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# Agroforestry extension and dietary diversity – an analysis of the importance of fruit and vegetable consumption in West Pokot, Kenya

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**Abstract** Worldwide, the challenges of nomadic, pastoralist systems are causing their slow but steady disappearance in favour of sedentary agropastoralism. This paper draws upon an existing household data set from a survey collected and organized by the Swedish non-governmental organization (NGO) Vi Agroforestry, directed at a livestock-based, agro-pastoralist area in West Pokot County, western Kenya. The study focuses on the question of food diversity and malnutrition and the role of agroforestry extension services, i.e. knowledge spread, transfer and development. Our basic hypothesis is that certain fruit and vegetable related food groups are under-consumed in West Pokot, especially in the dryland areas. The results of the study shows that agroforestry, combined with advice through extension efforts can imply a transition path for pastoralists which involves improved dietary diversity, especially concerning food groups that include roots, tubers, fruits and leafy vegetables. From the results certain restrictions that hinder this transition become clear. An important but often overlooked factor is lack of information and knowledge as a determinant of household behavior in developing countries. NGOs such as Vi Agroforestry can play an important role in overcoming this restriction by providing extension services. Developing countries in general are not information-rich environments, a fact that is especially the case for poor citizens living in rural areas. The paper illustrates that careful attention to the information and knowledge available to households is necessary when designing development cooperation.

**Keywords** Agroforestry · Dietary diversity · Pastoralism · Vi Agroforestry · West Pokot

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## Introduction

Worldwide, drylands cover 40 % of the world's land mass, and are host to one-third of humanity and half the world's livestock (e.g. McDermott et al. 2010; UN Environment Management Group 2011). An estimated 70 % of the world's poorest people rely on income from pastoralism/agro-pastoralism. In Sub-Saharan Africa, 40 % of total inhabitable land is used mainly for livestock (pastoral and agropastoral) and around 265 million farmers/livestock keepers have livestock as primary income source (Neely et al. 2009). The traditional land-use in these areas is nomadic pastoralism with land tenure systems that are communal and/or based on common property rights.

Dryland areas often have a history of overgrazing and are frequently degraded; with low productivity, recurrent famines, and conflicts about resources (Opiyo et al. 2011). Dryland areas are faced with many combined challenges: climate variability and change, population growth, accelerated demand for livestock products, continuing urbanization and changing food preferences (Thornton 2010; Herrero and Thornton 2013). There is need for sustainable intensification of livestock production in the Sub-Saharan drylands (McDermott et al. 2010; Catley et al. 2013; Sumberg and Thomson 2013).

In Sub-Saharan Africa, there is an increased use of enclosures as a land management tool. Enclosures refer to areas closed off

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from interference by humans and domestic animals for a specified duration of time in order to promote natural regeneration of plants and reduce land degradation on formerly degraded communal grazing land (Mekuria et al. 2011). There are different views on these enclosures. Some see them as a sustainable intensification of rangelands, driving food production towards more market-oriented agro-pastoral systems in Sub-Saharan Africa (Woodhouse 2003; Verdoodt et al. 2009, McDermott et al. 2010; Angassa and Oba 2010) and some see them as a "default" development[1] in semi-arid areas (Woodhouse 2003). Others argue that use of enclosures erodes traditional values and lifestyles as well as eroding collective property rights and thereby generating land and water conflicts (Woodhouse 2003; Beyene 2009, 2010; Angassa and Oba 2008; Lesorogol 2003; Napier and Desta 2011). In West Pokot, enclosures and agroforestry are mainly established to address land degradation and provide stable grazing lands for the local pastoral community (Makokha et al. 1999; Kitalyi et al. 2002; Wairore et al. 2015). Enclosed areas, i.e. periodically protected from grazing animals, enable the cultivation of crops, trees (including fruit trees) and vegetables, and often mark privatized land user rights (although not always formalized into legal tenure) (Wairore et al. 2015; Nyberg et al. 2015). Recent research confirms rapid transitional processes towards intensified, agro-pastoralist production systems in East African arid- and semi-arid lands (Gichero et al. 2012; Greiner et al. 2013).

People in pastoralist societies in dryland areas suffer from problems associated with malnutrition; the diet is often centred on the food groups that can be produced from livestock or poultry, i.e. meat, milk and eggs. Decreasing the number of food groups increases the importance of nutrient content of the foods actually eaten - a diet low in diversity can result in micro-nutrient deficiencies even if energy intake is adequate. Overall, eastern Africa has the lowest per capita fruit consumption of any region in the developing world, and it has been shown that expansion of fruit tree cultivation on farms can have a significant effect on both quantity and quality of nutrition, especially for children (Garrity 2004). 'Hidden hunger' arises from a deficiency of micro-nutrients in the diet, for example inadequate levels of iron, iodine, zinc, Vitamin A, and Vitamin B12 (Biesalski 2013). This can occur with or without accompanying deficiencies of energy and protein, and is related to poor diet quality and low diet diversity. It is a global phenomenon, mainly affecting young children and women.

The pastoral lifestyle is often associated with growing economic inequality and impoverishment, as well as to limited market access and limited possibilities of increasing livestock productivity. Given these challenges, there is a slow but steady disappearance of nomadic, pastoralist systems in favour of sedentary agropastoralism (Moritz 2012). Although this transition implies serious environmental and human impacts (Mortimore et al. 2009; Wairore et al. 2015), there have been few, if any, comprehensive studies of dietary diversity in emerging livestock-based, agro-pastoralist systems.

Kenya has the largest economy in East-Africa, growing at 5.4 % a year, but poverty and income inequality remain high, necessitating support from the World Food Programme (World Food Programme 2012). More than half of the population live below the poverty line, and about one third of children under five and women suffer from chronic malnutrition. Eighty percent of the land is arid or semi-arid, and recurrent drought and floods put additional strains on the country.

This paper draws upon an existing household data set from a survey directed at subsistence farmers, collected and organized by the Swedish, non-governmental organization (NGO) Vi Agroforestry in seven different divisions/locations[2] in West Pokot County, western Kenya. Although the data are rich and cover several topics, we will focus here on food diversity which is an indicator for the risk of malnutrition. Our basic hypothesis is that certain fruit and vegetable related food groups are under-consumed in dryland areas such as West Pokot. The type of agroforestry extension, i.e. spread, transfer and development of knowledge, of which Vi Agroforestry is an example, has the potential to alleviate this problem, and thereby improve dietary diversity, particularly with respect to fruit consumption. Especially for children, this can reduce the prevalence of micro-nutrient deficiencies related to limited fruit and vegetable consumption, e.g. vitamin A, and improve energy intake.

The *modus operandi* of the Vi Agroforestry project in the area changed between 1987 and 2000. Free advice on agroforestry, including cultivation of trees, crops, fruit and vegetables were given throughout, but provision of tree seedlings and tree seeds (mainly non-fruit trees), changed over time. In the early years, tree seedlings were given free of charge to farmers as an incentive, then, approximately between 1992 and 1997, only tree seeds were given and at the end of the project period neither seedlings nor seeds were given. A consequence of this is that it was the early adopters who obtained tree seedlings and tree seeds. Central to this extension service was the use of enclosures as a management tool to rehabilitate land, reduce erosion, increase fodder production, and to protect cultivated plants from grazing. Among participants in the present study, receiving advice from Vi Agroforestry was closely associated with receiving free tree seedlings.[3]

[1] *Default development* means that it will happen, unless someone (i.e., authorities) strongly pushes for the development not to take place.

[2] The boundaries of geographical areas have changed over time and are sometimes, in official documents, referred to as divisions and sometimes as locations.

[3] Nowadays, Vi Agroforestry is working through other NGOs and local organisations in other areas in Kenya and elsewhere in East Africa. Agroforestry advice and extension has been part of the package throughout.

We also discuss dietary needs with a focus on certain food groups that are under-consumed in West Pokot. This is related to issues of daily food intake in rural Africa in general and its relationship to knowledge of the importance of dietary diversity and conceptions of what types of crops can be eaten. Adoption of agricultural technologies, such as what crops to grow, is a complex process where education and information are important (Pommer and Picozzi 2014). As argued in e.g. Jalan and Somanathan (2008) under-provision of information plays an important role in developing countries and should be taken into account whenever the demand for environmental quality or, in this case, food diversity is studied. The method section will present the Vi Agroforestry survey from 2007/2008. We then present the WHO measure of minimum dietary diversity, and its relationship to data from the survey on different crops that are grown and animals that are reared in West Pokot. In the results section we present an analysis of the West Pokot survey data with a focus on the effects of extension system by Vi Agroforestry.

## Background

Agroforestry is a form of land use that combines trees and shrubs with crops and/or livestock to increase and diversify farm production (Molua 2005). When agroforestry is used, farm profitability may be increased through: (1) increases in total output through tree/crop/livestock combinations greater than that obtained with only one of these components, (2) protection of crops and livestock from wind and soil erosion, (3) financial diversity and flexibility from the production of additional goods. Furthermore, fruit trees can provide income and/or added essential micronutrients to ensure a balanced diet. However, to our knowledge, several aspects of the practice of agroforestry, such as the effect on food security and food diversity, have not been thoroughly verified.

Vi Agroforestry is a Swedish NGO working with tree planting and agroforestry education in Kenya, Rwanda, Uganda and Tanzania. Since the start in 1983 more than 100 million trees have been planted (www.viagroforestry.org). Agroforestry is the basis of Vi Agroforestry's work, including extension services on enclosed demonstration plantations, free and/or very affordable tree seedlings, and components such as organizational development, market oriented production, financial services, school gardens and measures to combat the greenhouse effect have been added over the years.

West Pokot County is largely a dryland area located in the Rift Valley Province in western Kenya (see Fig. 1). It borders Uganda to the west, the counties of Trans-Nzoia and Marakwet to the south and the county of Turkana to the north and east. The county covers a surface area of 9100 km$^2$ and includes seven geographical divisions: Chepareria, Kacheliba, Kapenguria, Kongelai, Mnagei, Sook and Tapach. West Pokot County had an estimated population of 512,690 in 2009. The annual population growth rate is about 3.1 %, slightly higher than the average for the whole of Kenya, which was 2.7 % in 2009. The traditional lifestyle in the area has been pastoralism, but through rapid cultural, institutional and land use transition this is now changing to sedentary agropastoralism. Within West Pokot there is also considerable variation – from the dryland, predominantly pastoralist division of Kacheliba in the north-western part of West Pokot, via the divisions of Kongelai and Chepararia, where communal land is increasingly being enclosed for intensified, livestock-based agropastoralist production; to the crop-based, agropastoralist[4] division of Kapenguria, with more rainfall at higher altitude in the south. The remaining divisions are situated in water-scarce and partly in severely-eroded lowland areas. Frequent overgrazing and increased population have led to a need for intensified and more productive land-use, including growing crops and trees.

The division of Chepareria is an area where Vi Agroforestry demonstrated and carried out intensive extension work on agroforestry and enclosures from 1987 to 2000 (thereafter less intensive). In the divisions of Kacheliba and Kongelai, Vi Agroforestry activities were less intensive and of shorter duration (2000–2004), and in Sook there has been no extension by Vi Agroforestry. Hence, in Cheperaria, most farmers/cattle owners adopted, and continue to adopt and adapt, the practices taught through the NGO, whilst in Kacheliba and Kongelai only a minority have done this. Cattle owners in Chepareria are nowadays less migratory, whilst in Kacheliba and Kongelai migratory pastoralism is still dominant. There has also been migration into urban centres in West Pokot County, e.g. the livestock based market in Chepareria has grown rapidly over the last decades. Other infrastructural changes may also be more pronounced in Chepareria. The individualisation/privatisation of land user rights has reached more land users there than in Kacheliba and Kongelai where pastoralism on common/communal land predominates. Overall, there are rapid cultural, institutional and land use changes in Chepareria. The climate is very similar among these neighbouring sub-counties, i.e. around 700–900 mm/year, with highly variable rainfall. In the highland divisions/locations of Kapenguria and Mnagei, extension intensity and duration was similar to that in Chepareria, whilst it was shorter and less intensive in Tapach (Vi Agroforestry, pers. communication).

[4] In development and other general literature (though less in scientific literature) it is presumed that transition from livestock based livelihoods, i.e. pastoralism, to agro-pastoral livelihoods means a transition to crop based agriculture where livestock keeping has a minor economic role. What we see in West Pokot is a transition from pastoralism to an agro-pastoral system that still has livestock as its economic and livelihood base.

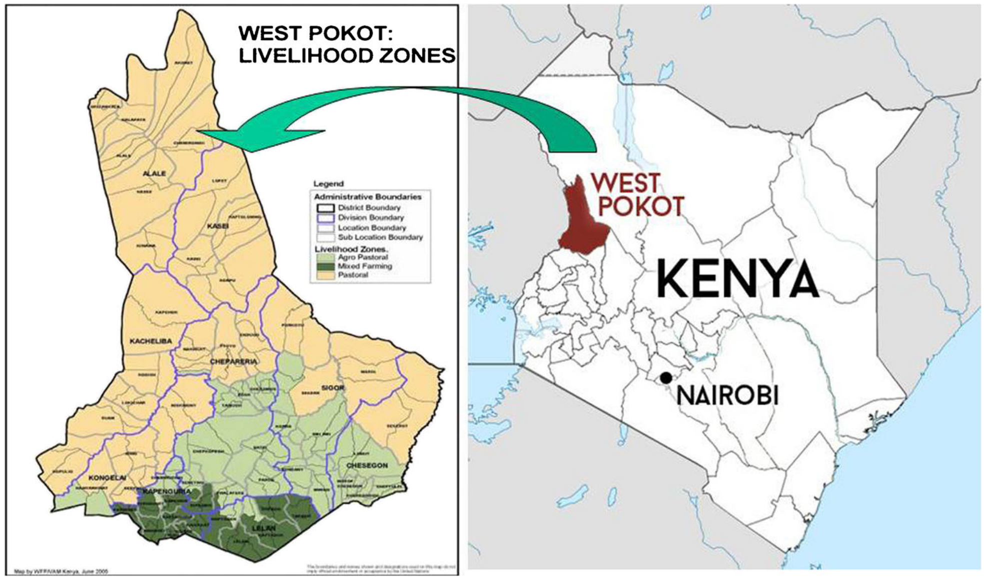


**Fig. 1** Map of West Pokot in Kenya. (NDMA 2014)

According to a UNICEF-funded study, food security in the county of West Pokot was reported to be critical in the northern part and moderate in other areas as of May 2011 (ACF-USA 2012). The same study found that on average 12.1 % of the children under 5 years suffered from severe or moderate wasting, a figure that is on the World Health Organization (WHO) alert level. Challenges in the county include endemic livestock diseases, high food prices, recurrent droughts, insecurity, and cattle rustling, especially in the north and central parts of West Pokot. The soils in West Pokot are also highly susceptible to erosion. Stress levels[5] have been consistent in the agro-pastoral zone, while in the mixed farming zone the situation had improved to no food insecurity.

## Materials and methods

### Participants in the Vi agroforestry survey

Since 2001, Vi Agroforestry in Kitale, Kenya, have carried out surveys in the areas where there were active agroforestry extension services. The 2001 survey was conducted using structured questionnaires directed at subsistence farmers. In the following years, Vi Agroforestry carried out surveys at least every two years. Unfortunately, the design of the questionnaire has changed several times over the years, making comparisons over time impossible for many questions, but these surveys were meant to assess the impact of Vi Agroforestry on its target group (cf. Vi Agroforestry 2007) not designed for long-term research purposes.

The present paper is based on data from the 2007/2008 survey, carried out from May 2007 to July 2008. The sample consisted of 296 subsistence farmers, retrieved from lists of farmers from the local official administration of different parts of West Pokot county. Of these, 164 farmers had received advice from Vi Agroforestry, 127 had not.[6] However, advice might have additionally spread from farmer to farmer, reaching also those who had not been in contact with the extension service. Indeed, that would have been a desired outcome for any extension service. A three-step multistage randomized sampling technique was used: 1) in each of the seven divisions, locations were selected at random from a list; 2) within the locations, villages were randomly selected from a list; and finally 3) in each village, participants were also randomly selected from a list. The goal was to randomly select ten farmers from each village. However, for reasons of time and/or budget constraints for the survey, the final sample in some villages consisted of fewer respondents. The survey was conducted using structured questionnaires in one-on-one interviews (Vi Agroforestry 2007). Questions included how often the household ate animal protein, fruits and vegetables. The response alternatives were daily, weekly, monthly, yearly[7] and never. Details were also asked about the types of crops, vegetables, and fruits grown and livestock kept by the household. Observation was also employed as a method of data collection, especially during tree inventories and inventories of agroforestry technologies present on surveyed farms.

[5] *Stress level* refer to the Integrated Food Security Phase Classification (IPC) - a set of standardized tools that aims to provide a "common currency" for classifying the severity and magnitude of food insecurity (www.ipcinfo.org). The five steps in the scale are: 1) minimal, 2) stressed, 3) crisis, 4) emergency, and 5) famine.

[6] Five respondents did not answer the question.

[7] Yearly means that the food item is eaten once, or just a few time per year.

### Food groups and dietary diversity

The Vi Agroforestry survey covered several topics, but we have chosen to focus on the variables connected with dietary diversity. Household dietary diversity is a measure of a household's food access and is a proxy indicator of a household's economic status. Throughout the analysis it was assumed that the surveyed households in West Pokot were subsistence farmers, mainly living off their own produce, i.e. the food diversity of the actual diet might be both over- and underestimated. Overestimation would occur if, for example, food items were sold rather than eaten by the household and underestimation if food items belonging to food groups not available from their own production were bought at the market.

Based on the survey with household heads,[8] a dietary diversity score was calculated for each household using the WHO indicators originally intended for assessing infant and young child feeding practices (WHO 2010). The seven foods groups used for tabulation of this indicator were (capital letters indicate food groups in Tables 1 and 2 below):

- grains, roots and tubers (A, C)
- vitamin-A rich fruits and vegetables (B, D, E)
- other fruits and vegetables (excluding legumes and nuts) (F)
- flesh foods (meat, fish, poultry and liver/organ meats) (G, H, J)
- eggs (I)
- legumes and nuts (K)
- dairy products (milk, yogurt, cheese) (L)

In the present study, access to food group G, H and J (flesh foods) was assumed if the household head reported consumption of animal protein more than once per week, while access to food groups I (eggs) and L (dairy products) are based on reported ownership of poultry, and sheep, goats and cattle, respectively. The WHO indicator *Minimum dietary diversity* was also used as it indicates the proportion deemed to be consuming foods from four or more food groups.

### Statistical analysis

Descriptive data are presented as proportions (%), mean (standard deviations; SD) and median [25th-75th percentiles]. Differences between those who had received advice from Vi Agroforestry and those who had not, were tested by a t-test. Regression analyses were used to determine the effects of household characteristics, geographical variation and counselling by Vi Agroforestry on number of food groups available and dietary diversity score. However, since descriptive statistics suggested that households where the household head had a higher education level also had a higher likelihood of being in the group receiving advice from Vi Agroforestry, an endogenous selection model was needed. For this reason the Heckman (1979) two stage estimation procedure was used. Note here that since the Heckman estimator is consistent, but not fully efficient, the Heckman estimates were then used as starting values to obtain maximum likelihood estimates using the Davidon–Fletcher–Powell formula (Davidon 1991). The probit version of this estimation procedure (Bliss 1934) was used to analyse the effect of Vi Agroforestry, together with other independent variables, on the respective food groups. Statistical significance was set at the $p < 0.05$ level.

[8] West Pokot is still a patriarchal society, which means that household heads are mostly men, but they can also be headed by women, e.g. widows.

## Results

### Food intake and dietary diversity

Even a cursory look at these data is sufficient to conclude that the studied area in West Pokot is very poor and is likely to have problems with malnutrition (Fig. 2). Daily consumption of animal protein and vegetables were reported by 50.5 % and 84.1 % of the household heads, respectively, while less than 10 % reported eating fruit daily. In fact, 24.5 % reported that they never ate fruit or did so only a few times per year. These results are fairly coarse as no details on amounts eaten are given, nor whether all in the household ate the foods. In addition, lack of information on kind of fruits and vegetables make it impossible to estimate adequacy of micro-nutrient intake.

A more detailed analysis is allowed through questions which asked households what kind of crops, vegetables and fruits they grew and what kind of livestock they kept. Organizing the data along the regional dimension provides a first look at geographical variation, as seen in Tables 1 and 2.

As can be seen from Table 1 the average size of land owned by the household varied considerably among divisions/locations, with households in Kacheliba having smaller land holdings, and households in Sook, Kapenguria and Tapach being above average. The proportion of households which had received advice from Vi Agroforestry also varied considerably in the sample; from Sook, where no households had received advice, to Mnagei, where all the households had been given advice by Vi Agroforestry. The overall mean dietary diversity score of 3.98 is low and corresponds well with the mean figure of 4.0 found in the previously mentioned UNICEF funded study (ACF-USA 2012). It is interesting to note that the UNICEF study recommended an increase in agricultural

**Table 1** Descriptive statistics by division/location for number of households, size of land (hectares), proportion of households receiving advice from Vi Agroforestry, dietary diversity score and proportion reaching minimum dietary diversity

| Division | Households in survey (n) | Size land (ha)[a] | Advice Vi (%) | Dietary diversity score[a, b] | Minimum dietary diversity[c] (%) |
|---|---|---|---|---|---|
| All divisions/ locations | 296 | 5.40<br>[4.0]<br>(7.14) | 56 | 3.98<br>[4.0]<br>(1.21) | 72 |
| Chepareria | 69 | 5.04<br>[3.0]<br>(7.37) | 78 | 4.56<br>[4.0]<br>(0.98) | 88 |
| Kacheliba | 46 | 3.59<br>[3.0]<br>(2.04) | 68 | 3.54<br>[4.0]<br>(0.65) | 59 |
| Kapenguria | 55 | 6.60<br>[3.0]<br>(9.56) | 73 | 4.38<br>[5.0]<br>(1.27) | 82 |
| Kongelai | 50 | 5.33<br>[4.0]<br>(6.20) | 92 | 3.54<br>[4.0]<br>(0.95) | 60 |
| Mnagei | 20 | 5.30<br>[3.5]<br>(4.40) | 100 | 4.20<br>[4.0]<br>(1.75) | 85 |
| Sook | 50 | 6.29<br>[3.0]<br>(8.64) | 0 | 3.44<br>[4.0]<br>(1.31) | 56 |
| Tapach | 6 | 6.17<br>[5.0]<br>(2.93) | 67 | 4.83<br>[5.0]<br>(0.75) | 100 |

[a] Mean [Median] (Standard Deviation)

[b] Dietary diversity score calculated for each household using the WHO-indicators (WHO, 2010)

[c] Proportion with a dietary diversity score of at least 4

extension services that could advocate more diversified crop production. The dietary diversity score and minimum dietary diversity was highest in Chepareria, Kapenguria and Tapach, while below average means were found in Kongelai, Sook and Kacheliba.

The small variation in access to grains (food group A) reveals the heavy dependency in West Pokot, and indeed in western Kenya generally, on maize cultivation. The UNICEF funded study (ACF-USA 2012) found that 80 % of households planted maize (food group A), while about 46 % planted different types of beans (food group K). As the Table 2 shows, the proportions are even higher in this study. Larger variation can be found among households in the different sub-counties who cultivate crops belonging to food groups B to F. The proportion of households cultivating food groups B (dark yellow/orange-fleshed roots, tubers and others), C (roots, tubers and plantains), D (dark green leafy vegetables), E (dark yellow/orange fruit) and F (other fruit/vegetables) were generally low, and especially so for the sub-counties of Kongelai, Sook and Kacheliba. A low intake of food groups B, D and E could indicate a low intake of vitamin A.

The averages for food groups G, H, I, and L are much higher, and variation between sub-counties is much smaller, suggesting that consumption of meat, eggs and milk-based products is less of a concern. The same goes for food group K (beans, peas, lentil, nuts, seeds), with the marked exception of Tapach. However, here it must be remembered that the sample for Tapach, with only six observations, is much smaller than for the other divisions/locations.

## Effects of agroforestry extension service

Another way to organize the descriptive statistics is to divide the total sample into the groups that received advice from Vi Agroforestry (164 households) and those that did not (127 households); the results can be seen in Table 3.

The two groups are not statistically different with respect to size of land owned by the household head, or the age of the household head. However, the education level of the household head is statistically significant for the group that received advice from Vi Agroforestry, which suggests a certain level of self-selection, i.e. that the more highly educated have

**Table 2** Descriptive statistics for percent growing crops belonging to food groups[a] A, B, C, D, E, F, and K, as well as having access to food groups G, H, I, and L

| Divisions/Locations | Food groups (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G & H | I | K | L |
| All | 98 | 11 | 24 | 53 | 24 | 37 | 84 | 84 | 97 | 81 |
| Chepareria | 100 | 14 | 40 | 58 | 58 | 71 | 88 | 43 | 97 | 100 |
| Kongelai | 100 | 4 | 0 | 30 | 24 | 10 | 80 | 76 | 82 | 98 |
| Sook | 100 | 27 | 38 | 82 | 0 | 10 | 70 | 72 | 82 | 94 |
| Kacheliba | 96 | 2 | 10 | 24 | 22 | 22 | 80 | 87 | 85 | 100 |
| Kapenguria | 90 | 15 | 25 | 70 | 13 | 53 | 94 | 74 | 89 | 91 |
| Tapach | 100 | 6 | 16 | 56 | 67 | 83 | 100 | 100 | 50 | 100 |
| Mnagei | 100 | 0 | 50 | 50 | 30 | 80 | 90 | 55 | 90 | 85 |

[a] Food groups: *A* grains, *B* dark yellow/orange-fleshed roots, tubers and others, *C* roots, tubers and plantains, *D* dark green leafy vegetables (based on assumption that those reporting growing food groups B and C also eat edible leaves from these products), *E* dark yellow/orange fruit, *F* other fruit/vegetables, *G and H* meat (based on proportion reporting consumption of animal protein at least once per week), *I* eggs (based on proportion owning poultry), *K* beans, peas, lentil, nuts, seeds, *L* milk-based products (based on proportion reporting owning sheep, goats and cattle)

themselves sought advice. Concerning dietary diversity the results show that, not only is overall dietary diversity significantly higher for the group that received advice from Vi Agroforestry, the effect is especially pronounced for food groups B (dark yellow/orange-fleshed roots, tubers and others), C (roots, tubers and plantains), D (dark green leafy vegetables), E (dark yellow/orange fruit) and F (other fruit/vegetables). This is very interesting, given the lack of food groups B, C, D and E is considered a matter of concern.

Although the *modus operandi* of the extension service changed during the Vi Agroforestry project period in the area (1987–2000), free advice on agroforestry, including cultivation of trees, crops, fruit and vegetables was given throughout. No explicit advice on nutrition was given, however, but as mentioned earlier, enclosures enabled increased cultivation of vegetables and fruit trees, thus indirectly affecting nutritional intake. Also, the distribution of tree seedlings and tree seeds (mainly non-fruit trees), changed over time. In the early years tree seedlings were given free of charge to farmers as an incentive, then in approximately 1992–1997, only tree seeds were given and at the end of the project period neither seedlings nor seeds were given. Thus it was the early adopters that did get tree seedlings and tree seeds. Central in this extension service was the use of enclosures as a management tool to rehabilitate land, reduce erosion, increase fodder production and to protect cultivated plants from grazing. Among participants in the present study, receiving advice from Vi Agroforestry was closely associated with receiving free tree seedlings. Of the 164 respondents who had received advice from Vi Agroforestry, 63 % ($n = 103$), also received tree seedlings, while of the 127 who had not received advice, 4 % ($n = 5$), had received tree seedlings. Simply put, tree seedlings from Vi Agroforestry generally came with advice, and advice sometimes came without free tree seedlings but rarely the other way around. Mean dietary diversity scores for the subgroup that received *both* advice and free tree seedlings was 4.26, while the corresponding mean for the sub-group that only received advice was 4.23, and 3.67 for those without advice ($p < 0.01$ between those receiving advice and those who did not; Table 3).

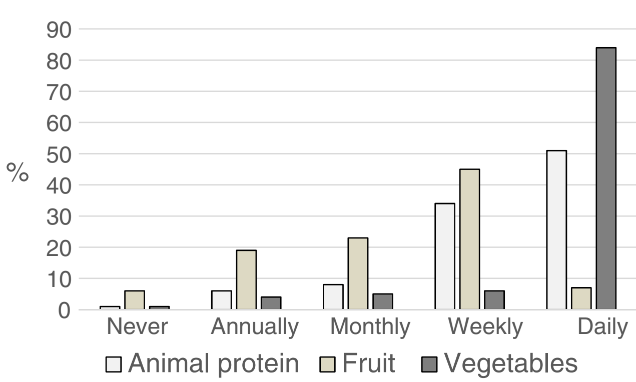


**Fig. 2** Frequency of intake for animal protein, fruit and vegetables among 296 subsistence farming households in West Pokot, Tanzania, 2007/2008

To determine the effects of household characteristics, geographical variation and advice from Vi Agroforestry, the number of food groups the households had access to and the dietary diversity score were used as dependent variables in regression analyses. As mentioned previously the Heckman (1979) two stage estimation procedure was used. In the selection (probit) equation the education level of the household head and dummy variables for the Kongelai and Kacheliba divisions were used as independent variables. Dummy variables for the other divisions were tried but not used due to lack of observations, lack of variation, or because they were not significant explanatory variables. In the second stage regression model the dependent variables were, respectively, the number of food groups the household had access to through the vegetables they grew or the animals they kept and the corresponding dietary diversity score were used. The household characteristics chosen as explanatory variables were age of the household head and the size of arable land; the hypothesis being that households with older and more experienced household heads and/or more arable land would grow and eat a more diverse selection of food. The hypothesis concerning geographical variation was that areas which on average receive less rainfall would only be able to eat a less diverse diet. Furthermore, all the regional variables were included as dummy variables with Chepareria as baseline, where extension service by Vi Agroforestry has been active for a much longer duration than the other sub-counties. Finally, the question of whether the household had received advice from Vi

**Table 3** Descriptive statistics for size of land (hectares), age of household head (years), education level of household head, dietary diversity, and percent growing crops belong to food groups[a] A, B, C, D, E, F, and K, as well as access to food groups G, H, I, and L, all depending on whether the household had received advice from Vi Agroforestry or not

| Variable | Received advice from Vi Agroforestry (*n* = 164) | Did not receive advice from Vi Agroforestry (*n* = 127) |
|---|---|---|
| Size land (ha) | | |
| Mean (SD) | 5.18 (6.09) | 5.65 (8.18) |
| Median [25–75 percentile] | 5 [2–25] | 3 [2–4] |
| Age, household head (years)[b] | | |
| Mean (SD) | 37.89 (10.46) | 39.91 (11.32) |
| Median [25–75 percentile] | 44 [26–44] | 44 [26–44] |
| Education, household head (1 = None, 2 = Primary, 3 = Secondary, 4 = Tertiary) | | |
| Mean (SD) | 2.23 (0.92)*** | 1.55 (0.78) |
| Median [25–75 percentile] | 2 [2–3] | 1 [1–2] |
| Dietary diversity score | | |
| Mean (SD) | 4.25 (1.2) ** | 3.67 (1.1) |
| Median [25–75 percentile] | 4 [3–6] | 4 [3–5] |
| Minimum dietary diversity (%)[c] | 80.5* | 61.4 |
| Farmers growing[a]: | | |
| Food group A (%) | 97.6 | 99.2 |
| Food group B (%) | 16.6* | 4.5 |
| Food group C (%) | 32.5** | 12.1 |
| Food group D (%) | 59.7* | 43.1 |
| Food group E (%) | 34.9** | 9.8 |
| Food group F (%) | 53.2*** | 15.9 |
| Food groups G and H (%) | 86.9 | 81.1 |
| Food group I (%) | 77.5** | 92.4 |
| Food group K (%) | 96.2 | 100 |
| Food group L (%) | 82.2 | 81.1 |

Differences between groups tested with Student's t-test: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

[a] Food groups: *A* grains, *B* dark yellow/orange-fleshed roots, tubers and others, *C* roots, tubers and plantains, *D* dark green leafy vegetables, *E* dark yellow/orange fruit, *F* other fruit/vegetables, *G and H* meat, *I* eggs, *K* beans, peas, lentil, nuts, seeds, *L* milk-based products

[b] Age groups in questionnaire: under 18, 18–35, 36–55, over 55. The first group was coded 18, the second 26, the third 44, and the last 55

[c] Minimum dietary diversity indicates the proportion (%) with intake from at least four food groups. This would give a high probability that the household had access to some kind of staple food (grain, root or tuber), at least one protein-rich animal-source food and at least one fruit or vegetable providing important micro-nutrients

Agroforestry was included to further investigate possible positive effects from agroforestry counselling. The results can be seen in Table 4 below.

All independent variables were significant in the selection equation and the regression results were similar, both when number of food groups the household had access to was used as dependent variable in the regression, and when the corresponding dietary diversity score was used. The household variables, age of household head and the number of hectares of arable land, did not contribute to explaining the variation in the dependent variables. Concerning the geographical dummies, it is clear that in the divisions/locations of Kongelai, Sook and Mnagei households had access to significantly lower number of food groups and thus had lower dietary diversity, compared with the baseline division of Chepareria. The results also show that a significant positive effect of extension by Vi Agroforestry on both number of food groups and dietary diversity score exists, even after correcting for endogenous selection. That said, the selected independent variables only explain 24 % and 16 %, respectively, of the variation in the dependent variables.

We also analysed the effect of Vi Agroforestry, together with other independent variables, on the respective food groups. A probabilistic classification model had to be employed as the data on the respective food groups were discrete - i.e. either a given household grows crops or has livestock that provide food belonging to a certain food group or they do not. Again, the Heckman (1979) two stage estimation procedure was used. In the selection (probit) equation the education level of the household head and dummy variables

**Table 4** Heckman two-stage maximum likelihood estimates of the effect of household characteristics, geographical variation and advice from Vi Agroforestry on number of food groups, and the corresponding dietary diversity score ($n = 283$). Chepareria division is used as baseline

| | Coefficient | T-Value | Coefficient | T-Value |
|---|---|---|---|---|
| Selection (probit) model | Dependent variable: received advice from Vi Agroforestry | | | |
| Constant | −0.874 | −4.11*** | −0.849 | −3.84*** |
| Education level, household head | 0.521 | 5.62*** | 0.512 | 5.31*** |
| Kongelai | 1.271 | 4.38*** | 1.317 | 4.46*** |
| Kacheliba | −1.179 | −3.17** | −1.254 | −3.52*** |
| Second stage model | Dependent variable: Number of food groups | | Dependent variable: Dietary diversity score[a] | |
| Constant | 6.093 | 9.45*** | 3.705 | 7.25*** |
| Age, household head (years) | −0.0002 | −0.02 | 0.0008 | 0.12 |
| Size arable land (hectares) | 0.017 | 1.44 | 0.014 | 1.74 |
| Kongelai | −2.267 | −5.53*** | −1.337 | −4.50*** |
| Sook | −0.859 | −2.24* | −0.716 | −2.36* |
| Kacheliba | −0.411 | −0.74 | −0.341 | −0.75 |
| Kapenguria | −0.209 | −0.69 | −0.214 | −0.94 |
| Tapach | 0.442 | 0.56 | 0.346 | 0.59 |
| Mnagei | −0.909 | −2.73** | −0.579 | −2.29* |
| Advice Vi-agroforestry | 2.291 | 3.87*** | 1.122 | 2.19* |
| $\sigma$ | 1.649 | 15.03*** | 1.132 | 15.82*** |
| $\rho$ | −0.573 | −3.56*** | −0.409 | −1.84 |
| Adjusted $R^2$ | 0.24 | | 0.16 | |

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

[a] Dietary diversity score calculated for each household using the WHO-indicators (WHO 2010)

for the Kongelai and Kacheliba divisions were again used as independent variables. In the second stage model the explanatory variables were the same as in Table 4, with the exception of food group K (beans, peas, lentil, nuts, seeds), where the regional dummies had to be dropped due to perfect collinearity. The result of probit estimations on the individual food groups are found in Tables 5 and 6, below:

Of the household characteristics, the age of the household head was not significant in any of the second stage probit regressions except regarding consumption of meat (food groups G and H), where households with older household heads were less likely to consume meat. Size of arable land was a significant explanatory variable behind growth and access to the staple foods roots, tubers and plantains (food group C). As noted by Pommer and Picozzi (2014), large farm size is generally associated with positive adoption decisions – in this case decisions to grow a wider variety of crops.

The division of Kongelai had a significantly lower access to almost all food groups, including food groups E (dark yellow/orange fruits) and F (other fruit/vegetables). The division/location of Sook had a significantly lower access to food groups F, while Kacheliba and Kapenguria had a significantly lower access to food groups E and F. Overall, the regional pattern follows what could be discerned from the descriptive statistics – that there is a larger regional variation in the access to fruit (food groups E and F) than grains and vegetables (food groups A to D). This is likely due to the fact that the extension programme started later in Kapenguria, Kongelai and Kacheliba, i.e. when free fruit tree seedlings as incentives were no longer used by the extension service. Furthermore, Kongelai and Kacheliba have a harsher climate and the use of enclosures was not as well adopted there as in Chepareria. Concerning food groups related to ownership of animals (i.e. G and H, I and L) only I (eggs), which is connected to ownership of poultry, show some regional variation. It should be noted that the second stage probit regressions for G and H (meats) and L (milk-based products) shows signs of multicollinearity problems, i.e. very low t-values and very similar values on the regional coefficients.

Concerning the extension service from Vi Agroforestry, significant effects can be found for food groups B (dark yellow/orange-fleshed roots, tubers and others), C (roots, tubers and plantains), D (dark green leafy vegetables) and F (other fruit/vegetables[9]), with the strongest marginal effect on food group B. As noted by Pommer and Picozzi (2014), factors related to education and information have the ability to change farmers' perceptions of the need to adopt, in this case grow a wider variety of crops, as well as decrease the risk and uncertainties associated with increasing the variety of crops.

[9] Mostly fruits and vegetables found in the wild.

**Table 5** Heckman two-stage probit regressions on the effect of household characteristics, geographical variation and the counselling by Vi Agroforestry on the probability of growing food group A (grains), B (dark yellow/ orange-fleshed roots, tubers and others), C (roots, tubers and plantains), D (dark green leafy vegetables), E (dark yellow/ orange fruits), and F (other fruit/ vegetables). T-values are within parentheses. Chepareria division was used as baseline

| | | | | | | |
|---|---|---|---|---|---|---|
| Selection model | Dependent variable: received advice from Vi Agroforestry | | | | | |
| Constant | −0.833 | | | | | |
| | (−3.63)*** | | | | | |
| Education level, household head | 0.505 | | | | | |
| | (4.94)*** | | | | | |
| Kongelai | 1.298 | | | | | |
| | (4.66)*** | | | | | |
| Kacheliba | −1.341 | | | | | |
| | (−4.11)*** | | | | | |
| Second stage model | Dependent variable: Availability of food groups | | | | | |
| | A | B | C | D | E | F |
| Constant | 16.692 | −2.367 | −0.795 | −0.009 | −0.326 | −0.097 |
| | (0.0) | (−3.86)*** | (−1.79) | (0.02) | (−0.73) | (−0.23) |
| Age, household head (years) | −0.060 | 0.009 | −0.003 | −0.013 | 0.008 | 0.001 |
| | (−1.41) | (0.92) | (−0.39) | (−1.66) | (0.81) | (0.14) |
| Size arable land (ha) | −0.0004 | −0.004 | 0.024 | 0.016 | −0.008 | 0.011 |
| | (−0.01) | (−0.23) | (2.00)* | (1.30) | (−0.51) | (0.91) |
| Kongelai | −6.184 | −1.01 | −1.171 | −0.949 | −0.912 | −1.888 |
| | (0.0) | (−2.19)* | (−3.82)*** | (−3.69)*** | (−3.50)*** | (−6.22)*** |
| Sook | −5.710 | 0.473 | −0.213 | 0.610 | −7.641 | −1.286 |
| | (0.0) | (0.92) | (−0.61) | (1.98)* | (0.0) | (−3.65)*** |
| Kacheliba | −0.888 | 0.194 | −7.008 | −0.129 | −2.003 | −2.053 |
| | (0.0) | (0.39) | (0.0) | (−0.42) | (−4.07)*** | (−4.32)*** |
| Kapenguria | 0.046 | 0.531 | −0.065 | 0.811 | −1.270 | −0.469 |
| | (0.0) | (1.88) | (−0.27) | (3.05)** | (−4.75)*** | (−1.95) |
| Tapach | −0.547 | −6.323 | 0.315 | −0.222 | 0.371 | 0.505 |
| | (0.0) | (0.0) | (0.58) | (−0.39) | (0.66) | (0.81) |
| Mnagei | −7.017 | −0.275 | −0.511 | 0.105 | −0.843 | 0.111 |
| | (0.0) | (−0.63) | (−1.45) | (0.30) | (−2.41)* | (0.30) |
| Advice Vi-Agroforestry | −5.889 | 1.041 | 0.672 | 0.779 | 0.294 | 0.677 |
| | (0.0) | (2.58)** | (2.43)* | (3.18)** | (1.08) | (2.62)** |
| Pseudo $R^2$ | 0.42 | 0.15 | 0.18 | 0.15 | 0.28 | 0.34 |
| No. of obs. | 283 | 283 | 283 | 283 | 283 | 283 |

Pseudo R2 is according to McFadden (1974)

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

## Discussion

In this study, we have analyzed a survey conducted in 2007 by the Swedish development cooperation organization Vi Agroforestry in West Pokot county in western Kenya. The results from the survey show that agroforestry, combined with advice through extension efforts can provide a transition path for pastoralists which involves improved dietary diversity, especially concerning food groups that include roots, tubers, fruits and leafy vegetables. From the results, certain important economic restrictions that hinder this transition towards sedentary agropastoralism become clear. One that seems obvious, is that financial constraints are preventing the purchase of necessary plants and crops. Non-governmental organizations can help to overcome this restriction by providing plants and crops freely, or at very low prices, to households involved in the organization's program. Among the direct, short-term benefits for the farmers participating in the Vi Agroforestry program are:

- Tree seeds and in some cases even some vegetable seeds.
- Fuel wood, available within a few months.
- Fodder.
- Construction material, and, a particular focus in this study: Trees providing fruits for own consumption or for selling in the market.

However, poverty is not the sole explanatory factor behind a lack of dietary diversity – an often overlooked factor is lack

**Table 6** Heckman two-stage probit regressions on the effect of household characteristics, geographical variation and the counselling by Vi Agroforestry on the probability of having own access to food group G (organ meats), H (any meat), I (eggs), K (beans, peas, lentil, nuts, seeds), and L (milk-based products). Chepareria division is used as baseline

| | | | | |
|---|---|---|---|---|
| Selection model | Dependent variable: received advice from Vi Agroforestry | | | |
| Constant | −0.833 | | −0.115 | |
| | (−3.63)*** | | (−0.24) | |
| Education level, household head | 0.505 | | 0.442 | |
| | (4.94)*** | | (1.82) | |
| Kongelai | 1.298 | | | |
| | (4.66)*** | | | |
| Kacheliba | −1.341 | | | |
| | (−4.11)*** | | | |
| Second stage model | Dependent variable: availability of food groups | | | |
| | G & H[a] | I | L[a] | K[b] |
| Constant | 15.449 | −0.207 | 7.711 | 10.722 |
| | (0.0) | (−0.40) | (0.0) | (0.0) |
| Age, household head (years) | −0.042 | 0.004 | −0.004 | −0.072 |
| | (−2.16)* | (0.37) | (−0.42) | (−1.12) |
| Size arable land (ha) | 0.173 | 0.006 | −0.0003 | 0.167 |
| | (1.72) | (0.37) | (−0.02) | (0.96) |
| Kongelai | −6.614 | 2.207 | −7.059 | |
| | (0.0) | (4.91)*** | (0.0) | |
| Sook | −12.981 | 1.754 | −6.952 | |
| | (−0.0) | (4.00)*** | (0.0) | |
| Kacheliba | −0.442 | 7.708 | −6.461 | |
| | (−0.0) | (0.0) | (0.0) | |
| Kapenguria | −0.058 | 1.722 | −6.957 | |
| | (0.0) | (5.39)*** | (0.0) | |
| Tapach | −1.168 | 7.834 | −0.0004 | |
| | (0.0) | (0.0) | (0.0) | |
| Mnagei | −6.567 | 1.191 | −7.646 | |
| | (0.0) | (3.08)** | (0.0) | |
| Advice Vi-Agroforestry | −6.221 | −0.167 | 0.146 | −6.630 |
| | (0.0) | (−0.52) | (0.43) | (0.0) |
| Pseudo $R^2$ | 0.34 | 0.38 | 0.16 | 0.19 |
| No. of obs. | 283 | 283 | 283 | 66 |

Pseudo R2 is according to McFadden (1974)

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

[a] Note that the probit regression for G & H (meats), and L (milk-based products) shows signs of multicollinearity problems, i.e. very low t-values and mostly very similar values on the regional coefficients

[b] Note: The probit model with regional dummies could not be estimated for food group K due to perfect collinearity between some of the independent variables

of information as a determinant of household behavior in developing countries. In fact, the present study found that getting free advice was more important than getting free tree seedlings, as free trees were only distributed for a limited period. Developing countries in general are not information-rich environments, a fact that also holds when it comes to nutrition in West Pokot County in western Kenya. Careful attention to the information and knowledge available to households is necessary when designing development cooperation interventions (cf. Somanathan 2010), for instance when it comes to the nutritional contents of different food sources. In these areas, awareness and knowledge about both how to compose a balanced diet, and about agroforestry are undersupplied (cf. Jalan and Somanathan 2008, who develop these ideas for environmental quality). Here, the Vi Agroforestry extension efforts can have a real impact on household health.

We argue that agroforestry is an important part of nutrition-sensitive agriculture and that the results of the Vi Agroforestry programme would improve even more by increased collaboration with different professions with competence in e.g. nutrition, plant breeding, food production, and education. The World Bank (2013, p 34) stresses the importance of 'Thinking multisectorally, acting sectorally' to improve nutritional outcomes. In a paper by Jaenicke and

Virchow (2013) five entry points for a nutrition-sensitive agriculture are described. These include: 1) enabling policies; 2) mechanisms for collaboration; 3) awareness and capacity building; 4) focus on appropriate beneficiary groups; and 5) elements of the food chain. They also stress the importance of collaborative approaches for successful implementation, and briefly mention agroforestry and agro-pastoral systems as possible buffers against the effects of climate change. Keding et al. (2013) discuss the problem that agriculture does not have nutrition outputs as explicit goals. They point out the importance of surveying the food availability and food consumption locally to enable detection of seasonal nutrition gaps, and based on these make decisions on tailor-made solutions, e.g. through agroforestry.

Healthy human growth and development depend on a combination of adequate intake of both energy and micro-nutrients (Biesalski 2013). The most vulnerable period occurs during the 1000-Day-Window - the time from conception until about the end of the second year of life. The main problem with Hidden Hunger is that it remains hidden unless it is measured. For most micro-nutrients, visible clinical symptoms are very late manifestations of poor intake, and increased morbidity as well as mortality are often seen in earlier stages. Women, especially during pregnancy and lactation, and children are therefore important targets for improved dietary diversity.

Agroforestry extension is the spread, transfer and development of knowledge in agroforestry and the possibility of combining trees with crop agriculture and/or livestock-based agriculture. However, it should be emphasized that the development of knowledge is often built on existing local and traditional knowledge and that farmers contribute to the knowledge development as much as the NGO workers. The extension service, i.e. spreading knowledge, was always at the core of Vi Agroforestry activities but, in the early days, tree nurseries, free seedlings and demonstration areas were used as incentives to get farmers interested. From 1997, extension services were provided without any such incentives.

The present study did not include evaluation of nutrient intake, only (fairly coarse) data on food availability. The nutrient content of foods is affected by many factors including genetic makeup, and differences between varieties of the same species can be 100–1000 fold (FAO 2008). In spite of increased research activity, scarcity of nutritional information about foods at subspecies level, especially on indigenous and traditional foods, is an important constraint when trying to evaluate the adequacy of dietary intake, even if the dietary assessment method is more precise than in the present study. This also affects planning and decisions about which plants to grow. Integrating biodiversity and nutrition would contribute to the achievement of Sustainable Development Goal 2, which aims to eliminate hunger through sustainable agriculture.

## Conclusion

We have established that agroforestry extension services indirectly result in positive effects on dietary diversity through, for instance, the use of enclosures which enable growing of vegetables, fruits and other crops, as well as diversified livestock herds. We suggest that this could be further emphasized through direct dietary information from trained nutritionists or dietitians in the extension service. Increased nutritional awareness among other staff and, as a consequence, also among farmers is crucial. Through this, extension services can bridge the information gap and provide an even stronger impact.

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**Compliance with ethical standards** All procedures performed were in accordance with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study and were told that results would only be presented at group level.

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