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Mass flowering of farmers' semelparous bamboo (*Arundinaria alpina* K. Schum.) in Seka-Chekorsa district, Western Ethiopia: its impacts and implications for management

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ABSTRACT

Highland bamboo (Arundinaria alpina, synonym Yushania alpina) is a characteristic and dominant semelparous species in the Afromontane vegetation of Ethiopia. It is utilized for numerous applications. Mass flowering of the species seems to be associated to conversion to other land uses. Objectives of the study were to document a mass flowering event, determine fruiting characteristics, understand the perception of communities, and assess its consequences in Seka-Chekorsa district, western Ethiopia. Focus group discussions and GIS-based assessment were conducted in 13 Peasant Associations (PAs). Our results show that highland bamboo flowering is gregarious and time to seed maturity takes about a year. The extent of mass flowering in each PA ranged from 41-88% of the the bamboo forest. Majority of the respondents (43%) perceived that the bamboo flowering event occurred because of God's wrath, 38% related it to the age of the bamboo plants, and 19% attributed the event to a disease, indicating low awareness regarding the reproduction of the species. Perceived impacts of the mass flowering event were an increased soil erosion, changes in microclimate, reduction in water flow, and negative consequences on farmers' economy. Farmers urgently need training on the management of the species at its reproductive stage.

KEYWORDS

Consequence; monocarpic; perception; reproductive stage; seed processing; consequence

1. Introduction

Semelparity and iteroparity are two contrasting reproductive strategies available to living organisms. A species is considered semelparous (related botanical term "monocarpic") if it is characterized by a single reproductive episode, no matter how long its life time is, before death; on the other hand, a species is iteroparous or 'polycarpic' if it is characterized by multiple reproductive cycles over the course of its lifetime (Patrick 2017). Most mass flowering bamboos are semelparous having an unusual life history which involves a long clonal growth phase, sometimes over 100 years, followed by mass synchronous flowering and subsequent death (Wang et al. 2016; Chen et al. 2017). Ethiopian highland bamboo *(Arundinaria alpina)* and lowland bamboo *(Oxytenanthera abyssinica)* are reported to flower after 50 and 40 years time, respectively (Yigardu et al. 2016). Despite the social and environmental impacts of bamboo mass flowering, the main advantage for humans and the

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ecosystem of this semelparous flowering is the possibility of enhancing genetic diversity of bamboo stands from the use of sexually produced germplasm, the seed.

The long duration of time the plant takes before its reproductive phase and the death of the plant after flowering have hindered documentation of stand changes and a thorough understanding of bamboo regeneration mechanisms and patterns (Chen et al. 2017). Understanding the dynamics of gregarious flowering events of bamboos and their impacts on ecosystem structure and community dynamics is imperative for conservation management (Wang et al. 2016).

Survival of the bamboo population after mass flowering is thus dependent on the regeneration from fallen seed. Bamboo seeds are capable of germinating in the leaf litter and under partial shade typical of open forest habitat but may have problems reproducing in burned-over areas with bare mineral soil (Paul and William 2008). Post-flowering bamboo forest management thus considers avoidance of interference (livestock grazing, aggressive suppressing weed, forest fire and human activities like ploughing for alternative land-uses).

Moreover, it had been shown that wise land management may help the regeneration of the bamboo forest. Opening gaps for sun light by removing upper story plants, weeding the regenerating bamboo seedlings within the previously flowered area, conducting enrichment planting on sites, which have limited regeneration are crucial management activities for a fast and cheap restoration of the bamboo forest (Gebremedihin 2018; Yohannes 2019; Yigardu 2021).

Mass flowering and death of highland bamboo populations have been occurring in different areas in Ethiopia, as part of their biological cycle, during their evolutionary process. However, in Ethiopia, there are many cases that mass flowering of bamboo is wrongly considered as a 'disease'. Worth mentioning, highland bamboo recent mass flowering events in the country include mass flowering in (1) Masha district, Masha area (Sheka Zone) covering more than 4,066 ha during 2008–2011; (2) Bure district, Jigo area (Gedeo zone) covering 300 ha during 2015–2016; (3) Tocha district, Tuta area (Dawro zone) covering 979 ha in 2010 and few years afterwards (Sertse et al. 2011; Mulugeta 2013; Yigardu 2021). Unfortunately, seed collection during these mass-flowering (and fruiting) events was not carried out.

Following a call from farmers on identifying the cause of highland bamboo 'drying' in some PA1s of Seka-Chekorsa district, a first field assessment was made in May 2022 and follow-up field visits and data collection were conducted afterwards, up to March 2023.

Specifically, this study aimed to: 1) determine the extent of the mass flowering event within one year time (2022/2023) in the study area; 2) investigate the impact of mass flowering in the study area; 3) Study the flowering and fruiting characteristics; 4) determine the seed maturation stage and identify best processing methods for bamboo seeds, and 5) understand the perception of the community regarding bamboo mass flowering and its consequences.

2. Materials and methods

2.1. Selection and description of the study site

Seka-Chekorsa district is located in the middle of the Jimma Zone (Figure 1). The altitude of this district ranges from 1580 to 2560 m above sea level, and we observed highland bamboo beginning at 2100-m asl and above. A survey of the land in this district shows that 44.9% was under annual crops, 6.1% pasture, 25.8% forest, and the remaining 22.8% is considered swampy, degraded or otherwise unusable (ONRS 2006). The district includes one of the highland bamboo growing areas within the Tropical Moist Afromontane Forests of Western Ethiopia. There are 53 Peasant Associations (PAs) in the district, of which 13 PAs grow highland bamboo.

2.2. Sampling methods and site selection

Thirteen PAs were selected based on the availability of bamboo resources in the district. The bamboo forest in the 13 PAs was divided into two groups (Figure 1). Northern group consisted of seven PAs (PA 1–7) located in the northern part of the district and where the bamboo population was in the reproductive stage or experiencing mass flowering. Southern group comprised the remaining six PAs (PA 8–13) located in the southern part of the district and where the bamboo population was not flowering or flowered 10 years ago. In each PA of the two groups, eight bamboo forest owning farmers were selected based on their relatively large bamboo forest

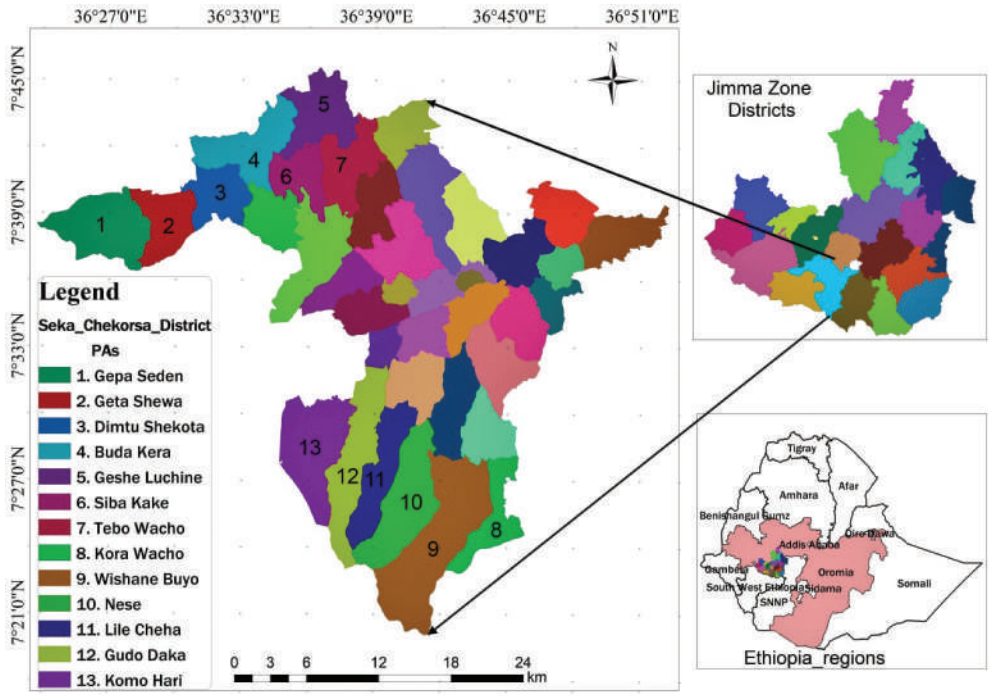

Figure 1. Map of the study area showing Seka-Chekorsa district and the 13 study Peasant Associations (PAs).

holdings and experience in managing and utilizing their bamboo forests, which could thereby make us generate comprehensive information on the mass flowering events happening in their area from practical encounters. The selected bamboo forests owning farmers were invited for group discussion and detailed interviews regarding the bamboo flowering events. The age of bamboo forest owning farmers engaged in the group discussions and interviews ranged from 27 to 70. The checklist prepared to guide the group discussions and interviews included: Have you experienced bamboo flowering in your area? If yes, when bamboo flowering started? Why the bamboo gets into flowering? What management measures do the community take during and after bamboo mass flowering? What is the perception of the community about bamboo flowering? What is the impact of mass flowering?

2.3. Flowered bamboo inventory

Following the group discussion, GIS-based area cover estimate of all bamboo forests was made in all the seven PAs found in the northern part and the six PAs found in the southern part areas of the district.

For the northern part, separate estimates were made for both flowered and non-flowered bamboo forests in each PA; in the southern part, estimates were made for the available non-flowered bamboo forests.

2.4. Description of flowering and fruiting characteristics

Thorough transect walks were made across flowered bamboo stands found at different reproductive stages in the different PAs. The assessment was made at different times to allow the description of the different reproductive structures of the highland bamboo.

2.5. Determining seed maturity stage and seed processing methods

Determining seed maturity stage, seed processing methods and preparing seed for distribution to other areas were undertaken by providing theoretical and practical training to, and working closely with, thirty selected farmers drawn from three adjoining and highly flowering PAs, namely Siba-Kake, Budo-Kera and Geshe-Luchine which are also relatively more accessible by car and motor cycle.

The farmers were selected based on their experience in bamboo management. Consensus was reached with the farmers so that they will identify plus mother plants, determine if the born seeds are mature and determine what the best indicator is for identifying maturity for collection. Through discussion with the farmers, therefore, the researchers determined the good indicators for identifying seed maturity.

3. Results and discussion

3.1. Farmers' highland bamboo cultivation practices and start up of bamboo flowering

Respondent farmers in our study area manage bamboos on their private land, mostly in homesteads and ravine areas. Farmers' bamboo forests, which are located along ravine areas adjacent to each ones farm, are often connected to each other, spanning long distances which explains the relatively large areas covered by continuous strips of bamboo forest.

Many bamboo stands are inherited by farmers from their fathers and forefathers. Berhane et al. (2023) have shown in their ethno-taxonomical study that highland bamboo in the area produce larger and higher culms (average DBH: 10.5 cm with maximum value 12.4 cm, average height 17.5 m with max 18 m) than in many other highland bamboo growing areas in Ethiopia. Berhane et al. (2023) indicated that area of bamboo forest owned by households ranges from 0.04 to 1.5 ha (average 0.47 ha). The ratio of bamboo cover to the total land owned by a household ranges from 6 to 75% (average 23.8%).

Bamboo flowering in the seven PAs of the northern group started within a short time, in October 2021 (Geta-Shewa and Gepa-Seden PAs) and in October 2022 (Geshe-Luchine, Siba-Kake, Budo-Kera, Dimtushe-Kotaand Tebo-Wacho PAs). Whereas, in three PAs of the southern group namely Komo-Hari, Nese and Gudo-Daka, respondents reported that mass flowering of bamboo occurred 10 years ago (2013–2014).

3.2. Extent of highland bamboo flowering in the study area

The area of flowered bamboo forest in each PA, as recorded in March 2023, is presented in Table 1. The average percentage area of the total bamboo forest which experienced mass-flowering was 61%, with a minimum of 10% in Tebo-Wacho and a maximum of 88% in Sika-Kake and Budo-Kera. In the southern group, where bamboos did not flower recently,

Table 1. Extent of flowered and non-flowered bamboo in the northern and southern PAs of Seka-Chekorsa district, as of March 2023.

	PA	Flowered area (ha)	non-flowered area (ha)	Total area (ha)	Proportion of flowered area (%)
northern group PAs					
1	Geshe-Luchine	137	60	197	69
2	Tebo-Wacho	3	23	26	10
3	Siba-Kake	47	7	53	88
4	Budo-Kera	210	29	239	88
5	Dimtu-Shekota	29	7	37	80
6	Geta-Shewa	21	21	42	50
7	Gepa-Seden	25	36	61	41
	Total	472	183	655	61 (average)
southern group PAs					
8	Komo-Hari	-	5	5	-
9	Gudo-Daka	-	7	7	-
10	Nese	-	7	7	-
11	Lile-Cheha	-	8	8	-
12	Wishane-Buyo	-	25	25	-
13	Kora-Wacho	-	26	26	-
	Total	-	78	78	-

The sign "-" indicates that the cell has zero value. Source: GIS-based field inventory.

we may note that four PAs have very small areas of bamboo forest. We cannot explain the small area recorded in Lile-Cheha, but we may assume that the small areas recorded in Komo-Hari, Gudo- Daka and Nese are linked to the mass flowering event that occurred ten years ago, which entailed land-use changes as reported by our respondents (Table 1).

3.3. Flowering and fruiting characteristics of highland bamboo

Our respondents revealed that flowering and fruiting of *Arundinaria alpina* extended from October to end September, i.e. it took about 12 months to finalize its grain filling and maturing stages. Flowering starts from branches found at the top part of the culm and progresses downwards till all the branches get flowered. The flower color of *Arundinaria alpina* is white whenf resh. The inflorescence is shown on Figure 2 (left) and the bract which envelops the flower is indicated in Figure 2 (right). McClure (1966) called this type of inflorescence 'semelauctant'(determinate) inflorescence. Based on the synchronous and relatively wide area coverage of bamboo flowering in the study area, the flowering type of highland bamboo can generally be classified as gregarious. This finding corresponds with the report by Sertse et al. (2011) which assessed the flowering of this species in Dawro zone and Masha area of Sothern Ethiopia.

3.4. Determining maturity stage of fruit

A close examination of the seed bearing structure, i.e. the spikelet (as also illustrated by Phillips 1995) reveals that it has the potential to bear varying number of seeds, ranging from 0 to 10 or even more. The number is dependent on several factors, including the number of

Figure 2. Inflorescence of *Arundinaria alpina* (left), the bracts enveloping the flowers (right). *Note: The flowering shoot is an aggregate of spikelets, i.e. small bracted spikes that make up the compound inflorescence.*

Figure 3. Mass flowered bamboo lot 2 (top); mature highland bamboo inflorescence shoot ready for extraction (bottom, left); pure seeds after processing (bottom, right).

florets or spikes present in the spikelet, and on the grain filling and seed development environmental conditions.

In our practical exercise of seed collection, it was apparent that pseudospikelets, i.e. spikelets which do not bear seed, are common in matured bamboo inflorescences. This results in large collection of fruits needed for obtaining reasonable amounts of seeds, for instance big sacks (0.148 m^3) containing 30 kg of fruit mass provided only 3–6 kg of pure seeds.

We identified that the best criterion for knowing that the fruit is mature is the color of the dried sheath at the back side of the fruit bearing branch which becomes white (Figure 3). Once mature inflorescences were harvested, pure seeds were obtained through repeated threshing, winnowing and sieving to remove the broken branches and the enclosing glumes, and through repeated drying of the mature fruits (Figure 3). According to previous studies (Tinsae et al. 2012; Getnet et al., 2022), highland bamboo seed length and width are on average 0.59 cm (range 0.5–0.68 cm) and 0.17 cm (range 0.1 to 0.2 cm), respectively.

3.5. Community's perception about bamboo flowering in Seka-Chekorsa district

As highland bamboo flowering is a rare phenomenon, farmers did not understand what was the origin and determinants of the recent mass flowering event in the study area and were thus quite frustrated. To the question 'Why the bamboos in your locality gets into flowering?', a large majority of the 104 respondents (95.2%) suggested that the event is because of God's wrath, while most respondents (83.7%) added that the cause of the event could also be the age of the bamboo plants. There were also some respondents (40.4%) who attributed the mass flowering event to a disease. Whereas bamboo mass flowering and fruiting is a normal biological phenomenon (Xiao et al. 2020), field assessments made by the first author of the present article in different parts of Ethiopia indicate that local communities consider bamboo mass flowering as a disease or pandemic and have given local names in different languages, for instance 'Shingil' in Assosa (North West Ethiopia),and 'Santo' in Hula district (Sidama region, Southern Ethiopia), both meaning 'pandemic'.

3.6. Consequences of bamboo mass flowering in the study area

To the question 'What is the impact of mass flowering of bamboo in the locality?', all respondents (104) agreed that bamboo mass flowering in the study area has negative economic and ecological consequences. Respondents then cited the reduction in spring water flow (99% of the respondents), the exposure of the soil to water erosion in the sloping terrain (79,8%), and the micro-climate changes (72.1%). Our observations in each PA on the land-use changes that were induced by the mass flowering event are presented in Table 2. Conversion of the bamboo forest to other land uses was observed in all the PAs assessed.In many mass flowering events, managing understory regeneration in the micro environmental conditions created after the flowering event significantly increases the growth of upcoming shoots which propagate vegetatively by themselves and in few years time produce full size bamboo culms (Victoria et al. 2009; Yigardu et al. 2016). However, as cutting of flowered bamboo stands in the assessed PAs occurred before the fruits were matured enough for collection or seed fall, we cannot expect regeneration and long-term viability of the bamboo forests in the study area.

Our discussions with farmers belonging to the three PAs of the southern group, who experienced bamboo flowering 10 years ago, confirmed that flowered bamboo forests were all converted to other land-uses since then.

Table 2. Observations by the survey team on the consequences of mass flowering in the northern group PAs of Seka-Chekorsa district.

Northern-group PAs	Observation from the site visit/Impact
Geshe-Luchine	The flowered bamboo forest of some farmer sis converted into eucalyptus plantation
Tebo-Wacho	The flowered bamboo of some farmers is converted into cash crop plantations such as tchat (*Catha edulis*)
Siba-Kake	The flowered bamboo forest of some farmers is converted into eucalyptus plantation
Budo-Kera	Bamboo culms in the flowered bamboo forest of some farmers are haphazardly harvested; grazing land is expanding into the flowered bamboo forest
Dimtushe-Kota	Bamboo culms in the flowered bamboo of some farmers are haphazardly harvested; agricultural land is expanding into the flowered bamboo forests
Geta-Shewa	Grazing land expanded into the flowered bamboo forests

Our results show that farmers react to the mass flowering of their bamboo forest as if it was a catastrophe, and they consequently convert their bamboo forest area to another land-use. What would they do if they knew that mass flowering is a normal biological phenomenon, and that new bamboos could grow afterwards, under certain appropriate management conditions?

This suggests that educating farmers about the natural cycle of bamboo mass flowering and its subsequent regeneration could lead to a more sustainable management of bamboo forests. With this knowledge, farmers could avoid converting their bamboo forest area to other land-uses, and instead implement appropriate management practices that would allow for the growth of new bamboos

3.7. Conclusion and recommendations

Following farmers' request, the flowering and fruiting characteristics of the species are described, while seed collection and processing technical aspects are provided for application at times of highland bamboo mass flowering in Ethiopia and elsewhere.

Our results showed that the communities in the study area depend on *Arundinaria alpina* bamboo for diversified applications. This dependence is however associated with a complete lack of knowledge regarding the biology of the species and especially its mass flowering, fruiting, and drying behavior. Mass flowering events are perceived by a very large majority of highland bamboo farmers as caused by a disease or by God's wrath, and as having important negative economic and ecological consequences, leading farmers to convert their affected land to other land-uses.

There is thus an urgent need to raise awareness among all highland bamboo forest owners on the biological causes of bamboo mass flowering and on the post-mass flowering management options. It is important that bamboo forest farmers know that conversion to other land-uses is not the best options after a mass flowering event and that restoring the bamboo forest is possible.

We thus recommend addressing the challenges posed by highland bamboo mass flowering through awareness creation, proper harvesting of dried culms after flowering and seed production, proper seed processing, and restoring the mass flowered forests through the use of appropriate management techniques.

Normally, quick and efficient regeneration of mass flowered stands after mass death is possible through protecting of the flowered areas from human intervention, careful harvesting of dead culms, and careful managing of the bamboo wildlings regenerated from fallen seeds. These could be complemented by introducing nursery raised bamboo seedlings from outside sources. A combined effort of all relevant stakeholders is required for developing a biology-based true silvicultural management of highland bamboo.

Notes

1. PA stands for Peasant Association. It is the lowest administrative unit next to district. It is also called Farmers' Association or locally *Kebele* (in Amharic language).
2. A bamboo lot is a small area of bamboo forest.

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