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Opinion paper

Conserving wild Arabica coffee: Emerging threats and opportunities

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ABSTRACT

Climate change and emerging pests and diseases are posing important challenges to global crop productivity, including that of Arabica coffee. The genetic basis of commercially used Arabica coffee cultivars is extremely narrow, and it is uncertain how much genetic diversity is present in *ex situ* collections. Conserving the wild Arabica coffee gene pool and its evolutionary potential present in the montane forests of SW Ethiopia is thus critically important for maintaining coffee yield and yield stability worldwide. Globally, coffee agroforestry helps to conserve forest cover and forest biodiversity that cannot persist in open agricultural landscapes, but the conservation of the wild Arabica coffee gene pool requires other priorities than those that are usually set for conserving forest biodiversity in mixed tropical landscapes. We show how forest loss and degradation, coffee management, in particular production intensification, and the introduction of cultivars, are threatening the genetic integrity of these wild populations. We propose an active land sparing approach based on strict land use zoning to conserve the genetic resources and the *in situ* evolutionary potential of Arabica coffee and discuss the major challenges including the development of access and benefit sharing mechanisms for ensuring long-term support to conservation.

1. Introduction

Coffee is grown in more than 70 countries across the tropics and the annual export value of coffee exceeds US$24 billion (FAO, 2015). The market demand for coffee is still rising, but climate change and emerging pest and diseases are posing important challenges to global coffee productivity (Läderach et al., 2010; Bunn et al., 2015). Outbreaks of coffee rust, coffee berry borer beetles and root nematodes have already reduced coffee yield and degraded coffee quality in coffee plantations around the world (Jaramillo et al., 2011; Avelino et al., 2015). The high susceptibility of commercial plantations to pests and diseases that seem to accompany global change and rising temperatures (Ghini et al., 2011), and the overall expected limited resilience of monocultures against environmental change in general (Lin, 2011), can be largely attributed to the very narrow genetic basis of the commercially used coffee cultivars (Anthony et al., 2001). These plants have a very limited potential to adapt, a feature shared with many other important crops (Fernie et al., 2006) including Cavendish banana, soybean, maize and cocoa. For Arabica coffee (*Coffea arabica* L.), accounting for 60% of all coffee produced globally and of higher organoleptic quality than the other commercially used coffee species *Coffea canephora* or 'Robusta' coffee, the narrow genetic basis is mainly related to major genetic bottlenecks during global dissemination of Arabica coffee. The plants that were originally introduced in Latin America and the Caribbean all descended from a few individuals that grew in Java, grown from seeds collected in Yemen, which in turn were the fruits of a few mother plants that most likely had their roots in the southwestern highlands of Ethiopia (Anthony et al., 2001). Given the very low genetic diversity of Arabica coffee cultivated worldwide, the extant wild gene pool of *C. arabica* in SW Ethiopia may prove to be essential to future-proof the global coffee economy and to secure the

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livelihood of millions of households that depend on Arabica coffee production or trade.

2. Wild Arabica coffee in Ethiopia

Wild *Coffea arabica* occurs as an understory shrub and has its center of diversity in the moist evergreen 'coffee forests' of southwestern Ethiopia (Anthony et al., 2001). Both wild populations and locally cultivated varieties (landraces) are still characterized by wide genotypic and phenotypic variability (Labouisse et al., 2008) and studies based on genotypic fingerprinting have provided evidence that Ethiopian wild provenances are genetically distinct from the most widely commercially used varieties *Typica, Bourbon* and *Caturra* (Anthony et al., 2001; Chaparro et al., 2004; Silvestrini et al., 2007; Tesfaye et al., 2014). The genes conserved in the Ethiopian wild gene pool are responsible for a number of desirable traits such as low caffeine content (Silvarolla et al., 2004), higher quality specialty grade (Berecha et al., 2014a) or resistance to root nematodes and coffee berry disease (Boisseau et al., 2009). These genes and genes related to other traits of wild coffee are essentially the genes needed to adapt coffee to changing climate and market demands. In these naturally regenerating populations, allele frequencies and gene combinations constantly change in a process of adaptation to external drivers, including climate change and disease pressure. Such evolutionary processes are lacking in *ex situ* collections of coffee (Schoen and Brown, 2001), including the collection of CATIE (*Centro Agronómico Tropical de Investigación y Enseñanza*) which includes c. 10,000 coffee trees, representing 1850 accessions, of which c. 600 accessions were collected in the Ethiopian center of Arabica coffee diversity (Anthony et al., 2007). In *ex situ* collections, coffee shrubs are kept outside their natural habitat under homogeneous environmental conditions and low disease pressure. Together with the typically clonal regeneration of the cultivars, this prevents adaptation of coffee collections to changing environments (Anthony et al., 2007). A dynamic, *in situ* conservation approach allowing natural regeneration and evolution is therefore the best way for conserving a coffee gene pool that is free to adapt to climate change and emerging pests and diseases, and that can be used to harness coffee cultivation worldwide in the face of such challenges (Sgrò et al., 2011; Sarrazin and Lecomte, 2016).

3. Imminent threats to wild Arabica coffee

Globally, coffee agroforestry helps to conserve forest cover and forest biodiversity that cannot persist in open agricultural landscapes (Tscharntke et al., 2011). Also in Ethiopia, extensive coffee production systems including semi-forest coffee and homegarden coffee have been demonstrated to support the conservation of forest cover (Aerts et al., 2011; Hylander et al., 2013) and associated components of forest biodiversity (Gove et al., 2008; Hylander and Nemomissa, 2008; Tadesse et al., 2014a; Buechley et al., 2015) in landscapes that in the absence of coffee would be entirely converted to open crop- and grazing land (Tadesse et al., 2014b). Nevertheless, the conservation of the wild Arabica coffee gene pool requires other priorities than those that are usually set for conserving forest biodiversity in mixed tropical landscapes, such as the conservation of small forest patches, isolated trees and hedgerows (Muñoz et al., 2013). Like cultivated Arabica coffee elsewhere, also wild Arabica coffee is susceptible to climate change, and a bioclimatic model for *C. arabica* predicts a 38 to 90% reduction of the suitable area within its native range by 2080 (Davis et al., 2012). However, multiple direct threats to the *in situ* conservation are currently more imminent. First, ongoing loss and fragmentation of natural coffee forests (Tadesse et al., 2014a,b) are directly threatening wild coffee populations and the genetic

Fig. 1. Coffee forest in SW Ethiopia. This part of the Belete-Gera National Forest Priority Area harbored an undisturbed, wild population of *Coffea arabica* in 2008 (A). The same stand was re-photographed in 2014 (B). The tallest canopy trees have been cut and the diverse understory vegetation has been replaced by a mixture of transplanted wild *C. arabica* seedlings and acquired *C. arabica* cultivars.