of highly impoverished communities and to reduce pressure on and conflict with forest wildlife. Of particular interest is the impact of total yield on the level of damage by wildlife since interventions to increase yield are a major aspect of development work. Increased yield could attract crop raiders, exacerbating the problem, or, conversely, might compensate for crop loss by wildlife.

Despite the increasing importance of cocoa to the West African economy, which is responsible for 70% of the world's production (Wessel and Quist-Wessel, 2015), the large land area given over to the crop, and the fact that crop damage is the most prevalent form of human-wildlife conflict facing Africa (Barua et al., 2013), there have been few studies attempting to quantify damage to cocoa by African wildlife (but see Adomako, 2007; Arlet and Molleman, 2007). Given the recent emphasis on cocoa as an environmentally-friendly alternative land use (Asare et al., 2014), there is a pressing need for studies which will help to address concerns over wildlife damage by communities reliant on the income generated by cocoa farming.

Greater understanding of how crop-raiding affects social and conservation outcomes is highly relevant for the application of Reducing Emissions from Deforestation and forest Degradation (REDD+) programs, one pathway by which diverse outcomes might be met and in which cocoa may play a part. Shade cocoa is one strategy used to contribute towards the sale of carbon credits under a REDD+ strategy by avoiding carbon loss to other agriculture in the "leakage belt" immediately surrounding the forest, but must result in an improvement in the livelihoods of the forest edge communities (FECs) and ensure that any impacts on biodiversity are minimised (UN-REDD, 2010; CBD, 2011). Such a livelihood improvement cannot be realised if actual or perceived cocoa losses to crop raiding are too high to make cocoa economically viable, and therefore greater understanding of the factors that influence cocoa raiding within REDD+ projects is needed so that their impact, if any, may be reduced.

Here, we present a survey of wildlife damage of cocoa around Gola Rainforest National Park (GRNP), in eastern Sierra Leone, which is the subject of the first REDD+ project in West Africa and where a cocoa development project is under way, aiming to improve cocoa yield through education and plantation management assistance. One of the major concerns within the FECs is crop raiding, particularly of cocoa, which presents a potential barrier to the success of the REDD+ project through community fears that investment in increasing cocoa yield may not provide the expected returns due to crop loss to wildlife. In 2015, 15 patches of cocoa in three FECs in the leakage belt were visited three times each in October and November when cocoa pods are ripe or nearly ripe and therefore at most risk of damage by wildlife. We counted healthy and damaged pods to obtain an estimate of the minimum loss of cocoa to wildlife, and assessed what habitat, management and landscape factors may influence the extent of damage by the different taxa to aid recommendations on the extent of the problem and mitigation measures that may reduce the impact of crop raiding by wildlife.

2. Materials and methods

2.1. Study site

GRNP, consisting of lowland moist evergreen high forest, lies in the East of Sierra Leone on the border with Liberia, between 7°18′ and 7°51′N and 10°37′ and 11°21′W (Fig. 1a). The Upper Guinea forest of West Africa is a global biodiversity hotspot with high endemism (Myers et al., 2000), and the study site incorporates the largest patch of such forest in Sierra Leone. It is the subject of a REDD+ project, which includes a 4 km leakage belt beyond the boundary of the park, where any deforestation above the REDD+ baseline will be considered leakage. This incorporates land lying in seven chiefdoms managed by 122 FECs. This community landscape consists of patches of community forest, slash-and-burn farmland (active farmland and fallow rotation) mainly for staple crops such as rice and cassava, various plantations such as oil palm, coffee and cocoa and permanent settlements supporting around 25,000 people. This study was carried out in cocoa plantations in two chiefdoms, Malema and Nomo, the first chiefdoms to receive cocoa development assistance as part of a livelihood improvement project for REDD+. In Malema chiefdom work was carried out at one FEC, Madina Malema, and in Nomo chiefdom in two FECs, Madina Nomo and Faama Nomo (Fig. 1b and c).

2.2. Study design

Perimeters of patches of active and abandoned cocoa were mapped using a Garmin GPSMap62s with identities and boundaries of adjacent habitat recorded. Active cocoa patches, where the plantations had been managed within the previous year, were selected in Nomo chiefdom to include as wide a range as possible of patch size and distance to GRNP. The cocoa patch in Madina Malema was selected as the largest patch of cocoa mapped. Patches ranged from 0.02 ha to 37.94 ha and from 0.79 km to 4.22 km from the GRNP boundary. In addition, three patches of cocoa and abandoned cocoa were surveyed at Madina Malema on direction of farmers as examples of plantations where there was a problem with chimpanzee crop raiding, but since these were selected by a different method, and as we knew our initial selection already contained plantations known to be raided by chimpanzees, the results from these were not included in the main dataset in order to avoid bias. In one plantation in Faama Nomo, one extra quadrat was placed where there was recent evidence of chimpanzee cocoa damage but this was also not included in the main dataset.

A 50 m × 50 m grid was superimposed on the land around the three communities with intersections corresponding to the 100 m and 50 m intervals of the X and Y UTM coordinates. In the selected active cocoa patches, 10 m × 10 m quadrats were placed at the intersections of the grid where these fell inside the patch of cocoa. If the patch contained more than seven grid intersections, random numbers were used to