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Research article

Species site matching of highland bamboo (*Oldeania alpina*) in Ethiopia

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ABSTRACT

Highland bamboo (*Oldeania alpina*) is fast growing perennial plant that occurs as small holder plantation and naturally in the highlands of Ethiopia with a wide range of values and uses. This study assessed environmental conditions where the species grows, and related the sites-suitability information to other potential regions in Ethiopia. Field survey was conducted to *Oldeania alpina* growing areas in Ethiopia. Data were collected on dendrometric and environmental variables from field plots of 400 m^2 of bamboo stands in three replications in each of the study districts in the regions. Consultations were also held with key informants, women, youth and elder focus group discussants on the common uses and production constraints of the species. The study identified wider uses of the species from being raw material for household utensils, furniture, fencing to building local houses in Ethiopia. Observations indicate that *Oldeania alpina* grows in the south, south-western, central and north-western highlands of Ethiopia at altitudes ranging from 2200 to 4000 m.a.s.l. It grows rapidly, where after planting from offset, starts to yield useable culm within three to four years. The species growing sites characteristics in the present study indicated that it's well performing in the altitudinal range between 2387 and 2979 m.a.s.l. We recommend promoting highland bamboo in Ethiopia for better culm yield on sites with elevation from 2300 up to 3500 m.a.s.l with mean annual rainfall >1200 mm, temperature varying from min. 6 °C to max. 30 °C and slope from 0 to 60% to attain optimum growth across the country.

1. Introduction

Highland bamboo (*Oldeania alpina*) (K. Schum.) Stapleton, taxonomically belongs to the family Gramineae (Poaceae) [1]. Its geographical distribution is governed largely by climate and soil conditions [2]. In Ethiopia, *Oldeania alpina* grows naturally and in small holder plantations covering a large area between Bale Mountains, Bonga and Metu, stretching from south-to-south western part of the country and up to Dangla in the North [3,4]. This species is also distributed in Cameroon (Mt. Cameroon), Zaire (Kivu), Rwanda, Burundi, the Sudan and the mountains of Uganda, Kenya, Tanzania and Malawi [5]. In Ethiopia, nearly 750,000 people are engaged in

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bamboo cultivation, management and utilization to support their livelihoods [6,7].

Ethiopia has not benefited from the resource due to lack of technical knowledge on bamboo management and utilization [8,9], despite the fact that highland bamboo has paramount economic and social importance. Nevertheless, there is a growing demand recently for bamboo raw materials among local processors, industrial product manufacturers and for the products from household users. Despite its higher potential uses for environment protection and economic growth, there is lack of in-depth scientific study and publications regarding environmental determinant factors that suit for better growth and production potential of the species. Hence, there is no relevant information to expand and promote the species to potential and new sites throughout the country. Therefore, this research was conducted with the aim of assessing and evaluating environmental attributes such as temperature, rain fall, altitude and slope, and growth characteristics in different areas to recommend species site matching areas for expanding of highland bamboo for ecological and economic uses in Ethiopia.

2. Study methodology

Field reconnaissance survey was conducted in purposively selected *Oldeania alpina* (highland bamboo) growing regions in Ethiopia. Identified regions were Sidama, Oromia, Amhara and Southern Nations, Nationalities and Peoples' Region (SNNPR). Within these regions, widely growing zones and areas were identified in consultation and discussion with regional and district level experts and local key informants. From selected district, three sample plots were considered for data collection. Plot with the size of 400 m^2 (20 m × 20 m) were established for data collection. In each plot, number of culms was counted; internode length at breast height, diameter at breast height (DBH) and height of culms from different age classes (<1 year, 1–3 years and >3 years) were measured.

2.1. Field data collection on culm characteristics

All relevant parameters including DBH, height, number of nodes, and internode length were recorded. Diameter tape, caliper and measuring tape were used for data collection. During field assessment geographic, climate and soil data were collected. From each site, three composite soil samples were collected at the depth of 0–30 cm. Previous reports were also considered concerning suitability to promote highland bamboo [6,10].

2.1.1. Desk review

Literature search was performed concerning highland bamboo, using available databases including Google Scholar, Science Direct, PubMed and Scopus. Dissertations, theses and technical reports were also consulted. Published and unpublished materials from different international and national sources were reviewed for general information on growth characteristic, utilization and site

Table 1
Site characteristics of the study areas for highland bamboo.

Woreda/District	Plot	Longitude	Latitude	Altitude (m.a.s.l.)	Soil texture	Slope (%)	Rainfall min–max (mm)	Temperature min-max (°C)
Chencha (SNNPR)	1	037°34′02.4″	06°12′44.3″	2571	Loam	0–2	1061–1169.70	10.6–24.2
	2	037°33′56.8″	06°13′01.7″	2564	Clay loam	0–2		
	3	037°34′04.7″	06°12′58.9″	2557	Clay loam	5–8		
Gurage (Eja and Gumer) (SNNPR)	1	038°07′00.7″	08°06′26.5″	2925		5–8	1042.70–1386.10	8.4–25.1
	2	038°05′54.0″	07°59′25.4″	2899	Clay loam	2–5		
	3	038°04′20.6″	08°00′31.2″	2899	Clay loam	2–5		
Dire Inchini (Oromia)	1	037°38′17.8″	08°50′40.4″	2454	Loam	2–5	1339.70–1554.60	7.8–23.6
	2	037°38′16.3″	08°50′40.8″	2467	Loam	2–5		
	3	037°38′19.2″	08°50′41,4″	2463	Loam	2–5		
Hula (Sidama)	1	038°33′18.4″	06°28′50.6″	2744	Loam	2–5	1313.50–1406.40	5.3–18.6
	2	038°33′14.6″	06°28′54.8″	2712	Sandy Loam	5–8		
	3	038°33′19.1″	06°28′57.6″	2735	Loam	2–5		
Sinan (Amhara)	1	036°4′9.06″	11°67′8.56″	2879	Sandy Loam	45–60	1239.40–1626.90	8.2–21.7
	2	036°5′4.22″	11°67′8.70″	2979	Loam	30–45		
	3	036°5′0.45″	11°67′9.30″	2946	Loam	5–8		
	4	036°5′0.19″	11°67′9.95″	2946		5–8		
Masha (SNNPR)	1	035°30′09.9″	07°37′09.2″	2423	–	0–2	2072.50–2190.90	8.4–23.1
	2	036°47′31.2″	07°40′22.2″	2505	–	2–5		
	3	035°30′25.6″	07°36′27.1″	2478	–	0–2		
Banja (Amhara)	1	036°57′50.6″	10°54′79.0″	2500	–	2–5	2061.20–2237.20	8.2–23.8
	2	036°57′27.8″	10°54′67.0″	2481	Loam	5–8		
	3	036°56′7.77″	10°56′34.4″	2539	Loam	5–8		
Seka Chokorsa (Oromia)	1	036°35′66.9″	07°42′92.7″	2387	Loam	0–2	1568.10–1703.60	7.6–24.1
	2	036°38′50.5″	07°42′99.3″	2571	–	2–5		
	3	036°39′15.8″	07°42′84.8″	2552	Silty Loam	5–8		

Source: Field Survey, 2020; ENACT Climate Database [12].

requirements of highland bamboo.

2.2. Data analysis

Considering the data, criteria was set for classifying a site both in the study regions districts and in elsewhere in Ethiopia, whether suitable or unsuitable for the species. Previous reports, mainly [6,10] were also consulted concerning suitability to promote highland bamboo. In this suitability matching list, weight has been given to the selected criterion and all involved factors were given the same weight for equal contribution to the overall multivariate analysis. Thus, the influence on the resultant suitability map comes from all factors. For all relevant parameters including averages of DBH, height, number of nodes, and internode length were analyzed. Parameters such as wider culm diameter and longer height of the species are indicators for site suitability.

3. Result and discussion

3.1. Distribution of highland bamboo in Ethiopia

In Ethiopia highland bamboo is distributed in montane forest, often on volcanic soils and forms extensive pure stands, occurring in *Afrocarpus falcatus* (*Podocarpus falcatus*) rainforest and with *Juniperus procera* in drier forests. It is found in different parts of Ethiopia as forest stand and plantations. Highland bamboo growing areas are indicted in Annex 1. The most common rain fall range was 1200–4000 mm per year [3,11]. Due to resource and financial limitation, this study did not cover some pocket areas in the country where highland bamboo is growing.

3.2. Site characteristics of the study areas

In order to study the actual situation of the stand structure under the existing conditions, the major bamboo growing areas were visited and data were collected from four regions. The site characteristics of the study areas are indicated in Table 1. The altitudinal range of the study sites lies between 2387 and 2979 m.a.s.l. The mean annual rainfall is between 1123 mm and 2144 mm [12].

3.3. Bamboo site suitability matching

In the interpretation of the site suitability, the authors used the species widely growing areas in the field data (Table 1), personal field observation (Chencha district, Gamo Zone, SNNPR: lower altitude 2300 m.a.s.l.; Choke mountains, East Gojam Zone, Amhara Region: higher altitude 3500 m.a.s.l.) and literature reviews for accommodating the lower and higher altitudinal ranges of the marginal areas.

The geographical distribution of bamboo is governed largely by the conditions of rainfall, temperature, altitude and soil. For good growth, most bamboos require a temperature range between 8 and 36 °C, a minimum annual rainfall of 1000 mm and high atmospheric humidity [2].

The ecological requirement varies widely among the numerous bamboo species [13]. Bamboo can grow in soils with soil acidity between the range of pH 5.0 and 6.5. Our study results also lie within this range except in Masha which was pH 4.4 (Table 1). Environmental attributes required for the growth of *Oldeania alpina* are indicated in Table 2. Our soil textural analysis results for the sites showed Loam, Clay loam, Sandy Loam, Silty Loam indicating appropriate for growing highland bamboo. Soil texture of sandy or clay loam with good drainage is suitable for bamboo growth [2].

A map showing suitable areas for growing highland bamboo in Ethiopia was produced based on geographic and agro-climatic information (Fig. 1). As the national map indicates, the suitable areas are located in seven regions and a city administration, where in some regions already it is growing, and in others presence of huge future potential (Benishangul Gumuz, Oromia, Amhara, SNNPR, Sidama, Gambela and the some part of Tigray) and in small parts of Somali, Afar, and Harari (Fig. 1 and Table 3).

3.4. Culm yield and growth characteristics of Oldeania alpina

Sustainable bamboo stand/forest management can help to make the right decisions on the timing and quantity of bamboo culms to

Table 2
Environmental attributes required for *Oldeania alpina* plantation.

Factor/Criterion	Unit	Highland bamboo
		Suitable
Temperature	Degree Celsius	10–21
Rainfall	mm/year	>900
Elevation	Meters	2300–3500
Slope	Percent	0–60
pH (H_2O)	–	5–6
Soil texture	–	Loam, Sandy loam, Clay loam, Silty loam

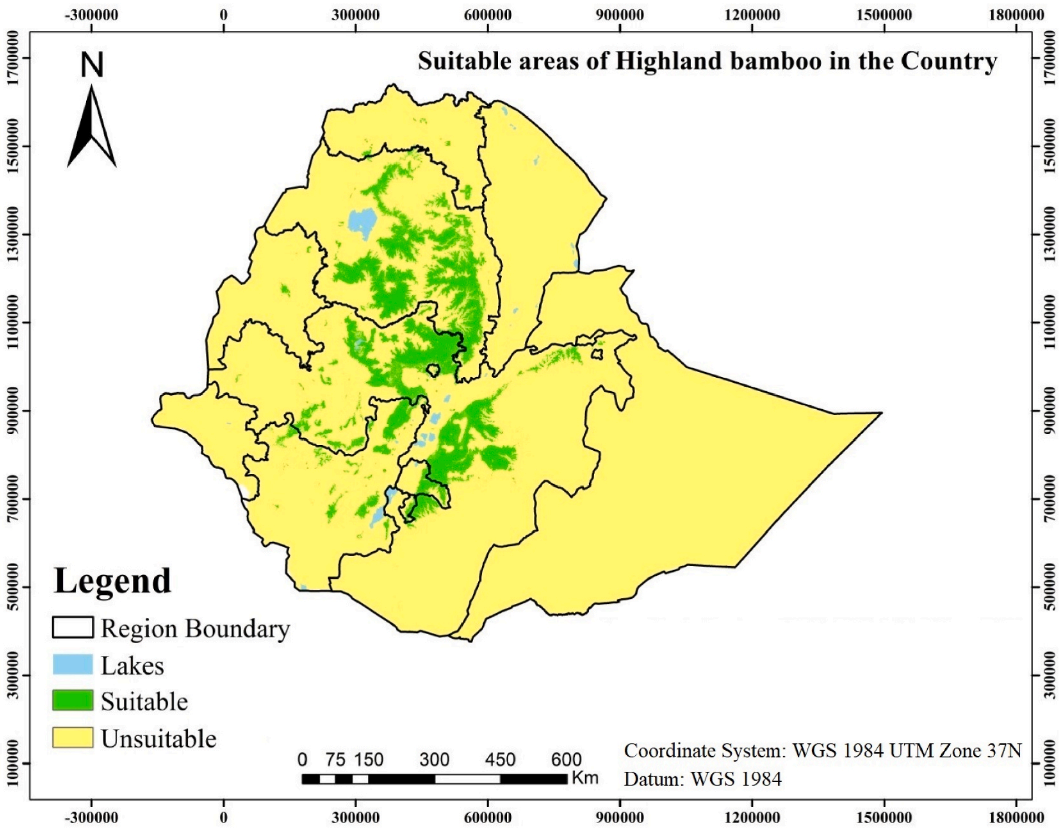

Fig. 1. Suitable area map for *Oldeania alpina* plantation in Ethiopia.

Table 3
Suitable areas size for highland bamboo plantation in Ethiopia.

Region Name	Suitable area (Ha)	% from the total suitable area
Oromia	4533229.3	45.9
Amhara	4129361.8	41.8
SNNP	866270.3	8.8
Sidama	210706.8	2.1
Tigray	86677.2	0.9
Benishangul Gumz	39275.9	0.4
Addis Ababa	14360.4	0.1
Dire Dawa	273.9	0.003
Gambela	109.6	0.001
Grand Total	9,880,265.30	100.00

be harvested each year. Culm production mainly depends on the harvesting regime [14]. Selective harvesting of 75% mature culms improves highland bamboo forest productivity [15] by increasing recruitment, height, internode length and thickness of new culms over years. Kigomo [16] also described that the removal of mature culms maintains the vigour of the plant and allows for the continuous generation of new shoots. On the other hand, Ref. [17] observed that productivity of bamboo stands deteriorated through over harvesting of young bamboo culms, livestock herbivory, and poor harvesting approach. In addition to this, clear felling of bamboo stand is not advisable because recovery of clear-felled stand will take long period of time [18].

Bamboo harvesting during the dormant season will ensure vigorous regrowth of sprouting shoots [19,20]. Harvesting in the active growing season leads the plant to poorly respond/activate sprouting because the underground parts may not have enough stored reserves to allocate for sprouting [19,20], because stored reserves are already used to initiate growth.

Bamboo stand structure tells us the growth and productivity of bamboo plantations/forests. Stand structure is the vertical and horizontal organization component of the bamboo clump (culms and rhizomes) in ages and numbers, which determines its properties and functions. Higher productivity of highland bamboo forest can be achieved by maintaining proper density, age, size of the culms and rhizomes (Fig. 2a and b).

The results from the study sites indicated variability in total culm number per ha among sites. The highest culm number were counted in Banja district (11,566 culms/ha) and the lowest culm number were in Dire Inchini (5250 culms/ha) (Table 4). The lowest culm number in Dire Inchini is attributed mainly to market-driven harvesting of selected quality bamboo culms based on the interest of the buyers. It also indicated that Dire Inchini bamboo producers have more market access than those in Banja district; hence, more culms were harvested per hectare and sent to the nearby market. Similarly, Ref. [17] showed that productivity of bamboo stands deteriorated through over harvesting of young bamboo culms and poor harvesting approach. Ref. [21] also described that annual harvesting of mature culms over several years jeopardize clump productivity.

In the studied areas, we observed that dead rhizomes and stumps are not extracted out in most *O. alpina* stands. This again causes underground congestion and impedes running of young rhizome as well as culm emergence (Fig. 3a and b). Consequently, too many poor and deformed mature bamboo culms in *O. alpina* stands have been noticed in the study areas.

Both browsing and soil compaction by livestock affects the growth of rhizome and roots [15], which forces the plant to allocate more resource to the aboveground biomass to withstand repeated browsing. This directly influences the amount of new shoot sprouting and causes mortality. Similar study observed that protection of bamboo from herbivory increased culm yield of previously unmanaged communal bamboo stands [22]. Moreover, weeding is important practice as bamboo stand management at early stage to improve bamboo stand productivity [23]. Therefore, herbivory protection is crucial. Bamboo is usually found in moist valleys, sheltered depressions along streams and lower hills slopes. However, it also occasionally occurs on higher slopes and hilltops [2].

The average DBH of highland bamboo for *Hula* and *Sinan* district was 4.7 cm and 8.2 cm, respectively. The average height of highland bamboo culm varied between 8.1 and 15.0 m (Table 5). The internodal length of the elongating culm increases gradually from base towards the middle portion of the culm and decreases upwards [24]. The average internode length of highland bamboo at breast height was ranging from 33.2 cm in Hula – 71 cm in Sinan. The results indicated higher values of growth parameters for Sinan woreda possibly due to optimum site quality as compared to other sites (Table 1).

Generally, to ensure a sustainable supply of bamboo culms and to create healthy stand, it is recommended to exercise selective harvesting of mature bamboo culms (older than three years). This removal of mature culms also maintains the vigour of the other younger ones and allows for the continuous generation of new shoots [11] through minimizing the competition for space among culms [24].

4. Conclusion

Highland bamboo is an economically important species currently preferred both by small scale and medium enterprise. We recommend promoting highland bamboo expansion on sites that are suitable for better growth in Ethiopia. Based on field data and

a b

Fig. 2. a and b: Managed highland bamboo clump.

Table 4
Average number of culms per hectare by age classes in the study districts.

Age class	Chencha	Gurage (Eja, Gumer)	Dire-inchini	Hula	Sinan	Masha	Banja	Seka Chokorsa
<1 year	1432.5	1692	1550	1450	1706	1733.3	3025	1991.66
1–3 years	4932.5	3608	2800	5457.5	4256	3225	6508	4883.33
>3 years	4200	2508	900	900	5493	1466.6	2033	2116.66
Total	10,565	7808	5250	7808	11,456	6425	11,566	8992

Source: Field inventory, 2020.

a b

Fig. 3. a and b: Unmanaged highland bamboo clumps.

Table 5
Mean DBH, Height aand Internode length of highland bamboo culms over location by age class.

District	DBH (cm)			Height (m)			Internode length (cm)		
	<1	1–3	>3	<1	1–3	>3	<1	1–3	>3
Chencha zuria	5.6 ± 1.2	6.1 ± 1.3	5.9 ± 1,6	10.7 ± 1.4	11.5 ± 1,7	11,4 ± 1.8	44.0 ± 5.0	44.0 ± 5.7	43.8 ± 4,1
Gurage (Eja and Gumer)	6.5 ± 1.6	6.3 ± 1.2	5.9 ± 1.6	12.0 ± 3.1	12.1 ± 2.6	10.7 ± 2.6	44.9 ± 8.6	46.7 ± 8.3	43.5 ± 8.4
Dire-enchini	6.0 ± 0.9	6.2 ± 1.2	5.1 ± 1.1	13.4 ± 1.2	13.6 ± 1.9	11.0 ± 2.2	40.2 ± 3.8	41.1 ± 3.8	40.0 ± 4.8
Hula	4.7 ± 1.2	5.1 ± 0.7	5.4 ± 1.2	8.1 ± 2.5	10.3 ± 1.8	10,3 ± 3.1	33.2 ± 7.2	36.7 ± 2.8	34,0 ± 4.8
Sinan	8.2 ± 1.5	7.9 ± 1.4	7.8 ± 1.5	14.6	15	15	66	67.5	71
Masha	6.5 ± 0.8	6.0 ± 0.9	5.4 ± 0.8	10.9 ± 2.1	11.3 ± 1.8	11.0 ± 2.0	47.8 ± 3.0	46.5 ± 3.0	45.2 ± 3.7
Banja	5.4 ± 1.3	5.1 ± 1.2	4.6 ± 0.9	7.2 ± 0.8			51.7 ± 6.4		
Seka Chokorsa	7.3 ± 1.2	7.1 ± 0.6	7.0 ± 0.6	12.5 ± 1.5	11.5 ± 1.6	12.6 ± 2.0	45.9 ± 3.6	43.6 ± 4.0	44.8 ± 3.8

Note: <1 refers bamboo culms less than one year; 1–3 refers culms one to three years old; > 3 culms older than three years.

available information from literature, suitable sites recommended are those with elevation >2300 up to 3500 m.a.s.l with mean annual rainfall >1200 mm, temperature varying from min. 6 °C to max. 30 °C and slope from 0 to 60% to attain optimum growth. The total potential area for promotion of highland bamboo in Ethiopia is about 9,880,265.30 ha which indicates big potential for the expansion of the species. Difference in culm number/ha was the highest in Banja district (11,566 culms/ha) and the lowest in Dire Inchini (5250 culms/ha). Average DBH of highland bamboo ranged between 4.7 and 8.2 cm, respectively and average height varied between 10.3 and 15.0 m. Provided the appropriate stand management discussed above, Ethiopia could reap huge economic and environmental benefit by expanding highland bamboo to the recommended new sites and supporting the processing industries through easing land acquisition and providing tax incentives on tools and equipment importation.

Author contribution statement

Conceived and designed the experiments; Berhane Kidane, Agena Anjulo, Yigardu Mulatu, Selim Reza, Performed the experiments; Berhane Kidane, Agena Anjulo, Yigardu Mulatu, Abera Getahun, Solomon Mulat, Urgessa Teshome, Melkamu Abere.

Analyzed and interpreted the data; Berhane Kidane, Agena Anjulo, Yigardu Mulatu, Selim Reza, Abera Getahun, Solomon Mulat, Urgessa Teshome, Melkamu Abere.

Contributed reagents, materials, analysis tools or data; Selim Reza.

Wrote the paper; Berhane Kidane, Agena Anjulo, Yigardu Mulatu, Selim Reza, Abera Getahun, Solomon Mulat, Urgessa Teshome, Melkamu Abere.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e13593.

Annex 1. Highland bamboo growing areas in Ethiopia]

Region	Zone	District/Woreda
Amhara	South Gondar	East and West Estie, Farta, Lay Gaiint
	Awi zone	Banja, Fagita, Ankasha-Guagusa, Guagusa-Shikudad
	East Gojjam	Sinan, Bibugn, Machakel
	West Gojjam	Sekela, Dega Damot
	North Shoa	Tarmaber
	South Wollo	Debre-Sina
Oromiya	West Arsi	Koffale and Arsi-Negele
	Bale	Goba
	West Shoa	Dire Inchini and Shenen
	Jimma	Dedo, Seka-Chekorsa, Mana, Kersa, Agaro, Gera, Gera-Lola
Sidama Region		Hula, Arbegona, Bensa
Southern Nations, Nationalities and Peoples Region	Gedeo	Bule, Yirga Chefe, Kochore
	Gamo	Chencha, Arbaminch zuria, Bonke, Kamba, Boreda, Kucha, Mirab Abaya, Deramalo, Dita,
	Gofa	Geze-Gofa
	Guraghe	EZA, Gummer, Cheha, Geta, Enemore, Endegagn, Sodo, Muhirna Aklil, Gedabanogutazer welene
	Hadya	Misha, Anlemo, Duna
	Kembata	Angecha, Doyo Gena
	South Omo	North Ari, South Ari
	Kefa	Gawata, Decha, Adiyo, Gesha
	Dawro zone	Tercha, Esera,
	Amaro	Amaro especial district
	Wolayta	Sodo Zuria
	Sheka	Masha, Anderacha, Debub Bech; Mizan Teferi- Kulish, Wushwush-Bonga, Bonga-Ameya

Source: Field Survey (2020) and Mulatu et al. (2016).

References

[1] B.G. Bareja, Bamboo Production and Propagation Methods, 2010, pp. 1–19.
[2] S. Kowit, S. Wariida, S. Prachoen, C. Suthep, Review of Bamboo Management Internal Technical Report, 2001. Internal Technical Report 1.
[3] E. Kelbessa, T. Bekele, A. Gebrehiwot, H. Gebremedhin, A Socio-Economic Case Study of the Bamboo Sectorin Ethiopia: an Analysis of the Production-To-Consumption System, INBAR Working Paper, 2000, p. 41.
[4] Azene Bekele, Useful Trees and Shrubs of Ethiopia: Identification, Propagation and Management in 17 Agroecological Zones, RELMA in ICRAF Project, Nairobi, 2007, p. 552.
[5] S. Philips, Flora of Ethiopia and Eritrea Volume 7. Poaceae (Graminae). Addis Ababa, Ethiopia, 1995.
[6] EEFCCC (Ethiopian Environment Forest and Climate Change Commission), Land Restoration Atlas of Ethiopia, 2018.
[7] Zenebe M., Adeires W., Temesgen Y., Mehari A., Demel T. and Habtemariam K. Bamboo resources in Ethiopia: their value chain and contribution to livelihood. Ethnobot. Res. Appl. 12:511-524.
[8] M. Yigardu, Growth, Morphology and Biomass of Arundinaria Alpina (Highland Bamboo) (Poaceae) as Affected by Landrace, Environment and Silvicultural Management in the Choke Mountain, Northwestern Ethiopia, PhD thesis, Addis Abeb University, 2012.
[9] X. Wang, Comparative Analysis and Policy Recommendations on Developing Bamboo Resource Tenure Systems in Asia and Africa (2005), 2006, pp. 1–99.
[10] INBAR, Remote Sensing-Based Regional Bamboo Resource Assessment: Ethiopia, Kenya and Uganda, Technical Report, 2018, p. 46. Beijing, China.
[11] V. Brias, T. Hunde, Bamboo Cultivation Manual Guidelines for Cultivating Ethiopian Highland Bamboo, Eastern Africa bamboo Project, 2009.
[12] ENACT, 2021. https://iri.columbia.edu/resources/enacts/. accessed July 10, 2021.
[13] W. Liese, G. Wiener, Ageing of Bamboo Culms: a review bamboo, people and the environment, in: Processing of the V Th International Bamboo Workshop and the IV International Bamboo Congress Libud, Ban, Hidonesia 19 22 June 1995. Volume I Propagation and Management INBAR Techntcal Report N0 8, 1995, pp. 132–148.
[14] V. Kleinhenz, D.J. Midmore, Aspects of bamboo agronomy, Adv. Agron. 74 (2001) 99–153, https://doi.org/10.1016/S0065-2113(01)74032-1.
[15] G. Abera, Y. Kebede, Z. Tadese, G. Jebiso, M. Alemu, B. Azene, Y. Mulatu, K. Berhane, A. Getent, Effects of Harvesting Intensities on Yield Production of Yushania Alpina (K.Schum.) W.C.Lin. (Ethiopian Highland Bamboo) in Ankeshia-Guagussa, North-west Ethiopia. EEFRI Report, 2019.
[16] B.N. Kigomo, Guidelines for Growing Bamboo, Kenya Forestry Research Institute (KEFRI), 2007.
[17] E.R. Sutiyono, Silvicultural aspect of bamboo plantations in Kaliurang Yogyakarta, Indonesia, Bul. Penelit. Hutan (1987) 14–20.
[18] PROTA, Sinarundinaria alpina (K.Schum.) C.S.Chao and Renvoize. Plant resources of tropical africa, Kew Bull. 44 (1989) 361.
[19] J. Hytönen, Effect of cutting season, stump height and harvest damage on coppicing and biomass production of willow and birch, Biomass Bioenergy 6 (1994) 349–357.
[20] R. Ceulemans, A. McDonald, J. Pereira, A comparison among eucalypt, poplar and willow characteristics with particular reference to a coppice, growth-modelling approach, Biomass Bioenergy 11 (1996) 215–231.
[21] A. Darabant, B.R. Prem, L.S. Christina, D.D. Tshewang, Evaluating bamboo harvesting methods for local needs: integrating local ecological knowledge and science, Environ. Manag. 58 (2016) 312–322, https://doi.org/10.1007/s00267-016-0702-6.
[22] M. Yigrdu, A. Asabeneh, T. Zebene, Bamboo Species Introduced in Ethiopia Biological, Ecological and Management Aspects Bamboo Species Introduced in Ethiopia: Biological, Ecological and Management Aspects, Ethiopian Environment and Forest Research Institute (EEFRI), 2016.
[23] G. Seyoum, Lemma Tiki, M. Yigardu, Indigenous knowledge on highland bamboo (Yushania alpina) management and utilization practices in Kokosa Woreda, South East Ethiopia, Sci. Res. Essays 13 (11) (2018) 111–122, https://doi.org/10.5897/SRE2017.6552.
[24] R.L. Banik, Growth, Behaviour and Silviculture of Bamboos, 2008.