Sustainable management of the montane rainforests with wild coffee (*Coffea arabica* L.) in the Bonga region of southwest Ethiopia

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Abstract

*Coffea arabica* L. has its origin in the montane rainforests of southwest and south Ethiopia where it is a natural component of the undergrowth. These rainforests, however, are highly fragmented and decreasing at a rapid rate through conversion into settlements and agricultural land. The remaining forests with wild coffee are used for traditional coffee production. This study assesses how much wild coffee can actually be harvested from the forest and evaluates the influence of wild coffee management on the floristic diversity and structure of the forest. Vegetation surveys were conducted in four forest fragments in the vicinity of Bonga (SW Ethiopia). In 85 study plots, all plant species were identified and height and diameter at breast height (dbh) measured if height ≥ 0.5 m or dbh ≥ 2 cm. The ripe fruits per coffee tree were counted, and the coverage of the forest vegetation as well as other environmental parameters was recorded. The data were analyzed statistically with multivariate methods. Coffee forest management was found to increase the wild coffee yields, but high management intensity led to a disturbance of the forest structure and to a change in the species composition of the natural forest. Sustainable management concepts are crucial to harmonize economic interests and forest conservation efforts.

1 Background and aim of study

Arabica coffee (*Coffea arabica* L., Rubiaceae) is cultivated in about 80 countries and for many of them it is an important export crop. Its genetic centre is in southwest and south Ethiopia, where it occurs naturally in the undergrowth of the montane rainforests between 1,000 and 2,000 m asl. The highly diverse gene pool of these wild coffee populations is of international importance, because it constitutes an important potential for the breeding of new varieties (DEMELE TEKETAY, 1999). In the past three decades, however, ca. 60 % of the Ethiopian forest area has been modified or destroyed by anthropogenic influences such as new settlements, conversion to other land uses and timber extraction (REUSING, 1998). At present, only about 2,000 km² of highly fragmented forest remain. Due to a high number of endemic species and a high floristic diversity, this area is part of the eastern afromontane biodiversity hotspot (CONSERVATION INTERNATIONAL, 2005).

The remaining forests with wild coffee are subject to traditional management practices, which range from the simple collection of mature coffee fruits to the removal of most of the original
forest vegetation for the enhancement of coffee growth. Recently, international companies have shown a strong interest in wild coffee, and this is an incentive for farmers to manage the coffee forests more intensively.

This study assesses how much wild coffee can actually be harvested from the forest and evaluates the influence of wild coffee management on the floristic diversity and structure of the forest. It is part of the project “Conservation and use of wild populations of *Coffea arabica* in the montane rainforests of Ethiopia (CoCE)” carried out jointly by German and Ethiopian research institutions (CoCE, 2005).

### 2 Research areas and methods

The study was carried out in four forest fragments in the Bonga region (Kafa Zone, Southern Nations National Peoples Regional State) in southwest Ethiopia. The fragments consist of afromontane rainforest with wild coffee in the undergrowth. They are situated on Nitisols, Cambisols and Acrisols on undulating to dissected mountain ranges at different altitudinal levels (Table 1). The number of study plots was chosen according to the size of the forest fragments. Disturbed as well as undisturbed forest areas were considered.

<table>
<thead>
<tr>
<th>Forest fragment</th>
<th>Total size (ha)</th>
<th>Disturbed forest (%)</th>
<th>Altitude (m asl)</th>
<th>Distance from Bonga</th>
<th>No. of study plots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Koma</td>
<td>2100</td>
<td>25</td>
<td>1800-2300</td>
<td>20 km NWW</td>
<td>34</td>
</tr>
<tr>
<td>Meligawa</td>
<td>500</td>
<td>60</td>
<td>1700-1950</td>
<td>4 km NE</td>
<td>12</td>
</tr>
<tr>
<td>Mankiria</td>
<td>900</td>
<td>70</td>
<td>1550-1800</td>
<td>10 km SO</td>
<td>17</td>
</tr>
<tr>
<td>Kayakela</td>
<td>1200</td>
<td>70</td>
<td>1600-1750</td>
<td>7 km N</td>
<td>22</td>
</tr>
</tbody>
</table>

Plots measuring 20 m x 20 m were used for the vegetation surveys. Depending on the topographic conditions, plots were located every 300 m along transects through the forest fragments or were placed subjectively in order to capture a representative variety of forest aspects. In each plot, all herbs, ferns and grasses (ground or epiphytic) were identified. In the case of woody plants and herbaceous climbers, individuals with height ≥ 0.5 m were measured and diameter at breast height (dbh) was recorded if dbh ≥ 2 cm. Additionally, *Coffea arabica* individuals ≤ 0.1 m were counted. The cover of four vegetation layers (< 0.5 m, 0.5-5 m, 5-15 m, > 15 m) was estimated. Environmental parameters such as slope, altitude, and exposition were recorded, and the coffee yield was estimated by counting the mature coffee fruits. Vegetation data were analyzed with CANOCO for Windows, version 4.5.

### 3 Results and discussion

#### 3.1 Characterization of the coffee management systems

Four coffee management systems can be described depending on the percentage of coffee plants in relation to the total vegetation and the disturbance degree of the forest structure (Table 2).

The classification of the forest in disturbed or undisturbed was done according to the %-cover of the shrub and herb layers. In the undisturbed forest, these layers are usually little developed, because the canopy is dense and absorbs most of the light. In contrast, in the disturbed forest the cutting of trees leads to an opening of the vegetation and to the development of a dense shrub and herb layer. Based on the collected data, disturbed forest is defined as a forest where the sum of the %-cover estimate for shrub and herb layer is ≥ 105%.
Table 2: Description of the coffee management systems: no management (NM), forest coffee system (FC), semi-forest coffee systems 1 and 2 (SFC).

<table>
<thead>
<tr>
<th>Management intensity</th>
<th>NM</th>
<th>FC</th>
<th>SFC 1</th>
<th>SFC 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest structure (for definition see text)</td>
<td>None</td>
<td>low</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>% of coffee plants&lt;sup&gt;1&lt;/sup&gt;</td>
<td>&lt; 20</td>
<td>&gt; 20</td>
<td>&gt; 50</td>
<td>&lt; 50</td>
</tr>
<tr>
<td>Average number of coppiced plants per plot</td>
<td>4</td>
<td>8</td>
<td>12</td>
<td>31</td>
</tr>
<tr>
<td>Number of coffee seedlings&lt;sup&gt;2&lt;/sup&gt;</td>
<td>low</td>
<td>low - high</td>
<td>medium - high</td>
<td>low - medium</td>
</tr>
<tr>
<td>Planting of coffee seedlings</td>
<td>no</td>
<td>no</td>
<td>possibly</td>
<td>possibly</td>
</tr>
<tr>
<td>Average number of big coffee trees (dbh &gt; 3 cm) per plot</td>
<td>1</td>
<td>6</td>
<td>24</td>
<td>17</td>
</tr>
<tr>
<td>Estimated coffee yield (kg ha&lt;sup&gt;-1&lt;/sup&gt; yr&lt;sup&gt;-1&lt;/sup&gt;)</td>
<td>&lt; 5</td>
<td>&lt; 15</td>
<td>40</td>
<td>30</td>
</tr>
</tbody>
</table>

<sup>1</sup> „Number of coffee plants (≥ 0.5 m)” / „Number of all plants (≥ 0.5 m)” * 100 per plot
<sup>2</sup> „Number of coffee seedlings (< 0.1 m)” per plot: low: < 200, medium: 200-600, high: ≥ 600

In forests with low management intensity, the wild coffee trees are thin and spindly and carry only few fruits. The percentage of coffee plants is low, because other shrub and tree species that are apparently more competitive than coffee grow in the shaded understorey. Management activities, i.e., the removal of canopy trees and competing undergrowth, lead to better growth conditions for the coffee. With increasing management intensity, the coffee yield rises due to the increasing population density of the coffee and to the fact that the individual trees carry more fruits. While in the FC system the forest structure remains undisturbed, in the SFC systems the original vegetation buildup is severely disturbed. In SFC 1, the density of the coffee trees and seedlings is very high, whereas in SFC 2 the coffee plants are thinned out and there are only few but large coffee trees. The trees become bushier and reach diameters at breast height of up to 15 cm. Some farmers transplant seedlings from adjacent forest areas or add seedlings of improved coffee cultivars distributed by government extension workers and non-governmental organizations.

3.2 Impact of wild coffee management on the species composition of the forest

As canopy trees and undergrowth vegetation are removed, more light reaches the forest floor and leads to an increase in the species number and abundance of forbs (Vernonia) and herbaceous climbers (Cyphostemma, Stellaria, Mikania, Rubus). Saplings of pioneer species like Clausena and Bersama also have a higher density as compared to the undisturbed forest. In sites that have been managed for decades, old growth canopy tree species have been replaced by disturbance indicators such as Maesa and Croton that regenerate quickly in gaps. Furthermore, Milletia is very common, because farmers like to retain this tree from the original forest vegetation as it is a good shade tree for coffee.

In the undisturbed forest, woody climbers (e.g., Hippocratea, Jasminium, Landolphia) reach lengths of over 40 m and can be more than 15 cm thick. In the intensively managed forest, however, large individuals are removed and most lianas are only present as saplings with lengths of 0.5 - 5 m (Figure 1). The same holds true for shrub and small trees that compete with coffee in the undergrowth (e.g., Chionanthus, Oxyanthus, Rothmannia, Galintiera, Psychotria): While in undisturbed forest these species develop into mature individuals, in disturbed forest with intensive management they are mainly present as young individuals (figure not shown).
This shows that in forest with high management intensity, there is a change in the species composition of the canopy, an increase in the number of ruderal and pioneer species and a change in the size class distribution of lianas and other typical forest species. It is still to be assessed for how long the regeneration potential of characteristic forest species is maintained in managed sites.

4 Implications for sustainable management

The results demonstrate that the wild coffee forests are not only endangered by the conversion into agricultural fields and settlements, but also by high intensities of coffee management. A conservation concept needs to integrate the remaining forest fragments into a network of protected areas and has to include a management plan that identifies appropriate sites for core zones, buffer zones and more intensive coffee production. Semi-forest coffee systems, for example, should be restricted to already disturbed forest areas and not be extended further into undisturbed forests. In the latter, coffee should be managed in such a way that the natural structure and species composition of the forest is maintained. This requires limitations for the removal of canopy trees and undergrowth vegetation with particular attention to the protection and rejuvenation of old growth canopy species. In addition, improved coffee cultivars should not be planted in or around the forest in order to avoid cross-pollination and an impact on the genetic diversity of the wild coffee.

These conservation measures can only be implemented successfully if the local population is in favor of the activities. In this respect, financial incentives for the farmers are important, e.g., the compensation of low yields from wild coffee produced with low management intensity with higher prices. In Bonga, a newly established coffee farmers’ cooperatives union is selling wild coffee on the international specialty market and has now started to implement such a compensation system.

5 References