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RESEARCH ARTICLE

Diversity, use and production of farmers' varieties of common bean (*Phaseolus vulgaris* L., Fabaceae) in southwestern and northeastern Ethiopia

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Abstract Legumes are a critical component of many agricultural systems and a major contributor to global food systems. Common bean (*Phaseolus vulgaris* L.) is the most widely grown legume crop in Ethiopia. It is an important source of food, income, and soil fertility management in southwestern (SW) and northeastern (NE) Ethiopia, and used as medicine, fodder, and honeybee forage in the NE. Diversity and use of farmers' varieties of common bean (*Phaseolus vulgaris*) bean were investigated in five administrative zones in SW and NE Ethiopia. Structured and semi-structured interviews were conducted with 288 general informants and 48 key informants in five agroecological zones inhabited by four cultural groups. Thirty-nine varieties were identified based on farmers' naming practices. Varietal richness and diversity were found to be highest in the humid, tepid mid-highlands of Kefa (13) and Bench Maji and Sheka (12). However, farmers in both research areas typically plant only one or two varieties. Interestingly, the number of varieties per household was highest (2.3) in South Wollo Zone of the NE, where only six varieties were found. We find that varieties per household are limited by small landholdings in the SW and varietal richness in the NE. Given these limitations, policies and programs to conserve varietal diversity and increase productivity are more likely to be effective if organized at the community level in the SW and the household level in the NE. Agromorphological and genetic characterization of common bean varieties would facilitate the management and conservation of their diversity as a source of resilience.

Betelhem Abera and Menbere Berhane share equal responsibility for this article.

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Introduction

Agrobiodiversity contributes to global food security by stabilizing food production, enhancing nutritional status through dietary diversity, maximizing the use of heterogeneous landscapes, and broadening market opportunities (Brown et al. 2007; Jarvis et al. 2007; Russell and Bessin 2008; Picasso et al. 2011). Traditional varieties of crops, commonly referred to as farmers' varieties or landraces, are an essential component of agrobiodiversity (Villa et al. 2006). Variation in growth habit, phenology, seed morphology, nutritional traits, and use values are the criteria that farmers use to distinguish between their varieties and give them names (Mekbib 2007; Loko et al. 2018a, b). Local demand for farmers' varieties is often high because they are required for the preparation of cultural foods. Under optimal conditions, yields of farmers' varieties are typically lower than those of so-called improved varieties; however, farmers' varieties are often more reliable under a wider range of conditions (Brush 1995; Altieri 1999). For this reason, farmers' varieties are valuable in the context of human-induced climate change, as they enhance yield stability under increasingly variable climate regimes (Redford and Brosius 2006; Gaudin et al. 2015). Landrace diversity also provides a pool of resources that can be used globally to breed crops that are resistant to pests, diseases, and abiotic threats (Sthapit et al. 2010; Padulosi et al. 2011).

Despite their many values, farmers' varieties are at risk of disappearing due to widespread transformations of farming systems. Erosion of crop diversity is driven by dissemination of varieties that require high-input farming practices to boost production such as mechanization requiring homogenous morphology and phenology, increasing demand for standardized products, and policy incentives to produce for global markets (Bellon 2004; Redford and Brosius 2006; Jarvis et al. 2007). It is necessary to conduct regular inventories of the farmers' varieties within localities and regions to monitor changes in their relative abundances and diversity over time so as to ensure their conservation. Furthermore, investigations of local knowledge related to varietal diversity can facilitate strategic utilization of germplasm and generate information for research and development (Hodgkin et al. 2007). Understanding the factors shaping farmers' management of varietal diversity is essential to design effective in situ and ex situ conservation strategies.

Grain legumes, defined as members of the Fabaceae that produce edible seeds, are among the most widely cultivated and consumed crops worldwide. Across Sub-Saharan Africa, as in many parts of the world, grain legumes provide protein, calories, minerals, and vitamins for both humans and domestic animals and opportunities for income generation (Petry et al. 2015). Use of legumes can enhance the economic and environmental sustainability of crop production by reducing dependence on inorganic fertilizers. Based on their mutualistic relationships with nitrogen-fixing microbes in the soil, grain legumes are used to improve soil fertility, either through crop rotation or intercropping. The maintenance of legume diversity within farming systems is, therefore, a key component of agroecological intensification.

Grain legumes in general and common bean (*Phaseolus vulgaris* L.) in particular have high intraspecific genetic diversity recognized by farmers in their seed and vegetative morphology (Heuze et al. 2013). Common bean varieties are broadly categorized according to growth habit into bush and climbing types. Throughout the world, common bean varieties have attained high diversity as a result of selection for specific agroecological conditions and purposes, including local agronomic practices and food culture (Santalla et al. 1999; Miles 2002).

Grain legume crops in Ethiopia are both native and introduced from the Americas. Common bean, which is reported to have been introduced to Ethiopia by Portuguese travelers in the sixteenth century (Wortmann and Eledu 1997), is currently the most extensively planted species, and the area planted has been increasing for more than a decade (CSA 2015). Its major production areas now include central, eastern and southern parts of Ethiopia (Legesse et al. 2013). It grows well in diverse environmental conditions, including well-watered and drought-prone areas between 1000 and 2200 masl (Asfaw et al. 2009). Most production of common bean is by small-holder farmers using traditional agronomic practices. In different parts of its range, it is planted in home gardens or as a field crop. It is usually grown for home consumption or sale at local markets and has served as a minor export crop for more than 40 years (Rahmeto 2007). Farmers use common bean residues as fodder and bedding for livestock, mulching, fuel and roofing material (Dagnew et al. 2014).

Despite it being the most widely planted legume crop and a major contributor to nutrition, there has been limited research on the varietal diversity of common bean in Ethiopia. The objectives of this study were (1) to document farmers' indigenous knowledge on the production and use of common bean in two major production areas, (2) to describe the diversity of common bean varieties according to farmers' criteria; and (3) compare the varietal diversity of common bean across multiple agroecological and sociocultural contexts in Ethiopia.

Materials and methods

Description of the study area

The study was conducted in two major production areas for common bean: the Kefa, Bench Maji and Sheka administrative zones of southwestern (SW) Ethiopia, and the South Wollo and East Gojjam administrative zones of northeastern (NE) Ethiopia (Fig. 1). Southwestern Ethiopia is known for its high cultural and linguistic diversity; people in the three zones maintain distinct ethnic identities and speak multiple languages including Kafi noono, Shekicho, and Bench. By contrast, cultural differences between two administrative zones in the NE Ethiopia are less evident, and most inhabitants speak Amharic as their first language.

Both production areas include warm lowlands (500 to 1600 masl) and tepid mid-highlands (1600 to 2400 masl) (MOARD 2005). The SW production area has longer growing seasons, categorized as either humid (241 to 300 days of rain) or per-humid (more than 300 days); whereas those in the NE are either sub-moist (61 to 120 days) or moist (121 to 180 days). The SW production area has a bimodal rainfall pattern that allows for two cropping seasons per year. The short rains, known in Ethiopia as BELG, begins in March and ends in June, whereas the long rains, known as MEHER or KIREMT, lasts from August to November. By contrast, rainfall in the NE production area is unimodal; the short rains rarely occur, and the long rains typically last from June through September.

Site selection

Five administrative zones were identified as major production areas of common bean based on a review of government agricultural data (CSA 2015), the inspection of herbarium specimens at Addis Ababa University, and seed collections at the Ethiopian Biodiversity Institute. Due to their small area, Bench Maji and Sheka zones were grouped together for the purposes of this study design and analysis. Within each administrative zone, three districts having high varietal diversity were selected based on interviews with university staff and government extension workers in the respective areas. The dominant agroecology of each sub-district within all twelve districts was identified using Geographic Information System (GIS) data from the Ethiopian Institute of Agricultural Research. Within each administrative zone and agroecological classification, three sub-districts were randomly selected for inclusion, giving a total of 24 sub-districts (4 administrative zones × 2 agroecological zones × 3 sub-districts) (Table 1).

Informant selection

For each sub-district, households were stratified into two categories of relative wealth (low and medium-to-high income households) from community-based assessments previously conducted by development agents. Six households were randomly selected from each relative wealth category, giving a total of 12 households per sub-district. Structured interviews were administered with three male and three female informants in each category. Only those households known to grow common bean were included in the study. In addition, two farmers from each sub-district (one male and one female) were identified as key informants for a more in-depth semi-structured interview based on their knowledge about common bean.

Data collection

Structured interviews with randomly-selected general informants (n = 288) and semi-structured interviews with purposively-selected key informants (n = 48)

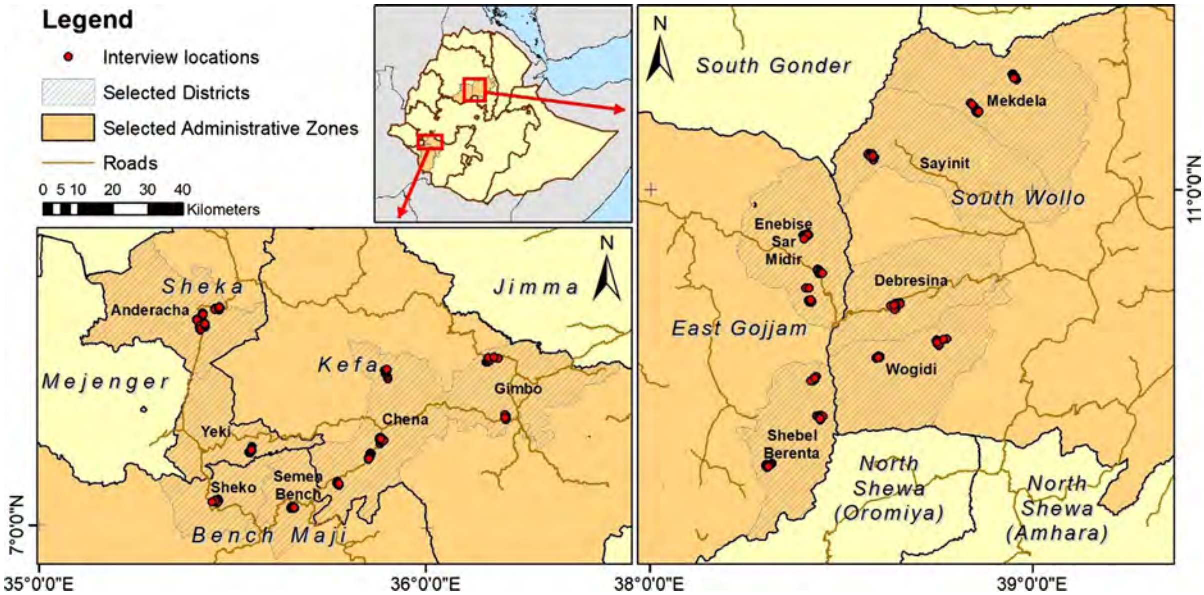

Fig. 1 Map of Ethiopia showing the study areas, including Kefa, Bench Maji and Sheka Zones in the SW and East Gojjam and South Wollo Zones in the NE

Table 1 Administrative zones, agroecological classifications, and sub-districts included in the study areas

Production area	Admin. zone	Agroecological classification (2 per administrative zone)	Sub-Districts (3 per admin. zone/ agroecological class)
Southwest (SW)	Bench Maji and Sheka	Per-humid, warm lowland (PH2)	Bajeka, Dakn, Komi
		Humid, tepid mid-highland (H3)	Beshifa, Getiba, Modi
	Kefa	Humid, tepid mid-highland (H3)	Eramo, Keja Araba, Tula
		Per-humid, tepid mid-highland (PH3)	Boba Bela, Kulsh, Shishinda Geter
Northeast (NE)	East Gojjam	Moist, tepid mid-highland (M3)	Adis Alem, Bonaya Sakala, Zihon Wiha
		Moist, warm lowland (M2)	Anshebna Zuchir, Liuil, Yeju Bayile
	South Wollo	Moist, warm lowland (M2)	Mendeyo, Mess, Zemod
		Sub-moist, tepid mid-highland (SM3)	Deja, Doka Debiresina, Serto Masay

were conducted from September through November of 2017. Informed oral consent was obtained from each informant before the start of the interview. Structured interviews were conducted using Open Data Kit (ODK), a digital data collection application on a mobile phone (MotoG 2nd Generation). The structured survey included questions about the production and use of common bean, including planting locations, the area planted, cropping systems, use of the crop for various purposes, gender roles in production and use, and the names and traits of the varieties. Semi-structured interviews were conducted using an interview guide and recording detailed notes. Because these interviews were conducted with farmers who had been identified as knowledgeable about common bean, questions were more in-depth regarding the production and use of common bean and the advantages of varieties planted within her or his community. Information from key informants was used to interpret quantitative analyses of the interview data obtained from general informants.

Data analysis

Interview data were compiled and cross-tabulated for graphic visualization in MS Excel. Descriptive and inferential statistical analyses were conducted in R (version 3.6). A two-factor analysis of variance (ANOVA) was conducted to determine whether there were significant differences in the area planted to common bean according to administrative zone and relative wealth category, followed by a post hoc Tukey test to identify pairwise significant differences.

Gender roles were analyzed by comparing the number of households reporting whether men, women, or both genders participate in activities related to common bean. A test of homogeneity was conducted for each activity, to determine if participation rates are significantly different between the two production areas in southwestern and northwestern Ethiopia.

Varietal richness was measured at both household and landscape scales. At the household level, varietal richness was calculated as the mean number of varieties planted per household in the same administrative zone and agroecological classification during the 2015/2016 season. For the landscape scale, richness was measured as the total number of varieties named by all farmers inhabiting the same administrative zone and agroecological classification. A second two-factor ANOVA was conducted to determine if there were significant differences in varietal richness according to zone and relative wealth, again followed by a post hoc Tukey test to identify significant differences.

The diversity of common bean was computed for each administrative zone and agroecological class using the Shannon diversity index (H').

$$H' = -\sum_{i=1}^{s} p_i \cdot \ln(p_i)$$

where s is the number of varieties listed by growers within the same administrative zone and agroecological class, and p_i is the total area planted by all informants to variety i divided by the total area planted by all informants to all common bean varieties.

Results

Production of common bean

In the SW, common bean grown during the short rains is typically planted in early to mid-March and harvested in early to mid-June depending on the variety. For the long rains, common bean is planted in mid-August and harvested around early November. By contrast, in the NE, the short rains are unreliable, so the common bean is produced only once per year, during the long rains. Depending on the onset of the rains, most varieties are planted between mid-June and mid-July and harvested in late September or early October.

Most farmers in the SW (78%) and almost all farmers (99%) in the NE plant common bean in their crop fields (Fig. 2). Across all four zones, a small fraction (19%) of the farmers plant common bean in their home gardens, particularly in Bench Maji and Sheka (33%). Farmers in Kefa (43%) and Bench Maji and Sheka (16%) also plant common bean either along field margins or fencelines. None of the farmers interviewed in East Gojjam or South Wollo reported planting common bean in either of these two kinds of places.

The area planted to common bean by smallholder households varied between production areas and relative wealth categories. The results of a two-factor ANOVA indicate that the areas planted to common bean in 2015/2016 were significantly different among administrative zones ($p < 0.0001$) as well as between relative wealth categories ($p = 0.0012$). On average, households in East Gojjam planted more land to common bean (0.57 ha), followed by South Wollo (0.43 ha), Kefa (0.20 ha), and Bench Maji and Sheka (0.14 ha). In addition, mid-to-high income households planted significantly more common bean than low-income households (0.39 ha compared to 0.29 ha). The post hoc Tukey test indicates that differences in area planted according to wealth are not significant within the same zone (Fig. 3). However, regardless of relative wealth, farmers in the NE planted more common bean than those in the SW, with the exception of low-income farmers in South Wollo.

Throughout both production areas, common bean was planted as an intercrop or in rotation with other crop species. Common bean was more frequently intercropped in fields or home gardens in the SW than the NE, where sole cropping was more common, particularly in East Gojjam (Fig. 4a). In the SW, common bean is nearly always intercropped with maize (*Zea mays*), and less frequently with enset (*Enset ventricosum*) or Ethiopian kale (*Brassica carinata*), whereas in the NE it is more commonly planted with sorghum (*Sorghum bicolor*) and

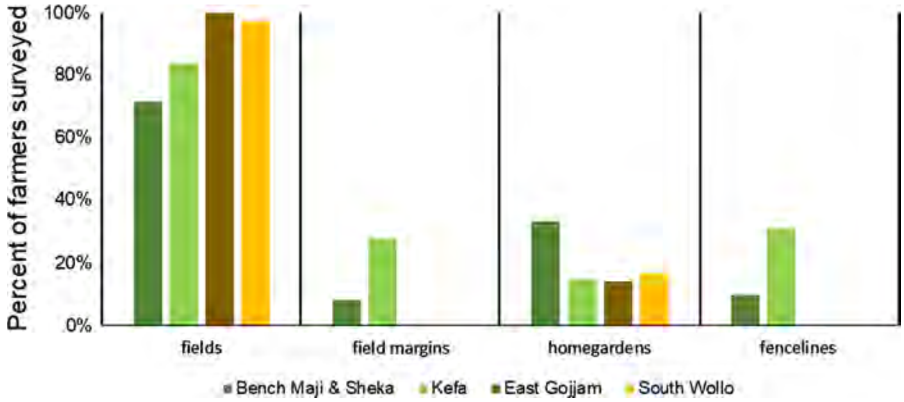

Fig. 2 Locations where farmers plant common bean in four administrative zones in SW and NE Ethiopia

sometimes maize (Fig. 4b). Key informants explained that common bean is usually planted after maize and sorghum, when its stems are mature enough to support the growth of common bean.

Almost all farmers in both production areas reported that they rotate common bean with other crops. Farmers in the SW, where there are usually two distinct rainy seasons, were able to plant common bean in rotation every year, whereas in the NE they tended to plant it on the same field every second or third year (Fig. 4c). In the SW, nearly all farmers rotated common bean with maize and sometimes with teff (*Eragrostis tef*); in Kefa, common bean was rotated with barley (*Hordeum vulgare*) (Fig. 4d). In the NE, the majority of (84%) farmers rotated common bean with teff, less frequently with sorghum (28%), and only sometimes with wheat (10%) (*Triticum* spp.), and rarely with barley (4%).

In the SW, there are usually two common bean harvests per year. At the end of the long rainy season (in September or October), farmers wait until the plants have fully dried, then uproot the whole plants, which are then threshed and stored without further cleaning. By contrast, during the short rainy season, harvesting is carried out earlier; the plants are uprooted when they have reached physiological maturity, and then suspended on a large tree or under the eaves of a house for sun drying (Fig. 5).

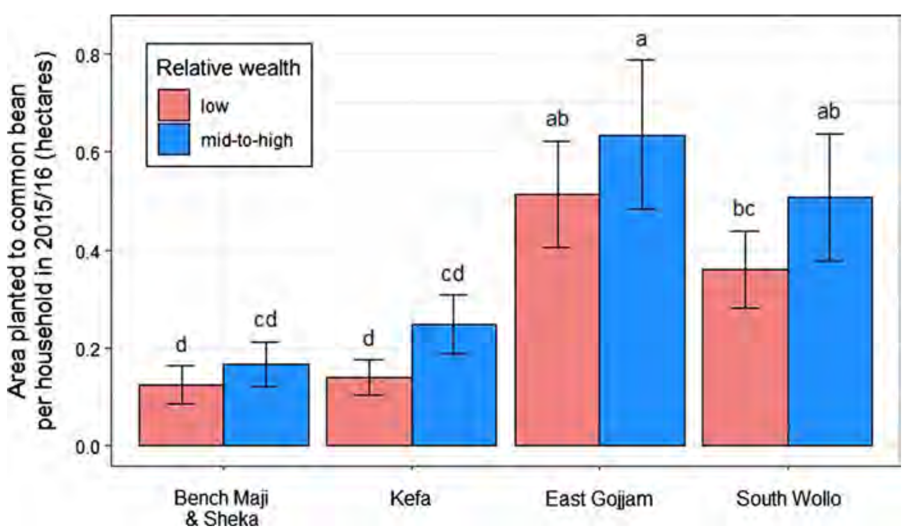

Fig. 3 Area planted to common bean during the 2015/16 growing season across four administrative zones and two relative wealth categories (n = 288). Bars with the same letter are not significantly different according to the post hoc Tukey test (α = 0.05)

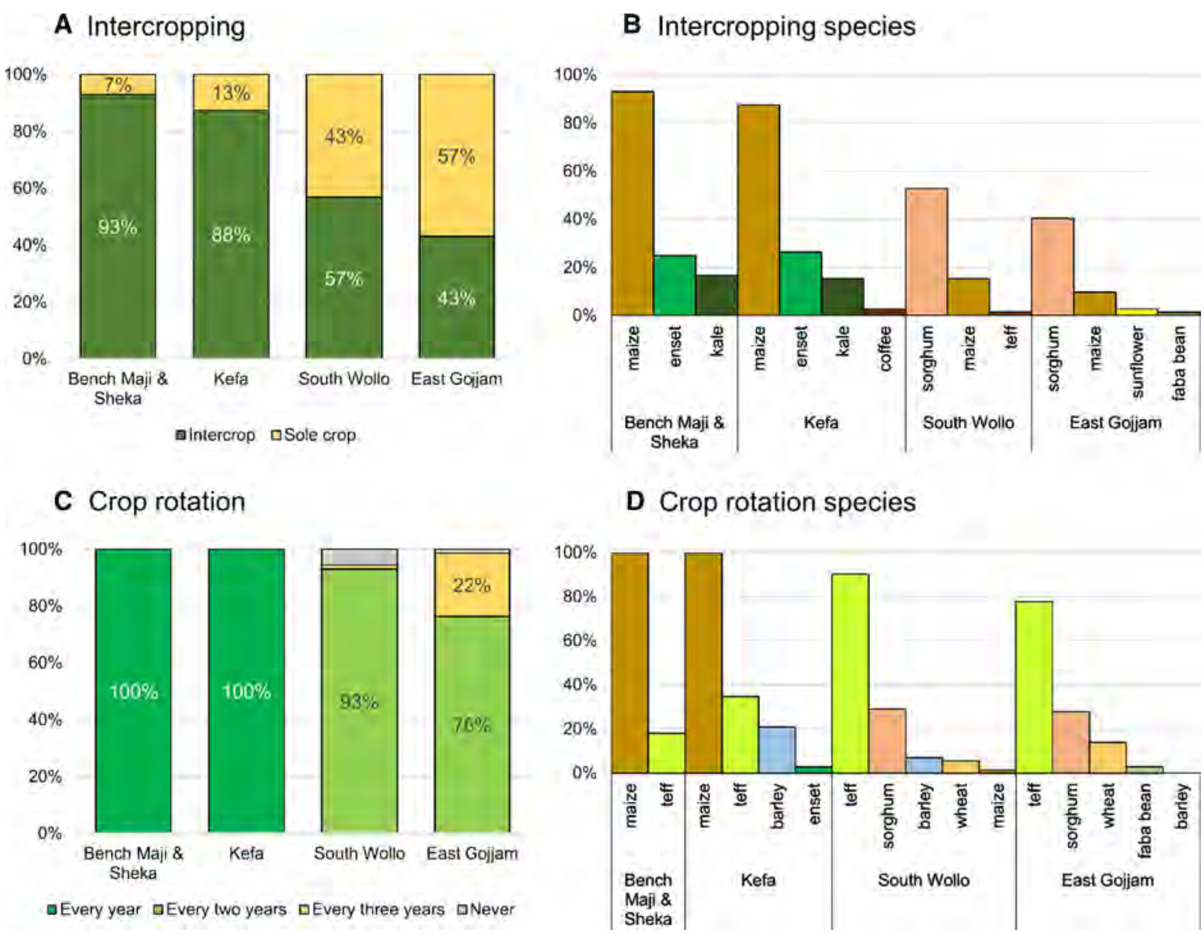

Fig. 4 Intercropping and crop rotation of common bean in four administrative zones of NE and SW Ethiopia (n = 288)

Use values of common bean

Farmers identified six uses of common bean; the diversity of uses was higher in the NE than in the SW. The vast majority of farmers in both production areas reported planting common bean as food for their household (Fig. 6). Key informants described how common bean is prepared as a stew, either SHIRO WOT (roasted ground seeds combined with spices including hot pepper) or KIK WOT (split grains simmered with spicy hot pepper). Common beans are also used to prepare NEFRO (dry or fresh common bean grains boiled with whole maize grains). Farmers in both production areas sell common bean in their local markets as a source of income. Farmers in the NE described several other uses, including as medicine for people and livestock. For example, eating boiled grains on an empty stomach is said to reduce gastric pain. According to key informants, common bean grains are soaked and boiled in salty water and fed to animals, particularly cows affected by drought. Farmers in the NE use common bean residues (stems, leaves, and pods) to feed livestock, whereas, in the SW, common bean residue is not an important source of livestock feed because the long growing period provides abundant alternative sources of fodder. In the NE, the importance of common bean as fodder is greater than grass pea (*Lathyrus sativus*), another important food and fodder crop. A small number of farmers in the NE mentioned that common bean flowers provide nectar for honeybees.

Gender roles in common bean production and use

Male and female farmers participate in different activities related to common bean, and these gender

Fig. 5 Sun-drying common bean after the harvest in the SW production area

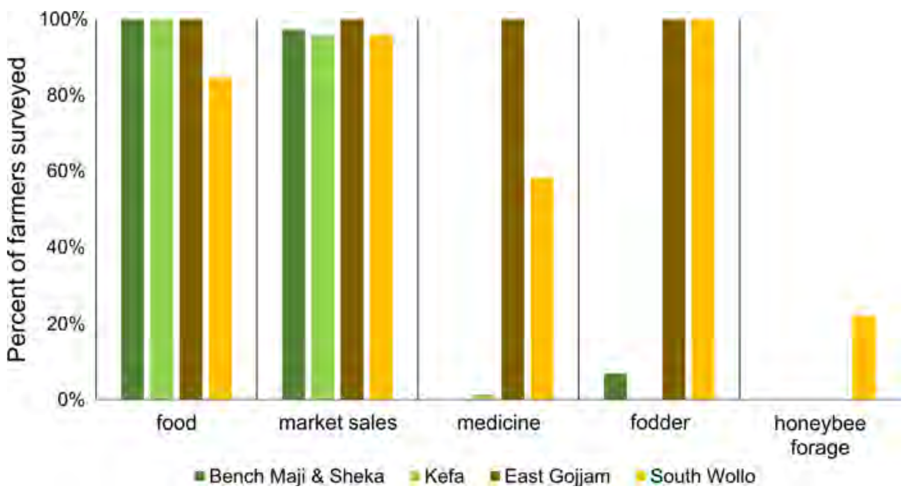

Fig. 6 Use of common bean by farmers in four administrative zones of NE and SW Ethiopia (n = 288)

roles are significantly different between the two production areas (Fig. 7). In both the SW and NE, there is a clear division of labor between men and women in the family regarding participation in common bean related activities. Men are primarily responsible for plowing and women are primarily responsible for food preparation, with no significant differences between the two production areas ($p = 0.08$ and 0.24, respectively). By contrast, there are highly significant differences ($p < 0.001$) between the SW and NE for most other activities. For example, the most pronounced difference in gender roles was observed for threshing, which is usually done by women in the SW and men in the NE. In the SW, only women are involved in marketing common bean, whereas both genders participate in this activity in the NE. Seed selection, which bears important implications for the conservation of varietal diversity, was reported to be the responsibility of both genders in the SW, whereas it is the sole responsibility of women in the NE.

Farmer identification of common bean varieties

Altogether, farmers named 39 varieties of common bean, including 17 in Bench Maji and Sheka, 17 in Kefa, three in East Gojjam, and six in South Wollo (Fig. 8 and Table 2). Of these, 37 were identified by farmers as their own traditional varieties, and only two were known to have been released by the government breeding system. Among a total of 32 varieties found in the SW, two of them in Kefa and Bench Maji and Sheka were determined to be the same based on farmer knowledge and observations of seed morphology.

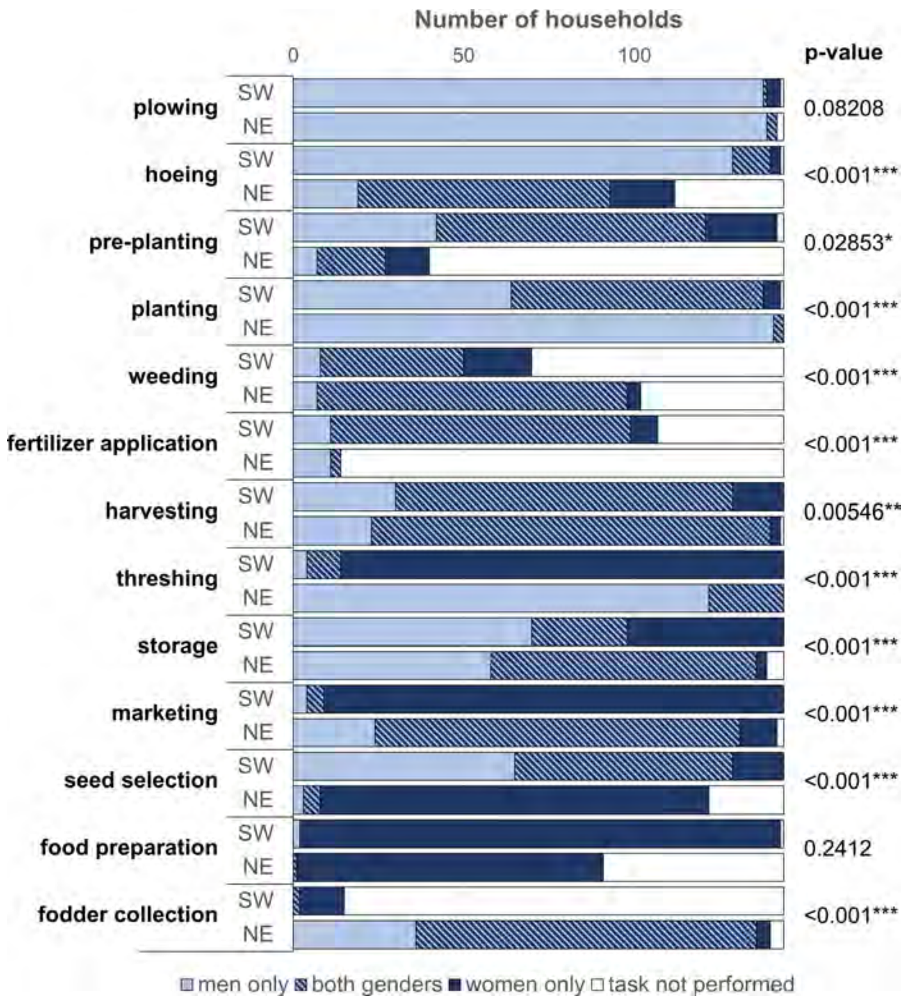

Fig. 7 Gender roles in common bean-related activities in southwestern and northeastern Ethiopia (n = 288). Each *p* values is based on a chi-squared test statistic from a test of homogeneity

Similarly, among a total six varieties in the NE, all the three varieties found in East Gojjam were determined to be the same as those varieties found in South Wollo.

Farmers have developed traditional naming systems for common bean in both SW and NE production areas. Of the 39 local names documented, 72% refer to seed color. In the NE, where common bean is known as BOLOQE in Amharic, varietal names include NECH—(white), KEY—(red), TIKUR—(black), DALECHA—(cream) and GUREAZA—(spotted) BOLOQE. Similarly, in the SW the names for common bean varieties include the descriptors AO (black), CHELE (red), and NACHE (white). Seed size was also commonly cited (21% of names); for example, in the SW, FOLFOLE, and YURE refer to beans with medium-sized seeds. Several variety names (15%) refer to growth habit; most of these are found in Kefa, where the epithet MCHIMIYATE refers to a climbing habit that requires planting with a wooden pole. Two names referred to places of origin (AWASH 01 AND SHASHEMENE), and one to maturation time: YE'ARBAKEN ('40 days') BOLOQE is said to mature in 40 days. Some names refer to multiple traits: for example, the name TEFTAFA NECH BOLOQE ('flat and white bean') describes both the seed shape and color. Furthermore, the same variety may be given alternative names based on its multiple attributes. For example, DALECHA BOLOQE is cream-colored (to which DALECHA refers), has a good taste, and is round and large. Farmers who want to emphasize its superior taste called it WALEBELAY ('superior') BOLOQE, whereas


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◀**Fig. 8** Farmers' varieties of common bean collected from four administrative zones in southwestern and northeastern Ethiopia. Numbers refer to Table 2

those referring to its size call it DUBA ('pumpkin') BOLOQE. In the marketplace, this same variety was referred to as KEMOZEM, because when it is boiled it becomes soft and easy to chew.

Preference and use of common bean varieties

In both the SW and NE, farmers' valuation of common bean varieties is often related to seed color; red and white varieties are generally preferred to black varieties. Figure 9 illustrates the frequency of planting of each variety among farmers in each zone. Key informants explained that red varieties (CHELE GOBO in the SW and KEY BOLOQE in the NE) have an appealing color and good taste, mature in a shorter time, and can be processed for food more quickly than others. In the SW, the small, white-seeded variety named NACHO GOBO was preferred over others due to its color, uniform harvest maturity period and culinary qualities; it is used to make MULO, a dish prepared with boiled beans. In the NE, the white variety NECH BOLOQE is grown primarily for export markets, so it is an important source of income, while the cream-colored variety (DALECHA BOLOQE) is preferred for making traditional food. In both areas, white and red varieties are more common in the market and sell at high prices. By comparison, black common bean varieties including AO GOBO in the SW and TIKUR BOLOQE in the NE, are considered unattractive and fetch lower prices than the other varieties.

Although red and white varieties are generally preferred, farmers plant multiple varieties based on different use-values. In the SW, climbing varieties such as CHELE YURE, FOLFOLE, and MCHIMYATE are grown for home consumption based on their size and taste. Similarly, farmers in the NE grow GUREAZA BOLOQE, primarily for home consumption. AO GOBO is known to withstand water logging and is planted in places where the soil is more likely to become saturated. In Kefa Zone, one farmer reported that AO GOBO is fed to malnourished children to prevent stunted growth.

Varietal richness and diversity between sociocultural and agroecological contexts

Equal sampling effort (36 interviews per stratum) revealed the highest number of varieties in the humid, tepid mid-highlands of the SW (Table 3); 13 varieties were recorded in Kefa, and 12 in Bench Maji and Sheka. Varietal richness was slightly lower in per-humid areas, particularly the per-humid lowlands of Bench Maji and Sheka, where eight varieties were documented. The numbers of varieties were much lower in the NE, with five varieties in both agroecological classifications in South Wollo, with two and three varieties in the lowlands and mid-highlands of East Gojjam, respectively.

Shannon diversity values, which account for the relative abundance of each variety, follow the same general pattern. The highest values are in the humid, tepid highlands of the SW, and the highest is in Bench Maji and Sheka. The index values are slightly lower in the per-humid areas of the SW, and considerably lower in the NE, with the exception of the moist-warm lowlands of South Wollo. Such low Shannon diversity values indicate that most of the area planted to common bean is dominated by one or two varieties.

The number of varieties planted per household exhibit a different pattern. In most areas, farming households planted either one or two varieties of common bean per year, even in those areas with high varietal richness. The number of varieties per household does not correspond to the total number of varieties. For example, one of the lowest average values was observed in the per-humid lowlands of Bench Maji and Sheka (1.3 varieties per household), despite there being eight varieties observed in those areas. By contrast, the highest number of varieties per household was observed in the moist, warm lowlands of South Wollo, where only five varieties could be found and yet households planted an average 2.3 per year. The fact that the average household is planting more than two varieties may explain why the Shannon diversity index is also relatively high in this area.

The number of common bean varieties planted per household is associated with relative wealth and administrative (Fig. 10). The results of the two-factor ANOVA indicate that both zone and relative wealth are significant factors influencing the number of varieties planted per household ($p < 0.001$). The ANOVA confirmed that mid-to-high income farmers

Table 2 Names of common bean varieties as provided by farmers in four administrative zones of southwestern and northeastern Ethiopia

Local name of variety[a]	Translation, meaning of the name	Admin. Zone[b]	Status[c]	Growth habit[d]	Photo[e]
AO	'Black' (seed color)	SH, KF	FV	IB	1
AWASH 01	Released variety	KF	RV	DB	2
BICHO DEFO	'Yellow' (seed color)	SH	FV	ISC	3
BORI DORI	Place of origin	SH	FV	ISC	4
BURABURE BOLOQE	'Spotty' (seed color)	BM, SH	FV	ISC	5
CHELE FOLFOLE	'Red', 'medium' (seed color, size)	SH	FV	ISC	6
CHELE GOBO	'Red' (seed color)	SH, KF	FV	DB	7
CHELE YURE	'Red', 'medium-sized' (seed color, size)	KF	FV	ISC	8
DALICHA AO FOLFOLE	'Cream', 'black', 'medium-sized' (seed color, size)	SH	FV	ISC	9
DALICHA BURE MCHIMIYATE	'Cream', 'mottled', requires stake (seed color, habit)	KF	FV	ISC	10
DALICHA FOLFOLE	'Cream', 'medium-sized' (seed color, size)	SH	FV	unk	–
DALICHA KEY BURE MCHIMIYATE	'Cream', 'red', 'spotted', requires stake (seed color, habit)	KF	FV	unk	–
DALICHA KEY MCHIMIYATE	'Cream', 'red', requires stake (seed color, habit)	KF	FV	unk	–
DALICHA KOTO DEFE	'Cream', 'small' (seed color, size)	SH	FV	DB	11
DALICHA NECH MCHIMIYATE	'Cream', 'white', requires stake (seed color, habit)	KF	FV	ISC	12
DALICHA YURE GOBO	'Cream', 'medium' (seed color, size)	KF	FV	ISC	13
DINGERI	Unknown meaning	SH	FV	ISC	–
KANJI DEFO	'Pink' (seed color)	SH	FV	ISC	14
KEY BURE MCHIMIYATE	'Red, mixed', requires stake (seed color, habit)	KF	FV	ISC	15
MANACHE GOBO	'Human skin' (seed color)	KF	FV	DB	16
MCHIMIYATE	Requires stake (habit)	KF	FV	ISC	17
NACHE YURE	'White', 'medium' (seed color, size)	KF	FV	ISC	–
NACHO GOBO	'White' (seed color)	SH	FV	IB	18
NASIR	Released variety	KF	RV	DB	19
PANTARKN	'red and yellow' (seed color)	BM	FV	DB	20
POLPOLE	'Light red' (seed color)	BM	FV	B	21
SHASHEMENE	Place name	KF	FV	DB	22
SOLOGE	'Tasteless' (taste)	SH	FV	DB	23
TENKRE	'Hard' (pod durability)	SH	FV	IB	24
TIKUR BURE	'Black', 'mottled' (seed color)	KF	FV	IB	25
WELE GOBO	'Dark yellow' (seed color)	KF	FV	DB	26
YE'ENCHET BOLOQE	'Woody' (habit)	SH	FV	ISC	27
DALECHA or WALEBELAY BOLOQE	'Cream' (seed color), 'above all' (taste)	EG, SW	FV	B	28
GUREZA BOLOQE	'Spotted' (seed color)	SW	FV	ISC	29
KEY BOLOQE	'Red' (seed color)	EG, SW	FV	IB	30
NECH BOLOQE	'White' (seed color)	EG, SW	FV	IB	31
TEFTAFA NECH BOLOQE[f]	'Flat', 'white' (seed shape, size)	SW	FV	IB	32
TIKUR BOLOQE	'Black' (seed color)	SW	FV	IB	33
YEARBA KEN BOLOQE	'Forty days' (time to maturity)	SW	FV	B	34

[a] Local names are phonetic translations of local pronunciation and may not adhere to standard spellings in local languages

[b] *BM* Bench Maji, *EG* East Gojjam, *KF* Kefa, *SH* Sheka, *SW* South Wollo

[c] *V* Farmers' variety, *RV* Released variety

[d] *B* Bush, *DB* Determinate bush, *IB* Indeterminate bush, *ISC* Indeterminate semi-climber, *unk* unknown

[e] See Fig. 7

[f] Identified by key informants, but not during structured survey

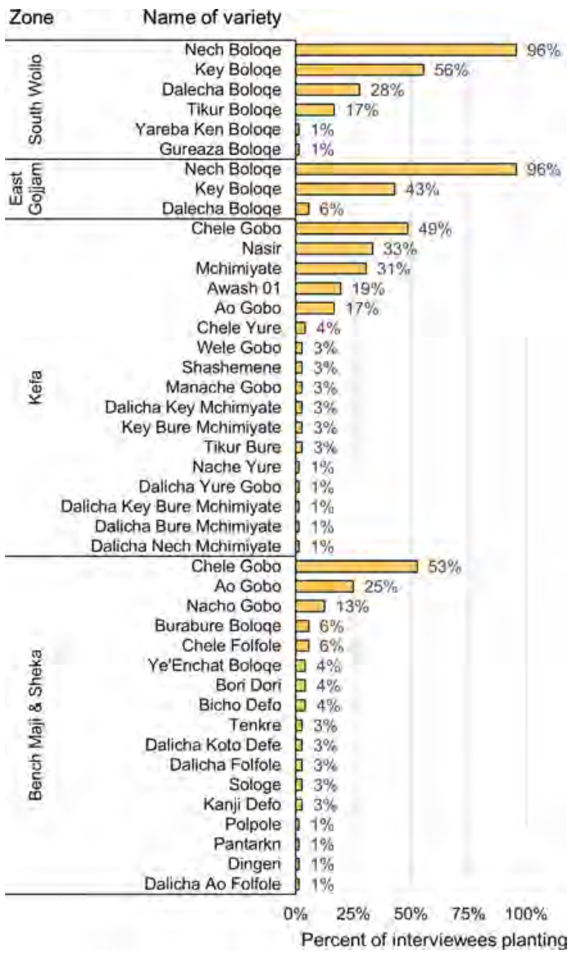

Fig. 9 Frequency of planting of common bean varieties in four administrative zones in southwestern and northeastern Ethiopia

in South Wollo planted significantly more varieties than all farmers in East Gojjam or Bench Maji and Sheka but not Kefa. However, the post hoc Tukey's test did not show any significant differences in the number of varieties planted by farmers of different wealth categories within the same zone.

Discussion

Common bean diversity is shaped by production and use, which varies substantially between zones, agroecologies, and sociocultural factors. Bimodal rainfall in the SW allows farmers to plant and harvest common bean twice a year, alternating plantings with cereals in an annual cycle; similar cropping practices are reported elsewhere in southern Ethiopia (Asfaw et al. 2013). However, yields are usually higher during the long rains, and the short rains are becoming less reliable because of human-induced climate change (Conway and Shipper 2011). However, because the SW receives the highest precipitation in the country, farmers are still able to maintain production of common bean twice a year. In contrast, because of the shorter growing season in the NE, common bean and other legumes are rotated with cereals in a two- or three-year cycle and as a result are harvested only once a year. The difference in the number of growing seasons may also explain the higher varietal richness in the SW. The advantage accrued by the shorter growing season in the SW encourages farmers to adopt faster-maturing varieties.

Differences in the area planted to common bean among zones correspond to the total area of land covered by grains (cereals and legumes) according to the data available at the Central Statistics Agency (CSA 2015). On average, farmers planted 0.38 hectares to grains in Bench Maji, 0.27 ha in Sheka, and 0.52 ha in Kefa, whereas they planted 1.13 ha and 0.68 ha in East Gojjam and South Wollo, respectively (CSA 2015). Assuming area planted to grain is a function of landholdings, it appears that access to land is a limiting factor for common bean plantings in the SW as compared to the NE. Furthermore, mid-to-high income farmers consistently planted larger areas to common bean than low-income households. These differences were not found to be statistically significant within zones, perhaps due to low sample sizes ($n = 36$ per relative wealth category per zone). Nevertheless, the relationship between wealth and area planted to common bean is likely due to landholdings. Another possible explanation is that low-income farmers only plant common bean when they have planted enough cereals to ensure the food security of their household.

All farmers in the SW reported intercropping common bean with other crop species, whereas roughly half of the farmers reported intercropping in the NE. The higher rate of intercropping in the SW is likely explained by smaller landholdings. Intercropping allows farmers to produce multiple crops when their access to land is limited. Therefore, this practice is more important in the SW than in the NE where average landholding is greater. Furthermore, low rates of intercropping in the NE may be related to the traits of popular varieties. NECH BOLOQE, which is widely

Table 3 Varietal richness and diversity of common bean at household and landscape levels (n = 288, or 36 per administrative zone and agroecological classification)

Admin. Zone	Agroecological classification	Total varieties	Shannon diversity	Varieties per household
Bench Maji and Sheka	Per-humid, warm lowland (PH2)	8	1.12	1.3
	Humid, tepid mid-highland (H3)	12	1.74	1.8
Kefa	Humid, tepid mid-highland (H3)	13	1.47	2.1
	Per-humid, tepid mid-highland (PH3)	10	1.21	1.6
East Gojjam	Moist, warm lowland (M2)	2	0.42	1.3
	Moist, tepid mid-highland (M3)	3	0.66	1.6
South Wollo	Moist, warm lowland (M2)	5	1.06	2.3
	Sub-moist, tepid mid-highland (SM3)	5	0.53	1.7

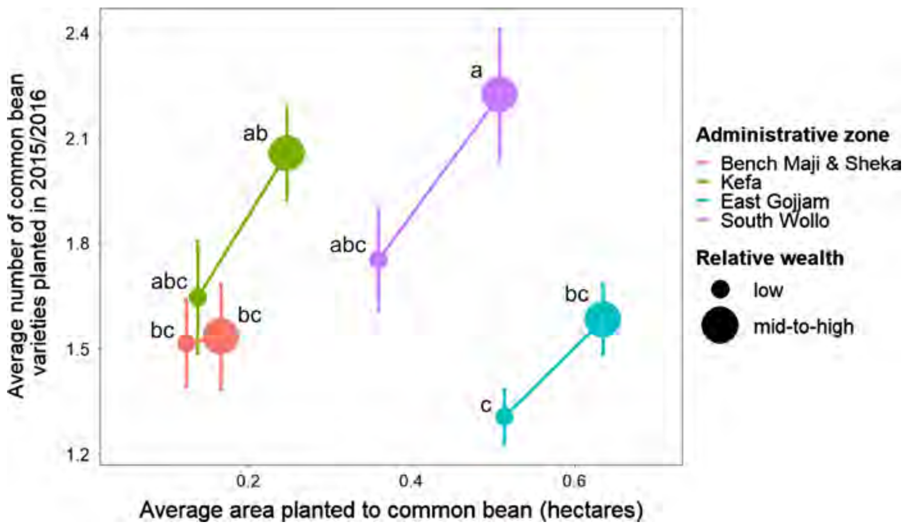

Fig. 10 Number of common bean varieties planted per household in relation to area planted to common bean, administrative zone, and relative wealth. Whiskers represent the standard error of the mean. Mean values that share a letter are not significantly different according to a post hoc Tukey test ($\alpha = 0.05$)

grown in the NE, is typically planted as a sole crop. Key informants explained that NECH BOLOQE shows lower yields when planted with cereals due to competition for water, especially during flowering and grain maturation. In addition, NECH BOLOQE is often planted on low-fertility soils because they have observed that planting it on richer soils results in high vegetative growth and low grain yields. Since farmers tend to plant cereals on richer soils, NECH BOLOQE is rarely included in intercrops with sorghum or maize.

Differences in average landholdings may also explain the use of field margins and fencelines to produce common bean in the SW. Where land is limited, farmers tend to optimize land use and are inclined to plant crops in marginal spaces. In turn, the use of multiple locations with different light regimes and physical structure may contribute to diversification, as farmers have selected common bean varieties for these different habitats. For example, farmers in the SW identified 14 climbing varieties, which could be planted along fencelines. In contrast, there was only one climbing variety reported in the NE, where most farmers plant common bean in their main fields and therefore prefer bush varieties.

Common bean is a multipurpose crop in both the SW and NE, but the variety of uses was greater in the NE. As in the rest of sub-Saharan Africa (Sibhatu et al. 2018), common bean is grown by almost all farmers as food for their households, the sole exception being farmers in South Wollo who grow NECH BOLOKE only for selling at local markets. Most farmers in the SW and NE areas sell common beans at local market, but its uses as medicine, fodder, and honeybee forage was reported mainly in the NE. The reason that farmers in the SW do not use common bean for these purposes may be due to the presence of other more alternative species in their surroundings; for example, there are multiple other sources of fodder available throughout the year. Medicinal use of common bean is reported in many parts of the world, including for treatment of jaundice in southern Ethiopia (Maryo et al. 2015) and rheumatism in Nigeria (Ajao et al. 2014).

We found women to be almost solely responsible for preparation of common bean as food and therefore more knowledgeable about the distinct culinary traits of varieties. The analysis also reveals cultural differences in gender roles with implications for the management and conservation of varietal diversity. Men often participate in seed selection in the SW, but in NE it is primarily the responsibility of women. In contrast, marketing is a shared responsibility in the NE, but primarily the responsibility of women in the SW. Therefore, women play distinct roles in the seed system at different stages of management. In the NE, they are the ones who maintain varietal traits based on their selection of seed for the next year's planting. In the SW, women are involved in the exchange of seed at their local markets, which impacts the distribution of varieties among households and communities.

Each common bean variety bears a local name recognized and maintained by farmers as a unit of diversity. As reported elsewhere (Kiwuka 2011; Asfaw et al. 2013; Loko et al. 2018a, b), names of common bean varieties are based on a wide range of morphological, agronomic, and functional traits. However, as in Asfaw et al. (2013), seed color was clearly the most important trait in distinguishing and naming bean varieties and assessing their diversity. Although the use of color in local taxonomies may appear superficial, it provides a visual index of varietal diversity to facilitate management (Olango et al. 2014; Loko et al. 2018a). Seed color, therefore, plays an important role in the on-farm conservation and development of varietal diversity.

Farmers in the NE appear to classify their varieties according to a hierarchical system that begins with seed color, followed by a wide range of other traits. Comparable studies in southern Ethiopia confirm that farmers use complex criteria to identify varieties based on seed color, taste, cooking time, growth habit, and marketability (Asfaw et al. 2013). The presence of multiple names for what key informants currently consider being the same variety may represent emergent differentiation. For example, the variety named DALECHA BOLOQE is also known as WALEBELAY when farmers emphasize its superior taste and DUBA BOLOQE in reference to its large seeds. One can imagine that households using these alternative names may look for different traits in their seed saving and that distinct varieties might emerge over time.

Further research could determine whether phenotypic traits (e.g., morphological or phenological features) differ among the common bean varieties as they are identified by farmers. In the present analysis, varieties are described and distinguished based on farmers' knowledge. Farmers' preference for red and white common bean varieties is confirmed in other parts of Ethiopia (Asfaw et al. 2009, 2013); despite local knowledge that black varieties have important advantages. In addition to the nutritional and agronomic advantages reported by farmers in the SW, black varieties are preferred by farmers in the Boricha and Konso (southern Ethiopia) due to their tolerance to drought (Asfaw et al. 2013). Where aesthetic preferences conflict with agronomic values, breeders might explore linkages between traits to determine if preferred traits are possible to combine.

The number of farmers' varieties described in the present study exceeds the findings of previous surveys conducted in Sub-Saharan Africa. For example, six landraces were identified in southern Ethiopia (Asfaw et al. 2013) and 12 landraces were named in Benin (Loko et al. 2018b). The current study relies on farmers' naming conventions and observations of seed morphology; therefore, agromorphological and molecular characterization is suggested to determine if genetic diversity corresponds to local taxonomies. In addition, the current study distinguished between varieties found in the two production areas. In some cases, local names have the same meaning; e.g. CHELE GOBO in the SW and KEY BOLOQE in the NE both refer to red seeds. Further analysis would be necessary to determine if these two varieties are genetically distinct and to avoid overestimation of common bean diversity across the two study areas.

The distribution of common bean varietal diversity within and among households differs between the four administrative zones included in this study. Although the two zones in the SW show the highest numbers of varieties, the number of varieties planted per household is comparable to the NE, where the total number of varieties is lower. As indicated earlier, smaller landholdings in the SW limit the area planted to common bean as well as the number of varieties planted per household. Previous studies from southern Ethiopia also indicated that most farmers planted only one variety (Asfaw et al. 2013). An interesting exception is reported from the Boricha District in Sidama (southern Ethiopia), where farmers planted 2.75 common bean varieties per household on average despite low average landholdings (Bareke et al. 2018). Nevertheless, varieties in the SW are distributed among households. Relatively high Shannon diversity indices show that different varieties are grown by households in the same zone, resulting in no dominance by one or two popular varieties. This indicates that varietal diversity is conserved more at the community rather than household level. Community-based conservation requires coordination within communities so that farmers continue to access the varietal diversity maintained among neighboring households and villages in the context of change. This is particularly important for low-income households, who plant smaller areas and fewer varieties, and therefore need varieties that are a reliable source of food security.

Farmers in the NE have fewer varieties but plant comparable numbers per household; in the case of South Wollo, varietal richness per household is higher than in the SW. Again, larger landholdings in these two zones likely explain why most farmers plant multiple varieties of common bean. However, the total number of varieties available remains an important limitation. The largest areas planted to common bean are found in East Gojjam, but the average number of varieties per household is low due to the presence of only three varieties. Lower diversity of common bean in East Gojjam may also be due to a focus on small cereals, which cannot provide as much physical support and space for climbing bean types as large cereals (maize or sorghum).

Conclusions

Farmers' knowledge related to the production and use of common bean varieties is a time-tested source of knowledge that can contribute to formal scientific efforts aimed at enhancing the resilience of Ethiopian and global agriculture. Despite being a relatively recent introduction to Ethiopia, common bean displays high varietal diversity based on selection for a wide range of agroecological conditions and multiple uses by farming communities. In the SW and NE production areas included in this study, common bean is an important source of traditional food and cash income; in the NE, the crop also provides medicine, fodder, and honeybee forage. Through intercropping and rotation, common bean contributes to soil fertility and therefore plays an essential role in agroecological intensification.

Farmers' varieties of common bean include a wide array of traits to confront the challenges of changing priorities and demands. Identification of varieties is based primarily on seed morphological characteristics, mainly seed color, that facilitates the organization of agroecological knowledge and communication among researchers, extension agents, and farmers. In addition to monitoring the culinary qualities of common bean varieties, women play important roles in the seed system: they are the primary agents of seed selection in the NE and marketing in the SW. Conservation of common bean varietal diversity must include women as vital knowledge holders.

Policies and programs to conserve the varietal diversity and increase the productivity of common bean in Ethiopia need to respond to limiting factors that differ among agroecological and social contexts. In the SW, most farmers plant only one or two varieties, despite the availability of 8 to 13 varieties that grow within the same agroecological zone. Therefore, conservation needs to be organized at the community level, to ensure that varietal richness is maintained and available to farmers when they need it. In contrast, in the NE, larger landholdings allow farmers to plant more varieties, but it appears that they are limited by the number of varieties available. Exchange of seeds and knowledge between households and communities—including across the two zones—might enhance productive stability and resilience and enable in situ conservation by individual households. Such activities could be facilitated by government agencies or non-governmental organizations to strengthen the capacity of farmers to anticipate climate variability and take advantage of emergent market opportunities.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical standards The research protocol (#1605006357) was determined to be exempt from review by the Institutional Review Board for Human Participants at Cornell University (USA) on the basis that the research consists of interviews that pose minimal risk to interviewees. Free and informed oral consent was obtained by the two first authors from all participants prior to each interview.

References

Ajao AM, Oladimeji YU, Babatunde SK, Obembe A (2014) A study of the use of honey and ethno-biological components in Nigerian trado-medical practices. Br J Appl Sci Technol 4(19):2796

Altieri MA (1999) The ecological role of biodiversity in agroecosystems. Agric Ecosyst Environ 74:19–31

Asfaw A, Blair MW, Almekinders C (2009) Genetic diversity and population structure of common bean (*Phaseolus vulgaris* L.) landraces from the East African highlands. Theor Appl Genet 120:1–12

Asfaw A, Almekinders CJ, Struik PC, Blair MW (2013) Farmers' common bean variety and seed management in the face of drought and climate instability in southern Ethiopia. Sci Res Essays 8(22):1022–1037

Bareke T, Asfaw Z, Woldu Z, Medvecky B, Amssalu B (2018) Diversity of common bean (*Phaseolus vulgaris* L., Fabaceae) landraces in parts of southern and eastern Ethiopia. Adv Plants Agric Res 8(6):449–457

Bellon MR (2004) Conceptualizing interventions to support on-farm genetic resource conservation. World Dev 32(1):159–172

Brown GG, Swift MJ, Bennack DE, Bunning S, Montáñez A, Brussaard L (2007) Management of soil biodiversity in agricultural systems. In: Jarvis DI, Padoch C, Cooper HD (eds) Managing biodiversity in agricultural ecosystems. Columbia University Press, New York, pp 224–268

Brush SB (1995) In situ conservation of landraces in centers of crop diversity. Crop Sci 35:346–354

Conway D, Schipper ELF (2011) Adaptation to climate change in Africa: challenges and opportunities identified from Ethiopia. Glob Environ Change 21(1):227–237

CSA (2015) Agricultural Sample Survey, report on area and production of major crops. Private peasant holdings, Meher Season, Addis Ababa, Ethiopia

Dagnew K, Haileselassie T, Feyissa T (2014) Genetic diversity study of common bean (*Phaseolus vulgaris* L.) germplasm from Ethiopia using inter simple sequence repeat (ISSR) markers. Afr J Biotechnol 13(36):3638–3649

Gaudin ACM, Tolhurst TN, Ker AP, Janovicek K, Tortora C, Martin RC, Deen W (2015) Increasing crop diversity mitigates weather variations and improves yield stability. PLoS ONE 10(2):e0113261

Heuze V, Tran G, Lebas F, Noziere P (2013) Common bean (*Phaseolus vulgaris*), Feedipedia.org—animal feed resources information system A programme by INRA, CIRAD, AFZ and FAO. http://www.feedipedia.org/node/266. Accessed 17 July 2019

Hodgkin T, Rana R, Tuxill J, Balma D, Subedi A, Mar I, Karamura D, Valdivia R, Collado L, Latournerie L, Sadiki M, Sawadogo M, Brown AHD, Jarvis DI (2007) Seed systems and crop genetic diversity in agroecosystems. In: Jarvis DI, Padoch C, Cooper HD (eds) Managing biodiversity in agricultural ecosystems. Columbia University Press, New York, pp 77–116

Jarvis DI, Padoch C, Cooper HD (2007) Biodiversity, agriculture, and ecosystem services. Managing Biodiversity in agricultural ecosystems. In: Jarvis DI, Padoch C, Cooper HD (eds) Managing biodiversity in agricultural ecosystems. Columbia University Press, New York, pp 1–12

Kiwuka C, Mulumba, JW, Adokorach J, Nankya, R (2011) Relating crop damage levels on-farm to crop varietal diversity measured by richness, evenness and diversity for common bean in Uganda. In: Jarvis DI, Fadda C, De Santis P, Thompson T (eds) Damage, diversity and genetic vulnerability: the role of crop genetic diversity in the agricultural production system to reduce pest and disease damage. Proceedings of an international symposium 15–17 February 2011, Rabat, Morocco, pp 45–54

Legesse H, Dechassa N, Gebeyehu S, Bultosa G, Mekbib F (2013) Response to soil acidity of common bean genotypes (*Phaseolus vulgaris* L.) under field conditions at Nedjo, Western Ethiopia. Sci Technol Arts Res J 2(3):3–15

Loko L, Orobiyi A, Adjatin A, Akpo J, Toffa J, Djedatin G, Dansi A (2018a) Morphological characterization of common bean (*Phaseolus vulgaris* L.) landraces of Central region of Benin Republic. J Plant Breed Crop Sci 10(11):304–318. https://doi.org/10.5897/jpbcs2018.0766

Loko L, Toffa J, Adjatin A, Akpo AJ, Orobiyi A, Dansi A (2018b) Folk taxonomy and traditional uses of common

bean (*Phaseolus vulgaris* L.) landraces by the sociolinguistic groups in the central region of the Republic of Benin. J Ethnobiol Ethnomed 14:52. https://doi.org/10.1186/s13002-018-0251-6
Maryo M, Nemomissa S, Bekele T (2015) An ethnobotanical study of medicinal plants of the Kembatta ethnic group in Enset-based agricultural landscape of Kembatta Tembaro (KT) Zone, Southern Ethiopia. Asian J Plant Sci Res 5(7):42–61
Mekbib F (2007) Infra-specific folk taxonomy in sorghum (*Sorghum bicolor* (L.) Moench) in Ethiopia: folk nomenclature, classification, and criteria. J Ethnobiol Ethnomed 3:38
Miles CA (2002) Niche market dry bean variety trial. USDA. Annu Rep Bean Improv Coop 45:224–225
MoARD (Ministry of Agriculture and Rural Development) (2005) Major agro-ecological zones of Ethiopia. Forestry, Land Use and Soil Conservation Department, Addis Ababa
Olango TM, Tesfaye B, Catellani M, Pè ME (2014) Indigenous knowledge, use and on-farm management of enset (*Ensete ventricosum* (Welw.) Cheesman) diversity in Wolaita, Southern Ethiopia. J Ethnobiol Ethnomed 10(1):41
Padulosi S, Heywood V, Hunter D, Jarvis A (2011) Underutilized species and climate change: current status and outlook. In: Yadav S, Redden R, Hatfield J, Lotze-Campen H, Hall A (eds) Crop evolution to climate change. Wiley-Blackwell, Chichester, pp 507–521
Petry N, Boy E, Wirth JP, Hurrell RF (2015) The potential of the common bean (*Phaseolus vulgaris*) as a vehicle for iron biofortification. Nutrients 7:1144–1173
Picasso VD, Brummer EC, Liebman M, Dixon PM, Wilsey BJ (2011) Diverse perennial crop mixtures sustain higher productivity over time based on ecological complementarity. Renew Agric Food Syst 26(4):317–326
Rahmato NR (2007) Determinants of adoption of improved haricot bean production package in Alaba special woreda, southern Ethiopia. Dissertation, Haramaya University
Redford KH, Brosius JP (2006) Diversity and homogenization in the endgame. Glob Environ Change 16:317–319
Russell K, Bessin R (2008) Integration of *Trichogamma ostriniae* releases and habitat modification for suppression of European corn borer (*Ostrinia nubilalis* Hübner) in bell peppers. Renew Agric Food Syst 24(1):19–24
Santalla M, Casquero PA, De Ron AM (1999) Yield and yield components from intercropping bush bean cultivars with maize. J Agric Crop Sci 183:263–269
Sibhatu KT, Qaim M (2018) Farm production diversity and dietary quality: linkages and measurement issues. Food Secur 10:47–59
Sthapit B, Padulosi S, Mal B (2010) Role of on-farm/in situ conservation and underutilized crops in the wake of climate change. Indian J Plant Genet Resour 23(2):145
Villa TCC, Maxted N, Scholten M, Ford-Lloyd B (2006) Defining and identifying crop landraces. Plant Genet Resour 3(3):373–384. https://doi.org/10.1079/PGR200591
Wortmann, CS, Eledu CA (1997) Distribution of bean seed types in Eastern Africa. Bean Improvement Cooperative. Annual Report. FAO USA, vol 40, pp 30–31