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ORIGINAL PAPER

Key factors influencing food security of smallholder farmers in Tanzania and the role of cassava as a strategic crop

Katrin Reincke[1] · Elisa Vilvert[1] · Anja Fasse[2] · Frieder Graef[1] · Stefan Sieber[1] · Marcos A. Lana[1,3]

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Abstract
Due to beneficial characteristics of cassava such as robustness and versatility for multiple uses, it can have a major role in contributing to local food security. The objective of this study was to find out whether and how the cultivation of cassava benefits smallholder farmers in the regions of Dodoma and Morogoro, Tanzania. In addition, the study assessed the main factors that support or threaten food security of smallholder farmer households in the survey region and analysed whether cassava cultivation could counteract them. We applied a mixed methods approach. Quantitative data were provided by a comprehensive household survey of the Trans-SEC project, and qualitative data were collected by conducting semi-structured interviews. To approach the complexity of our chosen food security definition, three approaches for household food security measurement were applied. These covered the components of food availability, food access, and food utilization. Additionally, dependent variables for regression models were constructed and a multivariate analysis was run. The results show that cassava contributes to food security in the households, but achieving food security through cassava cultivation was constrained by several factors, including pests, missing markets, poor processing, social perception and lack of knowledge. Besides these, other factors affecting food security in the study area were found, uncovering some roots of local food insecurity and serving as a basis for further research and action on how to enhance food security.

Keywords Tanzania · Cassava · Food security · Smallholder farmers · Mixed methods

1 Introduction

Smallholder farmers provide over 70% of the food consumed in Sub-Saharan Africa. Hence, they play a decisive role in terms of facilitating food security on the local, national and global level (IFAD 2005; Graeub et al. 2016). Human population growth and strong increases in global consumption will cause an ever-rising demand for food worldwide. Simultaneously, the adverse effects of climate change will jeopardize food security. These concerns have sparked a broad discussion among scientists and policymakers on how to sustainably increase and ensure food security (Devereux 2007; Brüssow et al. 2017). Rufino et al. (2013) highlighted the need for policy measures in East Africa to increase the cultivation and consumption of drought tolerant crops such as cassava (*Manihot esculenta*), sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*) and legumes as a beneficial strategy for future food security. They also pointed out the knowledge of local farmers about the use of these crops as an adaptation strategy to overcome the effects of drier weather. Due to its drought tolerance, its ability to grow in a range of agro-ecologies and its food calorie value, cassava is one the cheapest and most readily available staple food crops that can be used as a strategy to overcome food insecurity in Africa (Feleke et al. 2016; Parmar et al. 2017).

Tanzania depends on small-scale agriculture. Agriculture accounts for approximately 25% of GDP and more than 80% of the workforce are employed in the sector (Wenban-Smith et al. 2016; Cochrane and D'Souza 2015). With annual production of 4,755,160 t, Tanzania holds seventh position for cassava among African countries. It is the second most produced agricultural commodity in Tanzania after maize

✉ Marcos A. Lana
lana@zalf.de

1 Leibniz Centre for Agricultural Landscape Research (ZALF), Eberswalder Strasse 84, 15374 Müncheberg, Germany

2 TU Munich Campus Straubing for Biotechnology and Sustainability, Petersgasse 18, 94315 Straubing, Germany

3 Crop Production Ecology, Swedish University of Agricultural Sciences (SLU), Ulls väg 16, 75007 Uppsala, Sweden

(FAOSTAT 2014). According to Cochrane and D'Souza (2015) cassava accounts for 8.5% of total calories in the Tanzanian diet, being the third most important food group after maize and rice. Smallholder farmers particularly benefit from cassava cultivation. It is grown almost exclusively by low-income, smallholder farmers, and is one of few staple crops that can be produced efficiently on a small scale, without the need for mechanization or purchased inputs, and in marginal areas with poor soils and unpredictable rainfall. The Food and Agriculture Organization of the United Nations (FAO) expects great potential for cassava growers in tropical countries (Howeler et al. 2013). While in Asia production is mainly driven by demand for animal feed and by starch industries, in Sub-Saharan Africa there is increasing demand for cassava food products in urban markets due to population growth (Howeler et al. 2013; Bull et al. 2011; Parmar et al. 2017). The enhancement of food security by supporting an increase in cassava cultivation is discussed by several scientists and international agencies (Howeler et al. 2013).

The objective of our research was to 1) identify the key factors influencing food security in the surveyed regions, and to 2) analyse if these factors can be linked to the production of cassava. Additionally, the contribution of cassava production and its potential to enhance the food security of smallholder farmer households in Tanzania was assessed.

2 Food security

The food security definition agreed on by the World Food Summit in 1996 states that food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO 2008; Pinstrup-Andersen 2009). Hence, this definition is based on availability, access and utilization, underlined by stability (Brüssow et al. 2017). These four components have to be accomplished to maintain or achieve food security. Moreover, food security can be looked at on different levels such as global, national and household food security.

Food availability means the physical availability of food, focusing on the supply side. Hence, availability implies the supply of sufficient quantities of food of appropriate quality, achieved by domestic production, imports or food aid (FAO 2003). Food availability might be a challenge in the future due to limits on natural resources and a growing world population. Food access alludes to physical and economic access to available food and thus to be in possession of sufficient resources to obtain appropriate foods for a nutritious diet (Aidoo et al. 2013). The main aim here is the self-determined opportunity to purchase food given by income, safety nets or market access. Adverse shocks like unemployment, price spikes, little income or loss of livelihood producing assets affect food access. Food security's close relationship to poverty and to social, economic and political disenfranchisement comes into clearer focus through the access lens (Barrett 2010).

Food utilization includes a wide range of factors, particularly the contribution of food consumption to the health and nutritional status of the individuals. This involves the nutrient content of the food consumed and the diversity of the individuals' diet, as well as actual uptake of nutrients, micronutrients, and energy along with many factors such as safe drinking-water, sanitation and hygiene. Hence, utilization focuses on a nutritionally essential diet, realized by the obtained foods and circumstances affecting health positively (Gross et al. 2010).

The fourth component, stability, considers the susceptibility of the three aforementioned elements and affects the temporal dimension of food security. While transitory food insecurity captures sudden, temporary and seasonal disruptions, chronic food insecurity depicts a long-term lack of access to adequate food (Barrett 2013). In our study, we focus on food security of smallholder farmer households, including all household members.

In terms of food supply, Tanzania still does not cover the food demand (IFAD 2005) and the rural areas are the most affected by food insecurity (Haug and Hella 2013). Due to the importance of cassava production within Tanzania, a positive impact of cassava cultivation on the food security status could be assumed. About one third of the produced cassava is marketed, while the rest is consumed by producing households. This relatively small share of marketed production and high proportion of household consumption can be attributed to the perishability of the tuberous roots (Ahmed et al. 2011). In an attempt to increase the processing of cassava, several starch factories were built in Uganda and Tanzania, but their production of starch is low (Prakash 2008), limiting the farmers' profits available from cassava production, and leading to a decrease in the economic power to access food and so impacting local food security.

3 Methodology and data collection

3.1 Case study site description

Among the different initiatives to improve food security status in poor regions are international cooperation agreements and projects. The project "Trans-SEC - Innovating Strategies to safeguard Food Security using Technology and Knowledge Transfer: A people-centred approach" surveyed 899 households in two regions of Tanzania, namely Morogoro and Dodoma (Fig. 1). These regions were selected to represent contrasting food systems: while the Morogoro region is

Fig. 1 Map of Tanzania highlighting the two regions (Morogoro and Dodoma) and the respective villages participating in the Trans-SEC project (white points)

semi-humid and has an annual precipitation of about 600 to 800 mm, Dodoma is a semi-arid region with 350 to 500 mm of annual precipitation (Graef et al. 2014; Sieber et al. 2017; Kissoly et al. 2017). The households were randomly selected from village household lists provided by Tanzanian institutes. The survey was based on a questionnaire developed jointly by all the project partners focusing on the collection of detailed information on income generating activities, expenditures and food security at the household level. The survey describes the household's activities during the year 2013 (from January to December).

Together, both regions represent up to 80% of the farming types existing in Tanzania. Among important crops such as sorghum, pearl millet, maize and beans, cassava is considered to be one of the main staple foods in both regions.

3.2 Methodological approach

For this study, a mixed-methods design (Creswell 2003) that combines both qualitative and quantitative data sources was utilized. Data from both Trans-SEC study regions were merged.

3.2.1 Quantitative analysis

For the quantitative analysis, data of the Tran-SEC household survey (899 households in two Tanzanian regions) was utilized (Graef et al. 2014). In order to avoid selecting autocorrelated independent variables (Chatfield 2005), preselected variables were tested with the Durbin-Watson test (Field 2013) and only included if d was above 1.5 and below 2.5, $d = 2$ being absence of autocorrelation.

Initially, by means of the comprehensive datasets from the Trans-SEC household survey, three approaches to measure the food security status of smallholder farmer households at different levels were applied. Regression models, composed of applied indicators and constructed variables out of the household survey data, were run to find out the main factors of influence on food security in the surveyed regions and to examine whether cassava cultivation had direct impacts on food security. The factors presented in Table 1 were evaluated to assess their benefit to a further analysis of the potential impact of cassava production.

The approaches to measure household food security in this study were the Household Food Insecurity Access Scale (HFAIS) developed by Coates et al. (2007), to measure household food security in terms of access, and the Dietary

Table 1 Independent variables of the regression model used in Tanzania

Variable	Description	Explanation
Assets	Number of mechanical assets	Different farm tools considered such as tractor, water tanks, pipes, rake and rice mill
Cassava	Cassava cultivation	Cultivation yes/no
CollectiveAgri	Participating in collective agriculture	Producing, processing, selling or buying collectively agricultural goods
CropPest	Affected by crop pests	Suffered from crop pests in the last five years
Drought	Affected by drought	Suffered from drought in the last five years
Foodaidkind	Received food aid	Any household members participating in a food assistance program
Gender	Gender of household head	Gender m/f
Groundnut	Groundnut cultivation	Cultivation yes/no
Highfoodprices	Affected by high food prices	Experienced high food prices in the last five years
KnowledgeProcessing	Access to knowledge	Access to processing and conservation methods
Maize	Maize cultivation	Cultivation yes /no
MembersHh	Number of households members	All persons belonging to the household
MemberSick	Number of members affected by diseases	Health status of household member within one year
MilletSorghum	Millet and/or sorghum cultivation	Cultivation yes/no
Read/Write	Educational status of the household members	Ability to read and write
SaveIncome	Ability to save part of the income	Savings yes/no
Sesame	Sesame cultivation	Cultivation yes/no
ShareInfertile	Percentage of Infertile share of land	Land owned by the household
Sunflower	Sunflower cultivation	Cultivation yes/no
TotalIncome	Total income	Income per nucleus member
UseLivestProd	Use of produced livestock	Consumption of own livestock products in the last year
ValueFertilizer	Value of utilized fertilizer in TZS	in Tanzanian shilling
ValueSeedlings	Value of bought seedlings in TZS	in Tanzanian shilling
WagedEmployee	Members engaged in waged jobs	Number of household members

Diversity Indicator (DDI) derived from Hoddinot (1999) to measure food utilization. Following the approach of Hoddinot (1999), the indicator is composed of different foods consumed over a specific period; in this case per household. Previous studies and projects have shown that households consuming a wider range of varieties of food emerged as more food secure, which supports the value of the indicator. While the given instructions took the prior month into account, Trans-SEC data referred to the last week, based on the interview day. As 95% of the respondent households acknowledged that the considered week was an ordinary week for food consumption, the data were treated as valid and suitable. With regard to measurement of food availability, the Availability Index (AVIN) was applied. The AVIN is a synthetic indicator, calculated using data gathered from the Trans-SEC project. This index was created through use of two questions in the household survey addressing local food availability and premature harvesting. The first one of them is the ordinal variable derived from the question TS82019: "For each of the past 12 months, please tell us whether it was a good, normal or bad month in terms of food availability". The codes were "1" for good, "2" for normal, and "3" for bad. Those codes were changed to 0, 1, and 2 for the analysis, respectively. The codes of every month were added up. By applying the arithmetic mean, one component for the index was set. The other element of the index was based on the question TS82042: "For each season (post-harvest, planting, pre-harvest) in the past year, please indicate, how many days in a week do you harvest immature crops." As harvesting immature crops is one indicator for trying to cope with food insecurity (Maxwell et al. 1999), this variable was chosen as the second component of the index. Adding up all days of all seasons, the highest possible score of the second component is 21. As both components of the indicator ought to be equal in weight, component one is multiplied by 10.5, as the maximal value for the arithmetic mean of the first component is 2. According to this, the following formula was applied as AVIN:

$$AVIN = \frac{sum\ TS82019}{12} \times 10.5 + \text{sum TS82042}$$

The maximum score of the AVIN is 42. The higher the AVIN score, the less food secure households are in terms of food availability. Finally, the objective was to define the dependent variables for a multivariate regression model for food security assessment.

3.2.2 Qualitative analysis

The qualitative analysis proceeds by exploring semi-structured interviews (Livesey 2010), which were conducted with farmers in the semi-arid Dodoma region. Eleven smallholder farmers, that either cultivated cassava or planned to cultivate cassava, were interviewed. Sixteen questions were asked about crop cultivation, agricultural practices, processing, marketing and consumption. The questionnaire used in the semi-structured interviews targeted cassava cultivation by the smallholder farmers in terms of challenges, benefits and requirements.

3.2.3 Integration of quantitative and qualitative analysis

The qualitative and quantitative data were analysed and integrated. Data from the household survey were utilized for a descriptive analysis. Relating to this, the fundamental knowledge about the surveyed households and their underlying conditions was reflected in those data and was integrated in the results section.

Additionally, a multiple regression was conducted with selected data from the household survey. To address the complexity of the concept of food security, the approaches we chose necessarily represented three of the four elements that are part of the concept of food security: i.e. availability, access and utilization. As the fourth element implies stability of all other components, it was excluded as no time series data were present. Qualitative semi-structured interviews were used to supplement the information. Moreover, the application of an integrated perspective allowed a further interpretation of the results achieved.

4 Results

4.1 Influence of quantitative factors affecting food security

By analysing the data from the household survey, it became obvious that cassava production was not statistically significant among the households visited for the Trans-SEC survey, because of the low frequency of farmers reporting its cultivation. On average, the surveyed smallholder farmer households cultivated 2.9 different crops. The number varied between one and twelve crops in a household, with a standard deviation of 1.55. From the household survey, only 18 smallholder farmer households cultivated cassava (representing just 2% of those surveyed). These cassava farmers were dispersed around the six villages taking part in the Trans-Sec project, however the highest concentration (13 farmers) was located in Morogoro region especially at Changarawe village (seven farmers).

Placing this in context with the countrywide relevance and production of cassava and the statistical data available (FAOSTAT 2014), we assumed that farmers prioritized mentioning other staple crops such as sorghum, pearl millet and maize. However, in our field observations in Dodoma region, cassava was cultivated by almost all the farmers interviewed (just two of them did not cultivate cassava, but planned to do so), much more frequently than the survey indicated. We suspect some farmers did not mention this crop even when it was cultivated. This situation can occur when complex and very long questionnaires are applied. Because of this situation, it was decided to use a mixed-methods research design (Creswell 2003) combining both qualitative and quantitative data sources. Additionally, regional effects of cassava cannot be properly assessed with such a low sample. However, given the level of detail of the survey, the overall available data about food consumption was sufficient for reliable household level assessments. Before approaching specifically the effect of cassava on food security, data from the households' survey were collected to identify the factors that have a positive, neutral or negative effect on food security (Fig. 2).

4.1.1 Factors affecting food availability

The regression model for food availability (Table 2) can be considered adequate ($F = 21.29$ and $p < 0.00$). In total, 28% ($R^2 = 0.28$) of variation of the AVIN was explained. The higher the score of the availability index, the less food secure households are. The more members (waged employees) a household had, the higher the AVIN was expected to be. In addition to this, farmers interviewed qualitatively emphasized that during food shortages or bad harvest seasons, people look for waged casual labour jobs. The variables Drought and MilletSorghum had positive regression coefficients too. Since these variables are categorical predictor variables, B represents the average difference in AVIN between the categories 0 and 1. So, compared to smallholder farmers who cultivate pearl millet or sorghum, cultivators were expected to score a higher AVIN and therefore to be less food secure. According to the household survey, 52.3% of the smallholder farmers cultivated pearl millet, sorghum or both. Moreover, the Trans-SEC household survey showed that 39.5% of the surveyed smallholder farmer households were affected by drought in the last five years. Interviewees of the Dodoma region confirmed the strong impact of drought on food availability. Moreover, many of the smallholder farmers stated that their choice of which crops to cultivate was aimed at counteracting dry conditions. The variable Drought, which displays if a household experienced at least one drought in the last five years, had a negative impact on the regression model. Assuming that all other factors are fixed, households that did suffer from a drought were expected to have a higher AVIN and consequently be less food secure.

Fig. 2 Factors affecting positively (+),negatively (-) or not (○) the food availability, access and utilization dimensions of food security

Additionally, households which are able to save part of their income and households that utilize products from their livestock (UsesLivestProd) were expected to be more food secure. Of the surveyed smallholder farmers, 51.9% pointed out that they had used livestock products from their own production in the last year. Eggs, milk, manure, skins and honey were mentioned as the main products. During qualitative interviews, two farmers emphasized that they would like to increase their livestock to enhance food security.

4.1.2 Factors affecting food access

The regression model for food access (Table 3) can be considered adequate ($F = 12.86$ and $p < 0.00$). In total, 17% of the variation of HFAIS was explained. In complex assessments that involve different and non-correlated variables, relatively low values of explanatory variables are common, as presented by Sharaunga et al. (2016). The higher the HFIAS, the less food secure in terms of food access the households were. According to the regression model, households that did suffer from drought were expected to have a higher HFAIS score and therefore be less food secure. Due to the positive weight of the Gender variable, women are expected to be less food secure than men. By contrast, households with the ability to save parts of their income were expected to have a lower HFAIS score and therefore to be more food secure, assuming that when these households are affected by high food prices they could afford to buy food. In addition to this, households with a lower income scored a higher HFAIS, and therefore were expected to be less food secure in terms of access. Smallholder farmer households that had a higher share of infertile land were also expected to be more food insecure in terms of access. Concerning the regression model of food access, no crop variable is expected to have a significant contribution to food security. In the qualitative interviews, a high share of the smallholder farmers in the two villages stated that they cultivated crops such as pearl millet, sunflower, groundnut and sesame with the intention of generating income from their sale.

4.1.3 Factors affecting food utilization

The regression model used in Table 4 was assumed as adequate ($F = 13.82$ and $p < 0.00$). In total, 22.2% of the variation with the DDI is explained. The DDI displays the diversity of a households' diet, consequently the higher the DDI score, the more food secure the household in terms of utilization. The variable Read&Write had a significant positive weight on the regression model, indicating that the greater the number of household members who were able to read and write, the higher the diet diversity. Moreover the variable MemberHh contributed to the regression model, so the greater the number

Table 2 Regression model for food availability in Tanzania, indicating the different variables

Model	Unstandardized coefficients		Standardized coefficients		
	B	Standard error	Beta	t	Sig.
(Constant)	9.561	.752		12.708	.000***
Sunflower	.528	.543	.030	.973	.331
MembersHh	.227	.095	.075	2.392	.017
Drought	2.387	.488	.169	4.891	.000***
ShareInfertile	.856	.634	.040	1.350	.177
ValueSeedlings	.006	.008	.022	.746	.456
CollectiveAgri	−.359	.204	−.052	−1.759	.079
UseLivestProd	−1.316	.413	−.095	−3.182	.002**
SaveIncome	−1.726	.486	−.106	−3.551	.000***
Cassava	.776	1.441	.016	.539	.590
Maize	−1.199	.516	−.080	−2.322	.020
MilletSorghum	3.164	.550	.228	5.749	.000***
Gender	−1.242	.514	−.073	−2.414	.016
Valuefertilizer	−.004	.007	−.016	−.534	.593
MemberSick	.360	.255	.043	1.414	.158
Wagedemployee	1.390	.453	.095	3.070	.002***
Croppest	.119	.941	.004	.126	.899

dependent variable: AVIN

*, **, *** denote significance at the 10%, 5%, and 1% levels, respectively

Beta = standardized regression coefficient; t = value of t-test; sig. = significance

Table 3 Regression model for food access in Tanzania, indicating the different variables

Model	Unstandardized coefficients		Standardized coefficients		
	B	Standard error	Beta	t	Sig.
(Constant)	40.090	4.110		9.755	.000
Drought	9.187	2.644	.126	3.474	.001***
ShareInfertile	9.199	3.468	.083	2.652	.008*
Highfoodprices	−21.411	7.818	−.087	−2.739	.006*
ValueSeedlings	.080	.046	.056	1.755	.080
CollectiveAgri	−1.363	1.104	−.039	−1.235	.217
SaveIncome	−11.353	2.649	−.136	−4.286	.000***
Cassava	−6.360	7.904	−.025	−.805	.421
Maize	−6.122	2.773	−.080	−2.208	.027
MilletSorghum	7.250	3.531	.102	2.054	.040
TotalIncome	−.009	.002	−.122	−3.813	.000***
Gender	−7.341	2.819	−.084	−2.604	.009*
MembersHh	.857	.527	.055	1.627	.104
Groundnut	1.197	3.259	.016	.367	.714
UseLivestProd	−2.909	2.278	−.041	−1.277	.202

dependent variable: HFAIS

*, **, *** denote significance at the 10%, 5%, and 1% levels, respectively

Beta = standardized regression coefficient; t = value of t-test; sig. = significance

of members in a household, the lower the DDI score was expected to be. While households that cultivate maize were expected to achieve a higher level of diet diversity, households cultivating pearl millet or sorghum were expected to score a lower DDI (as seen in Table 4). Furthermore, households using their own livestock products were expected to attain a higher DDI score. The variables Foodprices and SaveIncome contributed significantly to the regression model. Both being affected by high food prices in the last 5 years and the ability to save a part of income led to the expectation of achieving a higher DDI score. Moreover, households that practise water conservation methods were expected to experience a more diverse diet than those that did not. The more assets, such as farm tools, implements and machines, a household owned, the higher was the DDI score.

4.2 The contribution of cassava production to food security of smallholder households in Idifu and Ilolo, Dodoma

By running a regression analysis with data from the household survey of the Trans-SEC project, no statistically significant impact of cassava cultivation on food security was found. Furthermore, according to the Trans-SEC household survey, only 18 farmers out of 899 farmers reported they cultivate cassava. Using data from the qualitative interviews, results were assigned to the three indicators of food security. According to the smallholder farmers we interviewed for the qualitative analysis in the Dodoma region, the main drivers of crop cultivation were the overall climate and specific weather conditions. Relating to this, farmers complained about intense drought seasons experienced in the past and present. Interviewees emphasized that cultivating cassava helped them to cope with these harsh conditions. Most interviewed smallholder farmers assessed their cultivation of cassava as a valuable component of their whole crop production system. Two out of 11 interviewees did not grow cassava, but were planning to cultivate it in the future. They pointed out that after planting cassava, there is hardly any additional work left to do.

With regard to the historical development of cassava cultivation, one farmer reported about political initiatives 20 years ago that prompted farmers to grow cassava, pearl millet and sorghum but not maize because the Dodoma region is too dry (Kapinga et al. 2005). He highlighted that, back then, people were loyal to the government and acted as required. He further explained that people therefore expected cassava to be a cash crop due to government promotion of cassava marketing and the establishment of starch industries. When they tried to sell their harvested cassava, they did not find reliable markets and

Table 4 Regression model for food utilization in Tanzania indicating the different variables

	Unstandardized coefficients		Standardized coefficients		
Model	B	Standard error	Beta	t	Sig.
(Constant)	12.323	.684		18.011	.000
ReadWrite	1.336	.458	.095	2.918	.004**
MembersHh	−.190	.070	−.091	−2.707	.007*
Drought	−.529	.347	−.054	−1.524	.128
ShareInfertile	−.934	.453	−.063	−2.064	.039
CollectiveAgri	.199	.144	.042	1.380	.168
UseLivestProd	1.041	.303	.109	3.436	.001***
Knowledgeprocess	1.517	.660	.070	2.299	.022
Foodaidinkind	−.904	.428	−.071	−2.112	.035
Gender	.248	.369	.021	.671	.502
Groundnut	.957	.436	.097	2.194	.028
Asssets	.516	.177	.092	2.914	.004*
Cassava	1.612	1.025	.048	1.573	.116
Maize	1.487	.368	.144	4.041	.000***
MilletSorghum	−2.003	.491	−.210	−4.077	.000***
WaterConservation	1.225	.360	.112	3.408	.001***
SaveIncome	1.788	.348	.159	5.144	.000***
Highfoodprices	3.648	1.022	.110	3.570	.000***
Sunflower	.315	.394	.026	.798	.425

dependent variable: DDI

*, **, *** denote significance at the 10%, 5%, and 1% levels, respectively

Beta = standardized regression coefficient; t = value of t-test; sig. = significance

therefore stopped cassava cultivation. He argued that today, because of distrust of the government, farmers do not listen to similar governmental instructions anymore and reject policies. During the interviews, a main factor with cassava cultivation was social acknowledgment; interviewees pointed out that cassava is regarded as a second-class food and a poor man's crop. According to them, farmers try to avoid consuming or cultivating cassava so as not to be regarded as a poor man or woman. This might be the reason for the very low frequency of cassava cultivators reported in the Trans-SEC household survey.

One interviewee emphasized that, in comparison with other crops, the cultivation of cassava is easier and less labour intensive, but it does require experience. In general, farmers claimed that certain knowledge is important for cultivating cassava successfully (control of pests and diseases, improvement of the sustainability of crop yields, use of new technologies and varieties) and they needed to become aware of the versatile uses of cassava. Considering this, smallholder farmers named different types of food preparations from cassava. One of the main uses is the preparation of ugali, a kind of mash, eaten nationwide. A decisive factor of how to prepare foods from a cassava crop depends on the variety grown. Farmers distinguished between sweet and bitter varieties. Some interviewees stated that it is hard to differentiate cassava roots in terms of sweetness or bitterness. Several smallholder farmers described a common processing method: bitter cassava roots are dried on the rooftop and afterwards processed as flour or cut into pieces. By doing this, storage of the highly perishable cassava roots is possible.

4.2.1 Contribution to food availability

As aforementioned, one of the main challenges of crop production in the Dodoma region is the dry weather. A high share of interviewed smallholder farmers revealed that cassava is intentionally grown to meet drought seasons and to ensure food supply. Nevertheless, one interviewee explained that because of the current bad year he had harvested very little food, in contrast to previous years when the weather was more favourable for the crops. Because of this, he had engaged in several casual labour jobs. As already indicated in the food security factor analysis, households with more waged employees experienced a higher level of food insecurity in terms of availability. One farmer pointed out that he tried to increase the water supply by mulching the plants so as to provide more cassava for his family. Several farmers pointed out that they had based their choice of crops on an assessment of soil fertility. Because cassava is tolerant of poor soils, some farmers argued that they cultivated it to better use infertile soils. As cassava roots may be kept in soil even when ready to harvest, one interviewee emphasized that cassava is a good crop for 'saving' food. He also stated that his cassava production was insufficient and he needed to buy additional food products. Another smallholder farmer confirmed that food shortages could be prevented by producing cassava because it is a 'permanent' crop that can stay in the ground over many months. One interviewed smallholder farmer pointed out that he consumed cassava when he was short of food. Moreover, he used cassava leaves as a vegetable. Relating to this, he highlighted that he would like to cultivate more cassava, introducing it as an alternative food. Having learned from farmer training events in Dodoma, one farmer emphasized that his knowledge had widened about different uses of cassava and its potential for being used as a substitute for other types of food. Another interviewee stated that cassava was the main crop for feeding his family because of a bad harvest of pearl millet. He pointed out that the cassava harvest was sufficient. Asked about what kind of crops he would like to increase cultivating, one interviewee emphasized that he wanted to grow more sunflower and cassava, in particular to have more feed for his livestock.

4.2.2 Contributions to food access

One of eleven interviewed cassava farmers emphasized that cultivating both cash and food crops was beneficial for him and that his decision on what to grow was based on this. Other farmers confirmed this. None of the interviewees cultivated solely food crops or cash crops. While most of the farmers stated that prices for cassava were too low and unstable, one farmer said that prices were very good. Some interviewees reported that sweet varieties of cassava were easily sold on the market. Nevertheless, the majority of the cassava cultivators interviewed complained about the lack of markets and sales opportunities. By contrast, one farmer said that cassava enabled him to build his house. However, he added that he was also looking for more markets now that he had noticed the importance of cassava. Others reported that cassava is best sold by going to another village and offering it to every household. On the whole, to generate income, interviewees listed sesame, groundnut, sunflower and Bambara groundnut as the most valuable crops. Few cassava producers cultivated it for financial profit. Some interviewees emphasized that they did not need to use fertilizer for cassava cultivation, and therefore production costs were low. One farmer reported that his father had cultivated cassava and considered that during period of high food shortages cassava was the main crop to overcome them. He also mentioned that people came to their house at that time to ask for cassava. Further, he outlined that due to certain events that negatively affected food security (such as drought or food shortage), cassava could emerge as a cash crop. Another interviewee reported, during food shortages in the 1980s, he had cultivated a lot of cassava, and as a result, he was able to access other foods such as chicken by exchange.

4.2.3 Contribution to food utilization

Concerning the contribution of cassava to food security in terms of utilization, several farmers pointed out that cassava gave them energy and subsequently had a high impact on their diet. In general, cassava, because of its starchy roots and green leaves, was assessed as a healthy and nutritious food crop which contributes to human nutrition. Additionally, two interviewees said they would like to grow more cassava and mix it with sorghum to prepare ugali. Another farmer pointed out that people have only limited knowledge about methods of preparation and uses for cassava. He emphasized that training was necessary to show alternatives. One interviewee stated that cassava had a positive impact on his health. According to him, in times of globalization, people refuse to eat traditional foods because of social pressures. Subsequently, he claimed that people in his village preferred eating more prestigious foods (rice, maize, meat) than nutritious, healthy food. Only two of the interviewees mentioned that they used cassava leaves as a vegetable. None of the interviewees mentioned the toxicity of cassava.

5 Discussion

Table 5 summarizes the positive and negative impacts of different variables on food availability, access and utilization for households participating in the Trans-SEC study sites in Tanzania. When a given variable has no sign, no significant impact could be identified.

A "+" shows positive significance and a "- "shows negative significance. No sign denotes no significant impact of the variable on the individual regression. To avoid judgement, the term "sign." (for significance) has been chosen for the Gender variable. Due to the positive weight of the Gender variable, women are expected to be less food secure than men.

To analyse potential contributions of cassava production to food security, our results were used in a logical chain of effects approach. By doing this, it was possible to show the effects of cassava cultivation on households (Fig. 3).

Based on the evidence from our interviews, increased cassava cultivation shows potential to improve food security in the semi-arid region. Some of the most relevant features mentioned by farmers interviewed during the field research were organized in the logical chain approach (Fig. 3). First, interviewees confirmed that drought and infertile soils are challenges faced in the surveyed regions. As revealed by literature review (Howeler et al. 2013; Bull et al. 2011; Parmar et al. 2017) and qualitative interviews, cassava is tolerant of drought and infertile soils. Because of the regression models

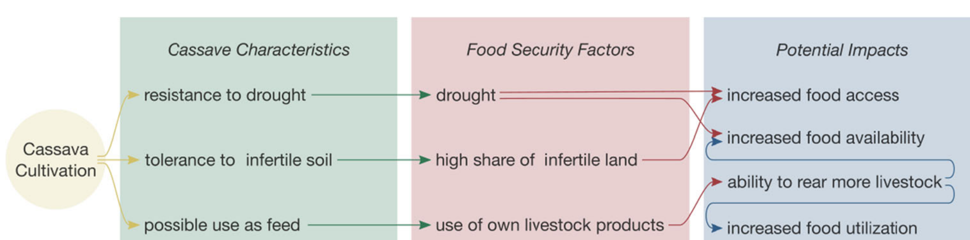
Table 5 Summary of variables with a significant influence in at least one of the three dimension of food security of the surveyed regions in Tanzania

Variables	Availability	Access	Utilization
Ability to save a part of the income	+	+	+
Application of measures to conserve water			+
Cultivation of maize			+
Cultivation of millet and/or sorghum	−		−
Experience of high food prices in the last five years		+	+
Gender of the household head		sign.	
Number of household members			−
Number of household members engaged in waged jobs	−		
Number of household members who can read and write			+
Number of mechanical assets			+
Percentage of Infertile share of land		−	
Suffered from drought in the last five years	−	−	
Total annual household income member	+	+	
Use of livestock products	+		+

it was found that drought and infertile soils have, as expected, a negative impact on local food security, especially in terms of availability and access (see Table 1 and Table 2). For instance, drought had an impact within the regression models of food availability and access. Rufino et al. (2013) reported critical levels of food insecurity related to drought periods, especially in regions of Kenya, Tanzania and Uganda with an annual rainfall of less than 700 mm. Regarding the logical chain in Fig. 3, as a consequence of combating drought by cultivating drought resistant cassava, food security was expected to increase for the availability and access dimensions, corresponding to the results of the regression model. Paavola (2008) reported a strategy of farmers from Morogoro region switching from the cultivation of maize to cassava or sorghum when facing drought or food insecurity. In a survey carried out in Kenya, Tanzania and Uganda, Rufino et al. (2013) stated that most farmers had knowledge of the use of cassava as a drought tolerant plant to overcome drought periods but few of them already cultivated cassava. In a recent study, also from the Trans-SEC framework, Brüssow et al. (2017) reported that the replacement of the usually planted food crop by drought tolerant crops seems to be a promising strategy to enhance food security in Tanzania. The authors also confirmed that some Tanzanian farmers already use this strategy. As pointed out by some interviewees, the resistance to cassava cultivation is, in general, related to the farmer's association of cassava with the ideas of poverty and inequality. This statement is emphasized by Parmar et al. (2017) who describe the role of cassava in Tanzania as still a famine reserve crop when maize production fails. In a previous study, Kinshella (2014) also highlighted the farmers' association of cassava consumption with stomach diseases as another resistance point against cassava cultivation. Health problems could probably be related to the toxicity of some cassava cultivars due to the lack of knowledge of farmers on how to process it correctly. However, the authors explain that stomach diseases could probably be related to a lack of vitamins due to the poor nutritional value of food consumed by the households, or even related to the effects of tropical diseases such as malaria.

Two interviewees pointed out that they tried to increase their livestock to enhance food security. Moreover, as aforementioned, the use of own livestock products showed a significant positive contribution to the regression models. Therefore, in relation to the logical chains model, increased cassava cultivation has the potential to enhance food security on the access and utilization levels through its use as a feed for domestic animals. According to Parmar et al. (2017), cassava is widely used as an animal feed in Asia and in the Americas and the use of fresh cassava leaves and roots can be an

Fig. 3 Logical chain of effects for the cultivation of cassava according results from the qualitative survey in Tanzania



affordable feed source for animal production in East African countries, contributing also to food security.

Even though the other influence factors cannot be matched with cassava characteristics, as was done in the logical chains analysis above, they are useful in providing relevant information on local food security since they can affect other important variables that impact availability, access and utilization. By regarding factors associated with different cash crops such as groundnut and sesame or staple crops such as pearl millet and maize, the analysis proved that cultivation of a single crop or group of crops cannot be a key determinant of food security. As stated by Altieri et al. (2012), only a diversified agroecosystem with crop-livestock integration, low external inputs and high recycling rates can contribute to food security. In conjunction with Liebig's law of the minimum (in this case, applicable to human nutrition as mentioned by Kaput et al. (2015), and due to the high dimensionality and complexity of food security), it turns out that a single limiting factor cannot prevent food insecurity. For instance, even though increased cassava cultivation could help to enhance food security, other restrictive factors still exist. For instance, a lack of income or missing necessary assets for further agricultural development could keep the enhancement of food security low, although more cassava production raises food availability. To sum up, increased cultivation of cassava is expected to enhance food security. Nevertheless, other limiting factors will still exist. More information and extension about high yielding varieties, disease-free plant material, the reduction of post-harvest loss and market development could be helpful for cassava development and availability in many African countries (Parmar et al. 2017; Howeler et al. 2013; Nduwumuremyi et al. 2016). According to Babu et al. (2014), generating market access and information for smallholder farmers in developing countries can have important impacts on their food security. Nduwumuremyi et al. (2016) pointed out that the combination of poor road infrastructure, the remoteness of production sites and the short shelf life of cassava leads to low market opportunities and an increase of post-harvest losses, causing high market costs for the farmers. For that, it is important to have cooperation among national governments and the private sector to promote investments at reasonable prices leading to an improvement in production and consumption. More information and extension services for cassava development in Tanzania could also be helpful in supporting increase in the cultivation of cassava as a drought tolerant plant and also in countering the local idea that relates cassava consumption with poverty (Rufino et al. 2013).

6 Conclusions

The objective of this research was to determine factors that are associated with food security in Morogoro and Dodoma Tanzania, and examine the contribution of cassava production to food security of smallholder farmer households. Through a logical chain approach we analysed if relevant factors could be linked to cassava production. By integrating a comprehensive selection of variables, including crop cultivation variables into regression models, it was found that many crops and drivers contributed to household food security, excluding the hypothesis that a single crop could solve the food insecurity problem. According to our interviews with farmers, cassava can improve household food security status. It was found that drought and infertile land have a negative impact on food security, while at the same time farmers emphasized that cassava production could be one of several measures to deal with them. As livestock products appear to have good potential for increasing food security, using cassava as animal feed could facilitate rearing of more livestock and consequently boost food security, especially when using crop residues. Financial means were crucial factors for food security. Interviewees emphasized the low monetary input for cassava cultivation.

With reference to the Trans-SEC quantitative household survey results, cassava cultivation was rare in both study regions, while in contrast, the qualitative in-field analysis found a significant contribution of cassava cultivation to food security. Two main explanations for the reported low share of cassava cultivators were found during the qualitative study: on the one hand, social perceptions affect cassava cultivation. By interviewing cassava producers in the region of Dodoma, the strong influence of the reputation of cassava as a "poor man's crop" caused people to avoid cassava cultivation. On the other hand, some of the interviewees indicated a lack of education and training led to people without knowledge on the versatility and benefits of cultivating cassava.

To sum up, especially with regard to the level of food availability, cassava was considered to be able to positively contribute to food security due to its beneficial characteristics, especially tolerance of drought. However, because of the poor reputation of cassava cultivation and consumption, lack of knowledge and prior political programs, the production of cassava remains low. Although cassava was relevant for the food security of households, without innovations and enhanced markets, we expect its potential impact to be very limited.

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Compliance with ethical standards

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

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Anja Faße is Professor at the TUM Campus Straubing of Biotechnology and Sustainability for the Weihenstephan-Triesdorf University of Applied Sciences, Germany. She holds a PhD in economics, specialised in environmental economics. Her research covers environmental value chain analysis and impact assessment on household welfare in developing countries, especially in Sub-Saharan Africa. At the moment she has a focus on multiple innovation implementations in traditional rural value chains and their impact on poverty and food security in rural and urban areas.

Katrin Reincke holds a Masters degree in Agricultural Economics from Humboldt University, Berlin, Germany. After a research stay in Azerbaijan, she started working on her masters thesis within the Trans-SEC project, where she focused on the contribution of cassava production to food security. Currently Katrin works as a dairy data analyst at IFCN -The Dairy Research Network in Kiel, Germany. Her position involves analysis in the area of global market developments such as production, trade and macroeconomics. She is also in charge of global long-term projections and analysis of national dairy sectors in cooperation with 100 local researchers from all over of the world.

Elisa Vilvert holds a degree in Agronomy and a Masters in Sciences from the Federal University of Santa Catarina State, Brazil. Currently Elisa is working as guest scientist at the Centre for Agricultural Landscape Research (ZALF) in Müncheberg, Germany. Her ongoing research activities focus on the assesement of sunflower food value chains in Tanzania, with an emphasis on adaptation strategies to improve production. Previously, she conducted research on the interaction between mycorrhiza fungi and plants and also on ecotoxicology of aquatic plants exposed to antibiotics.

Frieder Graef works at the Centre for Agricultural Landscape Research (ZALF) in Müncheberg, Germany. He holds a PhD in tropical agriculture from the University of Hohenheim, Germany, and specialised in soil science, GIS and land evaluation. Frieder is scientific coordinator of the German-Tanzanian research project Trans-SEC. This stakeholder-driven project aims at improving food security for the vulnerable rural poor population in Tanzania, applying upgrading strategies along local and regional food value chains. Previously he worked at the Federal Agency of Nature Conservation (BfN) in Bonn, Germany, where he was involved in the regulation of genetically modified organisms (GMO). There his special focus was on cultivation systems, and strategies for monitoring their potential effects on biodiversity and ecosystems.

Stefan Sieber is an agricultural economist working as a senior scientist and head of the department of Economics of Sustainable Land Use at the Centre of Agricultural Landscape Research (ZALF). He holds a PhD in agricultural sciences from the University of Bonn. He has extensive experience in agricultural sector modelling, particularly in terms of impact assessment of environmental and sustainability policies and in applied monitoring and evaluation methods of international development projects worldwide (Europe, Latin America and Africa). Stefan has managed more than 25 research projects and has authored or co-authored more than 35 peer-reviewed publications, 12 peer-reviewed contributions for books and research series, as well as 80 conference papers. He is currently completing his second PhD (Habilitation) and is a lecturer on the master's program "Environmental Sociology and Environmental Policy" at Humboldt University, Berlin.

Marcos Alberto Lana holds a degree in Agronomy and a Masters in Agro-ecosystems from the Federal University of Santa Catarina State, Brazil. He holds a Doctoral degree in Crop Production from the Christians-Albrecht Universität-Kiel, Germany. Currently Marcos works as scientist and lecturer at the Swedish University of Agricultural Sciences in Uppsala, and as a visiting scientist at the Centre of Agricultural Landscape Research (ZALF), Müncheberg, Germany. His work is focused on the use of crop models to assess the impact of climate change on crops, and precision farming, so as to propose suitable adaptation strategies for the rural sector. Marcos is also involved with the development and adoption of agroecology as a tool to support sustainable farming systems. He is active in different regions of Europe, Africa and Latin America. He also teaches at Humboldt Universität–Berlin and advises Bachelors, Masters and PhD students.