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Vulnerability to climate change of cocoa in West Africa: Patterns, opportunities and limits to adaptation

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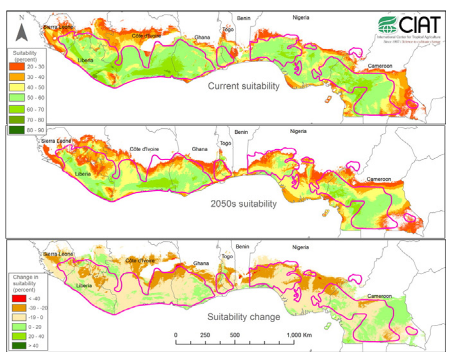
HIGHLIGHTS

- Comprehensive analysis of the climate change vulnerability of cocoa in West Africa
- Maximum dry season temperatures are projected to become limiting for cocoa
- Systematic use of shade trees in cocoa farms is needed, reversing current trends
- There is a strong differentiation of climate vulnerability within the cocoa belt
- Spatial differentiation of climate vulnerability may lead to future shifts in cocoa production

GRAPHICAL ABSTRACT



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ABSTRACT

The West African cocoa belt, reaching from Sierra Leone to southern Cameroon, is the origin of about 70% of the world's cocoa (*Theobroma cacao*), which in turn is the basis of the livelihoods of about two million farmers. We analyze cocoa's vulnerability to climate change in the West African cocoa belt, based on climate projections for the 2050s of 19 Global Circulation Models under the Intergovernmental Panel on Climate Change intermediate emissions scenario RCP 6.0. We use a combination of a statistical model of climatic suitability (Maxent) and the analysis of individual, potentially limiting climate variables. We find that: 1) contrary to expectation, maximum dry season temperatures are projected to become as or more limiting for cocoa as dry season water availability; 2) to reduce the vulnerability of cocoa to excessive dry season temperatures, the systematic use of adaptation strategies like shade trees in cocoa farms will be necessary, in reversal of the current trend of shade reduction; 3) there is a strong differentiation of climate vulnerability within the cocoa belt, with the most vulnerable areas near the forest-savanna transition in Nigeria and eastern Côte d'Ivoire, and the least vulnerable areas in the southern parts of Cameroon, Ghana, Côte d'Ivoire and Liberia; 4) this spatial differentiation of climate vulnerability may lead to future shifts in cocoa production within the region, with the opportunity of partially

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compensating losses and gains, but also the risk of local production expansion leading to new deforestation. We conclude that adaptation strategies for cocoa in West Africa need to focus at several levels, from the consideration of tolerance to high temperatures in cocoa breeding programs, the promotion of shade trees in cocoa farms, to policies incentivizing the intensification of cocoa production on existing farms where future climate conditions permit and the establishment of new farms in already deforested areas.

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1. Introduction

Roughly 70% of the world's cocoa (*Theobroma cacao*) production originate from the coastal areas of the Gulf of Guinea in West Africa, reaching from Sierra Leone, Guinea and Liberia along the West African coast to southern Cameroon (http://faostat3.fao.org; ECOWAS, 2007). Along the Guinea coast, the only country not producing cocoa is Benin, located in the Dahomey gap in the forest belt where the savanna reaches down to the sea and the seasonal dryness of the climate precludes the planting of drought-sensitive crops like cocoa (ECOWAS, 2007). This area is known as the West African (WA) cocoa belt (International Trade Centre, 2001). It was once covered by the Guinean lowland forests in the west and the Nigerian lowland forests transitioning through Cameroon into the Congo basin in the east (Burgess et al., 2004), although much of these forests have now been converted for agriculture, including cocoa farms (Norris et al., 2010; Gockowski and Sonwa, 2011). Some cocoa is also produced in Africa further to the east of the Congo basin (e.g. Tanzania and Democratic Republic of Congo), but the quantities are minor in comparison. Currently, the world's cocoa industry depends largely on the WA cocoa belt for its most important raw material, not only because of the sheer volume of cocoa grown there, but also because it is the most important origin of high-quality bulk cocoa (as opposed to specialty cocoa) that cannot be readily replaced by other cocoa origins. Ghanaian cocoa is generally considered the “gold standard” of bulk cocoa on the global market (International Trade Centre, 2001).

Cocoa farming in this region is similarly important to the largely developed-country based global cocoa industry and to the economies of the producing countries. In 2011, cocoa beans were the most important agricultural export by value for Côte d'Ivoire, Ghana, Nigeria, Cameroon and Sierra Leone, the second most important for Guinea and Liberia, and the third most important for Togo (http://faostat3.fao.org). Since the introduction of the cocoa tree from Brazil and its spreading in West Africa in the 19th and early 20th century, it has been grown mostly by smallholder farmers and is today considered an archetypical smallholder crop in Africa, differently from Latin America where large cocoa estates are also common (Clarence-Smith and Ruf, 1996; International Trade Centre, 2001). Currently, about 2 million smallholder farmers in West Africa depend on cocoa for their livelihoods (http://www.cargill.com/connections/more-stories/help-for-westafrica-cocoa-farmers/index.jsp).

Cocoa production in this region faces a number of challenges. These include the low productivity of the mostly over-aged trees and small farms that do not provide an attractive income to current and future cocoa farmers; the variability and, until the recent price increases, low level of farm gate prices making it difficult to afford costly inputs such as mineral fertilizers; the insufficiency and often complete absence of technical assistance to cocoa farmers in most countries; and the prospect of climate change (Läderach et al., 2013). Most parts of the WA cocoa belt have a relatively long dry season compared to other major global cocoa producing regions (Wood and Lass, 2001). During the second half of the 20th century, West Africa has experienced a further drying of the climate, leading to decreases in annual rainfall by 30% in the West African savanna (Kotir, 2011), and also affecting the forest zone (Léonard and Oswald, 1996; Ruf et al., 2015). As a result, some important cocoa producing areas in the eastern forest belt of Côte d'Ivoire in the 1960s had essentially become unsuitable for growing and especially for replanting cocoa by the 1990s (Kassin et al., 2008; Ruf et al., 2015). This trend of rapid deterioration of the climate has halted and perhaps even seen a reversal during the last decade (Niang et al., 2014; Ruf et al., 2015). However, there is a concern that the projected global temperature increase and concomitant increase in potential evapotranspiration (ETP) and plant water demand may result in increased drought stress during the dry season and a further deterioration of the climatic conditions for cocoa (Läderach et al., 2013). Based on climate models recognized by the Intergovernmental Panel on Climate Change (IPCC), these authors predicted spatially differentiated climate impacts for cocoa in Côte d'Ivoire and Ghana, with losses of climatic suitability especially near the forest-savanna transition, and smaller negative or positive changes in other areas. Overall, they predicted a decrease in climatic suitability for cocoa in these two key cocoa producing countries that, if not addressed, could impact future world cocoa supplies (Läderach et al., 2013). This modeling approach has been further developed and applied to Liberia (Schroth et al., 2015c) and then expanded to all of West Africa, with focus on developing a regional approach to adaptation planning for cocoa in this region (Schroth et al., 2016).

In the present study, we analyze the drivers of current and future climate vulnerability[1] of cocoa in West Africa by identifying those climate factors that could potentially become limiting for cocoa in parts of the region and therefore need to be given particular attention in developing adaptation strategies. We also suggest adaptation measures to reduce the vulnerability of cocoa to the projected changes. We further show which countries in the cocoa belt are likely to be more or less affected by future climate change and discuss opportunities and possible risks of cocoa expansion into climatically less vulnerable areas.

2. Methods

2.1. Characterizing the current and projected future climate of the WA cocoa belt

For characterizing the current and projected future climate of the WA cocoa belt, we followed the methodology described in Schroth et al. (2016). We created a map of the current extent of cocoa farming in the area and overlaid it with climate variables from the WorldClim database (www.worldclim.org; Hijmans et al., 2005). For the purpose of this study, we defined the WA cocoa belt as the cocoa producing areas between Sierra Leone in the west and Cameroon in the east (International Trade Centre, 2001). For the extent of cocoa farming in this area we used a map from the Atlas on Regional Integration in West Africa (ECOWAS, 2007) as a basis except for Nigeria where we used a map of cocoa producing districts from the 2007 national cocoa production survey (CRIN, 2008). We updated these maps with literature and field information. Specifically, we included all of Liberia as cocoa producing area because a recent report shows some cocoa production for essentially every part of the country (CAAS, 2007). We also included into the cocoa area the wet, southwestern parts of Côte d'Ivoire and Ghana where cocoa farming has expanded relatively recently (Ruf

[1] The term vulnerability to climate change as used in this paper refers to the combination of exposure (the nature and extent of climate change) and sensitivity (the impact of this change on local systems, here cocoa).

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