RESEARCH PROGRAM ON
Dryland Systems

CGIAR

December 10, 2016

Agricultural livelihood types and type-specific drivers of production diversification: an evidence from Karauzyak, Karakalpakstan, Uzbekistan

Technical Report 2

Agricultural livelihood types and type-specific drivers of production diversification: an evidence from Karauzyak, Karakalpakstan, Uzbekistan

Akmal Akramkhanov, Adkham Akbarov, Quang Bao Le

International Center for Agricultural Research in the Dry Areas (ICARDA)

Abstract

In presence of climatic variability and risks involved in agricultural production for rural people in Aral Sea region, current research extends the sustainable livelihoods framework to investigate the factors that discriminate agricultural livelihoods at village level and determine type-specific factors of households' production and livelihood diversifications, compared to the treatment of all household as a group. This study aimed to (i) reveal drivers of decisions in households that guide crop diversification, and (ii) inform stakeholders on a set of leverage points and processes needed for improving natural resources and livelihood resilience.

Consequently, in two rural villages of Karauzyak district, this study differentiated three types of agricultural livelihood types that are significantly distinct between each other. Overall, when total sampled population analyzed, results indicated that agricultural experience of household head, households with educated members, share of cattle, share of on farm income, landholding per household member and distance to food markets are drivers that influence household's decision to diversify crop production. Whereas different set of variables or non were significant in livelihood types.

1. Introduction

The importance of understanding land use decision making of rural households is the key to policy makers and researchers. Meeting future food demand in the face of demographic change and population growth is a perplexing challenge for decisions makers (Grote, 2014) particularly if one considers that achieving this will be contingent on achieving this within the context of the Sustainable Development Goals (SDGs). Globally the dominant producers of food crops and livestock products in developing countries are smallholder farmers and rural households. These farmers are not only producing food and livestock products for self-consumption, but also sell into local, national and global markets. Consequently, decisions on

which crops to cultivate and what livestock production systems to impose by these smallholder farmers and rural households have direct consequence beyond the farm gate.

Moreover, crop choice and livestock production strategy by rural households can help to cope with poverty and improve nutrition status of rural lives. In the presence of climatic variability, crop production is severely affected (Thulstrup, 2015), leading to high crop losses and making it difficult for rural households to leave the poverty trap and increase the nutrition. One of the strategies, followed in developing countries by crop producers, to cope with consequences of climatic variability is diversification of crop production (Mitter et al., 2015). Hence, identification of decision making drivers in land allocation for agricultural production by rural households can be used in elaboration of future policies that will efficiently improve rural lives.

Much research was carried out to improve resilience of the agricultural systems, however, most of approaches are one-dimensional often addressing either biophysical, technological, economical, or social dimensions. At the same time, there is understanding in research community that the issues being addressed are intricately linked to a number of other factors, thus the system is complex requiring different approach. As Robinson et al. (2014) correctly justifies, system approach is needed to address complexity of agricultural and livelihood systems and because of the difficulty of developing innovation and interventions that account for such complexity.

Current research is motivated by existing study Nguyen et al. (2017), and extends the sustainable livelihoods framework to investigate the factors that discriminate agricultural livelihoods at village level and determine type-specific factors of households' production and livelihood diversifications, compared to the treatment of all household as a group. It has been initiated within the framework of "Integrated Systems Analysis and Modeling in Aral Sea Region" activity in Uzbekistan, by ICARDA, DS-CRP.

This study attempted to define and characterize clusters of smallholders' livelihood systems and contexts in the Aral Sea Region (ASR) through functional livelihood typology that allows better targeting in system research/development and up-/out-scaling of place-based findings. Our objectives were to (i) reveal drivers of agropastoral system in ASR households that guide crop diversification, and (ii) inform stakeholders (including policy decision-makers) on a portfolio of leverage points and processes needed for improving natural resources and livelihood resilience. Results of this study can be fed into development of an

aggregated system dynamics model capturing livelihood contexts and key drivers of change and to run systems' scenarios.

To the best of our knowledge, there has been no other studies conducted that investigates factors affecting rural household's decision-making regarding crop-diversification in Central Asian region. As a demonstrative case the study conducts research in Aral Sea Region (Karauzyak district) with its harsh environmental conditions, relatively cold winters and hot summers in the region that largely influences the crop productivity and livestock.

2. Materials and Methods

Study site

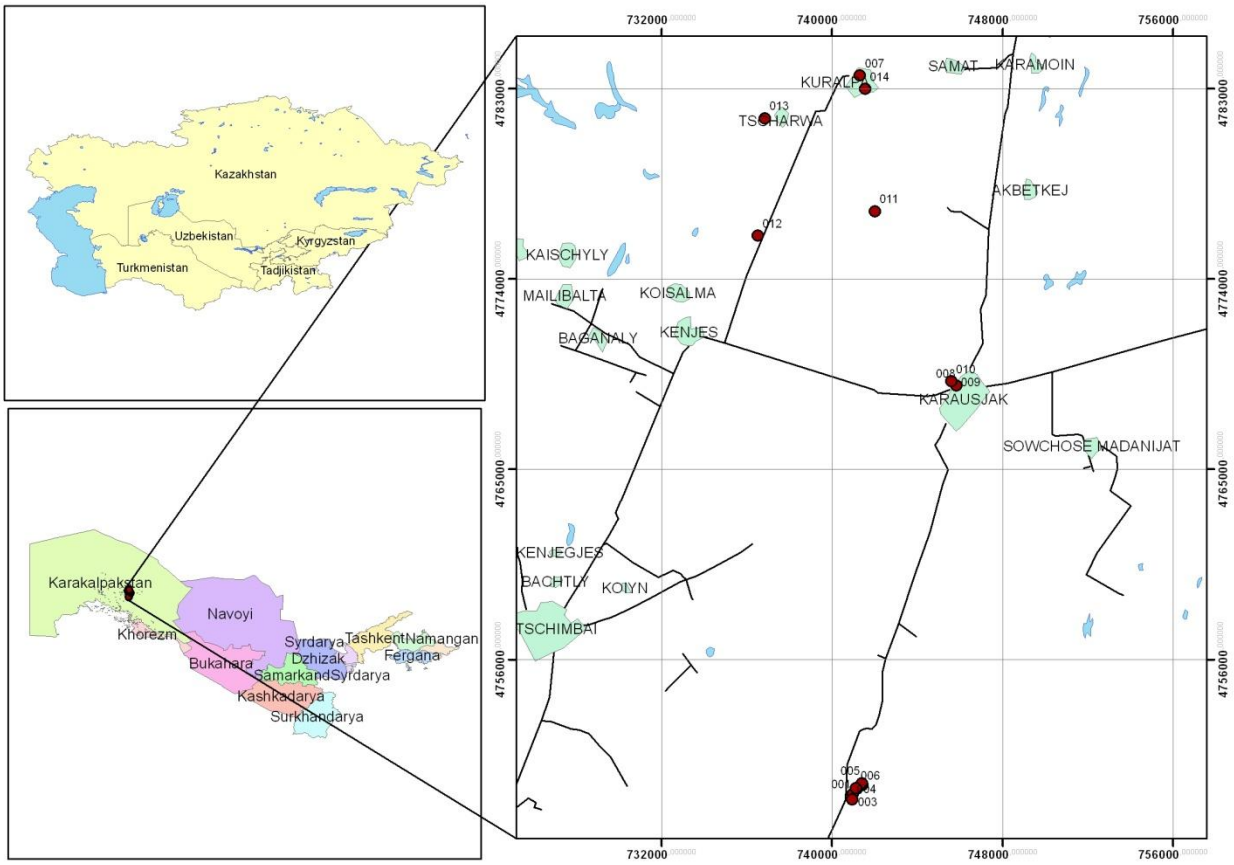
Republic of Karakalpakstan is located in the Northwest of Uzbekistan, and embraces the vast dry lands in the lower reaches of the Amudarya river Basin and also the Aral Sea. Harsh environmental conditions, with cold winters and hot summers, largely impact the productivity of crop and livestock in the study area, which are characterised as generally low. Reflecting external conditions, the vulnerability of the livelihood system in Karakalpakstan is very high and the area is considered to be one of the regions with low income in Uzbekistan. Hence, crop and livestock production under ongoing land degradation and scarce irrigated water resources is a huge challenge for rural households in the Aral Sea Region. To mitigate negative impacts of Aral Sea disaster, it is necessary to formulate optimal rural livelihood strategies, via modelling of current crop and livestock subsystems in selected sites.

Two villages in *Karauzyak* district of Karakalpakstan were selected for the survey and analysis: one, located to the South from the district centre and having more favourable conditions, and the other one, located to the North from the district centre and having harsh climatic conditions and greater impact of the Aral Sea Disaster.

The study district – *Karauzyak* – is one of the 14 districts of the Republic of Karakalpakstan. It was established on the 26th of September, 1975. The district is located in Northeastern part of Karakalpakstan. Total territory of *Karauzyak* district is 5.9 thousand km^2, of which agricultural arable land covers ca. 32.2 thousand ha, arable land – ca. 18 thousand ha, pastures – 380.1 thousand ha, and plots of local population (‘*tomorqa’*) cover 2.2 thousand ha. Climate is sharp continental with average air temperature in January of 6 ...8^0 C below zero, in June of 28 ...32^0 C above zero. In July-August the temperature can rise above 45^0 C.

Administratively *Karauzyak* district is comprised of 1 urban settlement (SCC), 4 Mahallya Citizen Councils (MCC), 8 Village Citizen Councils (VCC). *Karabuga* and *Algabas* Village Citizen Councils (VCC) in *Karauzyak* district have been selected for the survey, representing

25% from total number of village settlements in the district. Out of total 1,384 households in selected two villages, 100 households were surveyed, constituting over 7% of total households that is assumed to be sufficient for such reconnaissance study to get an overview of the villages and hence the district.



Source: GIS lab of NGO "KRASS"

Figure 1. Study area

Karabuga

Karabuga is one of the eight VCCs in Karauzyak district. Total population of the village comprises 4,920 people (as of January 1st 2015), living in 709 rural households. The village is favorably located in the upstream of an irrigation channel. Moreover, villagers have pumps and can cope with water shortages during agricultural season. There is a possibility to add some land to agricultural production upon sufficient labor for agricultural production.

The houses in Karabuga are well constructed with households' land plots located close to the house and in many occasions with additional land plots (tomorqa) within farmers' fields.

There are several big orchards with fruit trees, including the newly established. There are some plans to develop fruit processing capacities in the near future in Karabuga.

According to official statistics as of August 1st 2015 there were 3,293 heads of cattle, 6,857 small ruminants (mostly goats) and over 13 thousand poultry in Karabuga.

The villagers are hard-working and experienced agricultural producers, easily managing subsistence production. The number of private farms is low. There is one prominent cattle breeding farmer, who produces and sells milk in Nukus, both for consumers and processors.

With regards to social infrastructure, there are 4 schools, 1 kindergarten, and a newly built restaurant for celebrating local feasts, weddings. There is 1 medical point, providing first aid and medical treatment and awareness campaigns against diseases, including animal transmitting diseases. A vet station provides veterinary services to the villagers, such as vaccination of animals, curing of animals and treatment against pests and parasites.

Algabas

Algabas is the other surveyed village out of eight VCCs in Karauzyak district. Algabas includes 19 auls. Total population of the village comprises 5,208 people (as of January 1st 2015), living in 675 households, but 779 families since it happens that one household may be comprised of more than 1 family (sons get married and stay and live in one house). Besides rural households (dehqons) there are 27 farmers in Algabas, which fulfill state ordered production of cotton and wheat.

According to Karauzyak administration, Algabas has the worst socio-economic and climatic conditions. This VCC is located to the North of the district, at the tail end of the irrigation channel and thus facing stronger deficits of irrigation water and higher temperature extremes (above $+50^0$C in summer and below -20^0C in winter). Villagers are not very wealthy; there are not many big houses, not much vegetation in Algabas.

With regards to infrastructure, Algabas is connected to gas supply and electricity, but cuts are frequent, especially in late autumn-winter-early spring. Heating of the houses is possible only with fuel wood, or coal. With regards to transportation, there are some bus routes from Karauzyak center to other districts and Nukus city. In order to get to Karauzyak district center private cars or taxis are used.

Each VCC has a female consultant who acts as intermediary between regional/local government and villagers with regards to various topics including health, agriculture, human and animal diseases, trainings, etc. According to the consultant of Algabas, female villagers lead harder life, since much housework is on their shoulders coupled with low energy supply

for cooking, heating and cleaning. On the other hand female villagers are more active and eagerly participate on seminars, meetings, trainings. The peculiarity is that elderly females, or at least after getting married (on average at the age of 18-20) are allowed to be active in public life of the village.

Since it is hard to do agriculture in Algabas, there is high seasonal labor migration to basically Kazakhstan (closest to Karakalpakstan and similar language). Besides, very many families, Kazakhs by ethnicity, have already left the village. Currently migration is lower, when girls leave the village after marriage, or educated villagers find jobs in Nukus or even Tashkent. Rural households manage to grow forage crops, very little vegetables. Local people lead very simple lives, do not have ambitions to become rich or have better houses and cars. There are 4 schools, but no kindergarten, 1 medical point, providing first aid and medical treatment.. Finally, a veterinary station provides veterinary services to the villagers of Algabas VCC.

School education provided in the village is of satisfactory quality and as a result only 5-10 teenagers manage to enter University. In case a teenager starts higher education on contractual terms, some parents, who can afford such education, sell livestock in order to cover educational fees. Girls with higher education have higher chances for a good marriage outside the village.

Analysis flow

For the analysis, in total 100 households living in 2 Village Citizen Councils *Karabuga* and *Algabas* have been randomly selected and surveyed, where survey was prepared in correspondence to Sustainable Livelihood Framework (SLF). Main factors differentiating household's agricultural livelihood system (ALS) are identified by using Principal Component Analysis (PCA), and their results are used further to identify livelihood types in cluster analysis. With respect to type-specific and overall drivers of production and livelihood diversification, Shannon diversity indices are calculated per each cluster type and their drivers are estimated by Multiple Linear Regression (MLR) model.

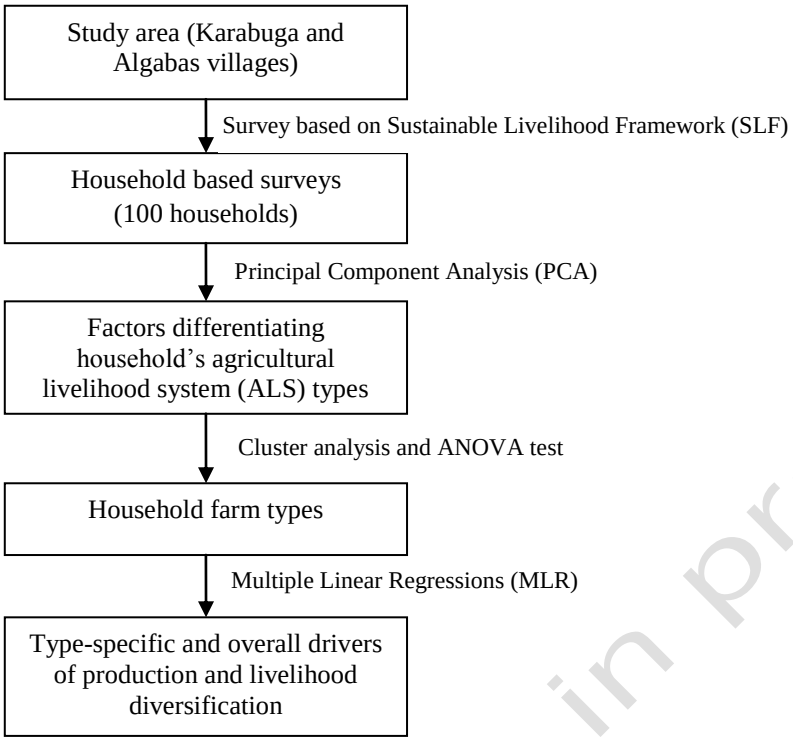


Figure 2. Flow chart of analytical steps

Household-farm sampling and surveys

In total 100 households living in 2 Village Citizen Councils "Karabuga" and "Algabas" have been randomly selected and interviewed. Of great help and support have been the head of local administration, his assistants, the Head of the Veterinary Service and Heads of the Village Citizen Councils. The consultants of the Village Citizen Councils (females) helped to find interviewees, set contacts with local population and provide some local statistics. Since the interview took place in the peak agricultural season, sometimes there were problems with finding the respondents or with keeping them for 2 hours during the interview. Thus based on the advice of the Village Citizen Councils consultants, a mix of individual and group interviewing methodology was applied. Group interviews took place sometimes in the local houses, sometimes in the office of Village Citizen Councils or in the buildings or local schools, medical stations or even kindergarten.

Interviewing of key informants

Key informant interviews – UNDP office in Nukus for contacts, head of local administration and his assistants, head of the veterinary service, heads of village citizen councils of selected areas Karabuga and Algabas, consultants from village citizen councils.

The questionnaires were guided by the Sustainable Livelihood Framework covered mainly household characterization (e.g. demography, education and profession), farm lands inventory and land tenure, agricultural and farm tools inventory, crop and livestock production, off-farm income and remittance.

Principle Component Analysis (PCA) and subsequent Cluster Analysis (CA)

For the analysis of livelihood type-specific behaviors in Karauzyak district, livelihood types are determined in two steps. The first step included using Principal Component Analysis (PCA) to identify a few of strong variables that are uncorrelated with each other from the existing dataset. In other words, PCA helps us to identify few major uncorrelated variables that contain most of the variance and reduce the number of variables in the analysis. Since our sample is small, and after dividing the sample into livelihoods types, the number of observations for the further analysis will get smaller too. Hence, in this case PCA will be useful in reduction of variables. For the purpose of the study PCA is performed with the statistical package STATA version 11. After the running the PCA, the number of principal components (PC) are selected using the two rules: first, PCs with eigenvalues equal or bigger than 1 should be retained, and, second, PCs should represent sufficiently high variance. But the final decision is still made by the author and based on logical reasoning. In this study PCs are chosen with eigenvalues at least equal to or higher than 1.

In the second step, after identifying the number of Principal Components (PC) that explains the highest variance and with eigenvalues of equal or higher than one, the scores of PCs were computed for our observations. These computed scores are used further for k-means cluster analysis to identify our livelihood types. Since the dataset contains mainly quantitative information, the k-means cluster analysis is more suitable to assign our households using information on means.

Variables used for principal component analysis were selected under the guidance of Sustainable Livelihood Framework (SLF), that gives broad explanation of the livelihoods of the poor and reveals major factors that influence people's livelihoods (DFID). SLF provides five livelihood assets, such as Human capital, Natural capital, Financial capital, Physical

capital and Social capital, based on which this study selects related factors from the existing dataset.

Table 1. List of candidate variables for PCA

Variables	Definition	Source*
Human asset		
H_{AGE}	Age of household head (years)	Direct
H_{EXP}	Agriculture experience of household head (years)	Direct
H_{SIZE}	Household family size (number of persons)	Direct
H_{EDU}	Whether household has members with higher education (dummy)	Compound
H_{LABOR}	Household labor (number of workers)	Direct
H_{FLABOR}	Female household labor (number of workers)	Direct
$H_{PWORKERS}$	Household potential workers (number of workers)	Compound
$H_{DEPRATIO}$	HH dependency ratio (ratio between 0 and 1)	Compound
Financial asset		
$H_{ONFARMINC}$	Share of on farm income in total income (%)	Direct
$H_{OFFFARMINC}$	Share of off farm income in total income (%)	Direct
$H_{NONAGROINC}$	Share of non-agricultural income in total income (%)	Direct
$H_{LVSTUNIT}$	Total livestock unit[1]	Compound
H_{CATTLE}	Share of cattle in total livestock (%)	Compound
$H_{RUMINANT}$	Small ruminant share in total livestock (%)	Compound
$H_{POULTRY}$	Poultry share in total livestock (%)	Compound
$H_{NONAGRO}$	Household members with non agricultural income (%)	Compound
H_{AGRO}	Household members with agricultural income (%)	Compound
Natural asset		
H_{LAND}	Total landholding area (m^2)	Direct
$H_{LANDIRR}$	Share of irrigated landholding (%)	Direct
H_{LANDPC}	Land per capita area (m^2/person)	Compound
$H_{IRRIGATION}$	Irrigation water quality access (clean water irrigation=1, sewage irrigation=0)	Compound
Physical asset		
H_{ASSET}	Housing asset index[2]	Compound
$H_{WELFARE}$	Welfare score[3]	Compound
Social asset		
H_{SOCIAL}	Social capital (points)[4]	Compound
Production orientation		
$H_{VEGETABLES}$	Vegetables area (m^2)	Direct
$H_{WATERMELONS}$	Watermelons area (m^2)	Direct
H_{FODDER}	Fodder area (m^2)	Direct
H_{FRUIT}	Fruit trees area (m^2)	Direct
Geographical variables		
$H_{LVSTDIST}$	Distance to livestock market (km)	Direct

[1] For the calculation of total livestock unit, each livestock type owned by a household is multiplied by respective coefficient and summed in total. Amount of mature sheep, rams, lambs, mature she-goats, he-goats, young animals are multiplied by 0.1, amount of turkey by 0.03, amount of chickens and ducks by 0.014, and cattle, horses and mules by 1.

[2] Housing asset index is calculated by the following formula: HAI=(number of living rooms)/ (total number of rooms) + (number of rooms with heating)^2 + (number of rooms with electricity)/(total number of rooms).

[3] In calculation of welfare score, it sums all household's physical assets, where each type of asset is multiplied by a coefficient and discounted for its condition. Tractor and car multiplied by 10; water pump by 5; grain storage facility by 5; satellite antenna, refrigerator and furniture by 2; TV, radio, audio player, mobile phone and carpet by 1. For discounting, the item is divided by 2 if the condition is satisfactory and divided by 3 if the condition is bad.

[4] Social capital score is calculated by adding scores of several criteria: if household member is recognized as a leader, then it receives 3 points; if household member is at any public organization, then it receives 1 point; if household can rely upon state subsidy in case of harvest loss, then it receives 1 point when loss is 25%, 2 points for 50%, 3 points for 75% and 4 points for 100%; if household's woman (incl. single) can access to services of extension agents, then it receives 1 point; if household's woman (incl. single) can access to trainings and seminars on agriculture out of community, then it receives 1 point.

$H_{FOODDIST}$	Distance to food market (km)	Direct

Note: * Direct = directly extracted from the survey; Compound = information calculated based on survey data.

Production and livelihood diversity indexes

For the further analysis the study estimates the production and livelihood diversity indices in order to see whether the livelihood types are significantly different from each other in terms of their diversifications with respect to income sources, crop production and livestock production. For that purpose, Shannon's diversity index technique is followed. The study calculates diversity of income sources using income sources of the household such as on-farm income, off-farm agricultural income and off-farm non-agricultural income. Diversity of crop production is estimated using cultivated areas for vegetables, watermelons, fodder crops and fruit trees by the household. Diversity of livestock production is estimated using amounts of cattle, small ruminants and poultry owned by the household.

$$(1) \qquad H = -\sum_{i=1}^{S} p_i ln p_i$$

where H= diversity index, i= 1,2, 3. … S with S= number of types, p_i is the abundant coefficient of type i.

for each household three types of diversity indices are calculated:

1. Diversity of income sources (H_income): type = income source (on-farm income, off-farm agricultural income, off-farm non-agricultural income). The abundant coefficient is % of the income type compared to total income.
2. Diversity of crop production (H_crop): type = crop type (vegetable, water melon, fodder, fruits). The abundant coefficient is % of the total cropping area.
3. Diversity of livestock production (H_livestock): type = livestock type (cattle, small ruminant, poultry). The abundant coefficient is % of the total livestock units.

Inferential statistics

Multiple linear regression model is estimated to identify driving factors of crop diversification. The model is estimated for each livelihood type and total sampled population. This finds group-specific determinants of households' livelihood diversifications, compared to the treatment of all households as a group. Due to the high number of explaining variables in the model, the Variance Inflation Factor (VIF) test is run to check for potential multicollinearity in the regression model. In cases when VIF test indicated a high correlation

between the explaining variables, the model was improved by exclusion of highly correlating and comparably less relevant variables.

Households' diversification indices that found to be statistically different between livelihood types enter the regression model as the response variable. In this study, crop diversification index (H_crop) enters the model as the response variables that found to be significantly different between the livelihood types. Income diversification index (H_income) and livestock diversification index (H_livestock) are found to be insignificantly different among the livelihood types, and the regression model estimations for these response variables showed very poor model performance with overall insignificance of the model.

Explanatory variables entering the multiple regression model are identified by plausible theories, common sense and regional setting. Several relevant variables, that should also have impact on the response variable, are dropped from the model to avoid multicollinearity. The entering variables are following:

Human asset: Agricultural experience of household head (H_{EXP}) gives better understanding on cultivation of different crops and, hence, it is hypothesized to positively influence the household to diversify its crop production. Households with more potential workers ($H_{PWORKERS}$) are able to cultivate any type of crop (that requires less or more labor force) without being constrained on crops that require less labor force, and it is hypothesized to have a positive effect on crop diversification. Households that have members with higher education (H_{EDU}) should have rational approach towards agricultural activity and hence diversify its crop production. High dependency ratio ($H_{DEPRATIO}$) of the household might constrain household members to work more on agricultural plots and concentrate only on crops that require less labor or crop that has highest return on investment. On the other hand, high dependency ratio might push household to cultivate more types of crops to be more self-sufficient in agricultural products. Hence, the real effect of the dependency ratio can be seen in our results.

Financial asset: High shares of cattle (H_{CATTLE}) and small ruminants ($H_{RUMINANT}$) in total livestock usually drive household to cultivate mainly fodder crops and less diversify in crops to feed the livestock. High share of on-farm income ($H_{ONFARMINC}$) in total income might indicate that the household is mainly involved in farm production, and would be carrying a diversified agricultural activity.

Natural asset: Larger landholding ($H_{LAND\ (ha)}$) of the household have a possibility to cultivate more types of crops compared to those who are land constrained to reach optimum cultivation area per each crop. Irrigation water quality access ($H_{IRRIGATION}$) provides an opportunity to cultivate crops that require proper irrigation. Hence, households that have an access to clean water irrigation would have a chance to cultivate preferred type of crops compared to those households that do not have the access and are constrained only to those crops that require no good irrigation. It is expected that households with the access to good irrigation would be relatively more diversified in crop production.

Social asset: Higher social capital (H_{SOCIAL}) increases the accessibility to necessary institutions, inflow of information (extension) and cooperation that eventually would lead to better farming and also diversified crop production. Social capital was evaluated by using criteria such as: leadership, membership in public organization, access to state subsidy, access of woman to extension services, seminars and trainings on agriculture out of community.

Geography: Further distance to food markets ($H_{FOODDIST}$) makes it difficult for households to commute to the market for selling or buying food. From one side, far distance might push households to diversify their crop cultivation in order to be more self-sufficient in food. One the other side, it might lead to cultivate a crop that is convenient with transportation.

Linear model takes the following form:

$$(2)\ H_{crop} = \beta_0 + \beta_1 H_{EXP} + \beta_2 H_{PWORKERS} + \beta_3 H_{EDU} + \beta_4 H_{DEPRATIO} + \beta_5 H_{CATTLE} + \beta_6 H_{RUMINANT} + \beta_7 H_{ONFARMINC} + \beta_8 H_{LAND(HA)} + \beta_9 H_{IRRIGATION} + \beta_{10} H_{SOCIAL} + \beta_{11} H_{FOODDIST} + \beta_{12} H_{LVSTDIST} + e$$

where: H_{crop} is the Shannon diversity index of crop production as the response variable, H_{EXP},…,$H_{LVSTDIST}$ are the explaining variables that are discussed above, β_0, β_1… β_{12} are parameters to be estimated, and *e* is an error term.

Table 2. List of response and explaining variables in multiple regression analyses

Variables	Definition	Hypothesized effect*
Response variables		

H_crop	Shannon diversity index of crop production	
H_livestock	Shannon diversity index of livestock production	
H_income	Shannon diversity index of income sources	
Explaining variables		
Human asset		
H_{EXP}	Agriculture experience of household head (years)	+
$H_{PWORKERS}$	Household's potential workers (number of workers)	+
H_{EDU}	Whether household has members with higher education (yes=1, no=0)	+
$H_{DEPRATIO}$	Household's dependency ratio (ration between 0 and 1)	+/-
Financial asset		
H_{CATTLE}	Share of cattle in total livestock (%)	-
$H_{RUMINANT}$	Small ruminant share in total livestock (%)	-
$H_{ONFARMINC}$	Share of on farm income in total income (%)	+
Natural asset		
$H_{LAND\ (ha)}$	Total landholding area (hectare)	+
$H_{IRRIGATION}$	Irrigation water quality access (clean water irrigation=1, sewage irrigation=0)	+
Social asset		
H_{SOCIAL}	Social capital (points)	+
Geographic		
$H_{FOODDIST}$	Distance to livestock market (km)	+/-
$H_{LVSTDIST}$	Distance to food market (km)	+/-

* + and – indicate positive and negative effects, respectively. +/- indicates unclear/no prejudge effect.

3. Results

Key variables representing smallholders' agricultural livelihoods

The PCA has revealed main factors discriminating among smallholder systems. In the PCA analysis 11 principal components were selected that are explaining 74.8 percent of the initial total variance. To determine the PC loadings the orthogonal rotation is applied. In the Table 1, PCs were labeled after the variables that has the highest loading within each component. It founds the most discriminating factors among surveyed households with at least 8% of the initial variance are PC-1, PC-2 and PC-3. PC-1 with the highest initial variance (9.7%) highly correlates with the household labor amount (loading =0.56) representing the Human asset of the household and labeled as Labor PC. Next PC with 9.3% of initial variance is highly correlated with household members with non-agricultural income (loading =0.54) which represents households Financial asset and labeled as Non-agricultural members PC. PC-3 with 8.5% of initial variance highly correlates with land per capita (loading = 0.58) which represents households Physical asset and labeled as Land per capita PC. Remaining PCs, from PC-4 to PC-10, each with initial variance of around 4-8% and are considered as factors of Higher education (PC-4), HH head age (PC-5), Cattle share (PC-6), On-farm income (PC-7), Food market distance (PC-8), Livestock market distance (PC-9), HH dependency ration

(PC-10) and Off-farm income (PC-11) in accordance to their highly correlated variables within the components.

Table 3. Key components and variables representing agricultural livelihoods of smallholders in Karauzyak district

	PC-1: Labor	PC-2: Non-agr members	PC-3: Land per capita	PC-4: High edu	PC-5: Hh head age	PC-6: Cattle share	PC-7: On-farm income	PC-8: Food market distance	PC-9: Livestock market distance	PC-10: Hh dep. ratio	PC-11: Off-farm income
	9.7%	*9.3%*	*8.5%*	*7.9%*	*6.9%*	*6.2%*	*6.1%*	*5.6%*	*5.4%*	*4.6%*	*4.6%*
Human asset											
H_{AGE}	-0.05	0.03	-0.03	-0.01	**0.67**	-0.03	-0.02	-0.01	0.01	-0.01	0.02
H_{EXP}	0.05	0.02	0.05	-0.04	0.57	0.09	0.00	-0.01	0.01	-0.03	0.01
H_{SIZE}	0.32	-0.11	-0.10	0.19	0.17	-0.05	0.01	-0.06	-0.03	0.29	-0.15
H_{EDU}	0.03	0.12	-0.09	**0.43**	-0.05	-0.32	-0.12	-0.09	-0.10	-0.15	-0.01
H_{LABOR}	**0.56**	0.07	0.01	-0.05	-0.03	0.07	0.03	-0.06	-0.06	0.05	0.05
H_{FLABOR}	0.51	0.01	-0.01	-0.05	-0.10	0.18	-0.12	-0.01	0.05	0.04	-0.02
$H_{PWORKERS}$	0.44	-0.07	0.00	0.07	0.14	-0.18	0.07	0.06	0.04	-0.17	-0.02
$H_{DEPRATIO}$	-0.27	0.06	-0.12	0.09	-0.03	0.23	-0.05	-0.16	-0.03	**0.55**	-0.08
Financial asset											
$H_{ONFARMINC}$	0.00	-0.05	-0.04	-0.03	0.00	0.00	**0.68**	0.00	0.01	0.02	-0.20
$H_{OFFFARMINC}$	-0.01	-0.20	-0.07	0.04	0.03	0.08	-0.16	0.05	-0.02	0.03	**0.62**
$H_{NONAGROINC}$	0.01	0.24	0.04	-0.07	0.05	-0.08	-0.44	0.05	-0.07	0.06	-0.22
$H_{LVSTUNIT}$	-0.03	0.02	0.04	0.40	0.13	0.10	0.11	0.07	0.05	0.11	0.05
H_{CATTLE}	0.06	-0.02	0.07	0.08	0.01	**0.57**	-0.02	0.13	0.04	-0.06	-0.10
$H_{RUMINANT}$	-0.05	-0.09	-0.01	0.41	-0.15	0.09	0.10	-0.02	0.09	-0.16	0.03
$H_{POULTRY}$	-0.05	-0.10	0.03	-0.03	-0.06	-0.54	-0.06	0.12	0.12	-0.01	-0.16
$H_{NONAGRO}$	-0.01	**0.54**	-0.01	-0.01	0.03	0.02	-0.06	0.00	0.05	0.00	-0.02
H_{AGRO}	0.01	-0.54	0.01	0.01	-0.03	-0.02	0.06	0.00	-0.05	0.00	0.02
Natural asset											
H_{LAND}	0.03	-0.07	0.57	0.07	0.08	-0.01	-0.05	0.00	-0.05	-0.02	-0.06
$H_{LANDIRR}$	0.02	0.17	0.08	-0.01	-0.02	-0.11	0.17	0.06	0.54	0.08	-0.08
H_{LANDPC}	-0.07	0.00	**0.58**	-0.06	0.01	0.02	-0.06	0.01	-0.05	-0.14	0.04
$H_{IRRIGATION}$	-0.03	0.07	0.01	0.06	0.00	0.06	0.02	0.54	0.07	-0.03	0.27
Physical asset											
H_{ASSET}	0.04	0.00	0.04	0.42	-0.07	0.02	-0.24	0.10	0.00	0.08	-0.04
$H_{WELFARE}$	0.08	0.29	-0.01	0.32	-0.11	0.00	0.17	-0.08	-0.14	-0.10	0.14
Social capital											
H_{SOCIAL}	-0.04	0.21	0.11	0.07	0.15	-0.21	0.27	0.04	-0.07	0.15	0.43
Production orientation											
$H_{VEGETABLES}$	-0.02	0.07	-0.27	-0.02	0.04	0.10	-0.01	0.17	0.49	-0.16	-0.04
$H_{WATERMELON}$	-0.09	-0.14	0.03	0.31	0.18	0.00	0.00	0.06	-0.04	0.14	-0.32
H_{FODDER}	0.05	0.08	0.43	0.01	-0.15	0.08	0.11	0.00	0.22	0.18	-0.03
H_{FRUIT}	-0.15	0.02	-0.02	0.11	0.08	0.18	0.00	-0.15	-0.02	-0.61	-0.14
Geographical variables											
$H_{LVSTDIST}$	-0.01	-0.19	0.07	0.11	0.05	-0.05	-0.21	-0.33	**0.57**	0.03	0.17
$H_{FOODDIST}$	-0.01	-0.09	0.00	0.03	-0.01	-0.03	-0.07	**0.66**	-0.02	0.04	-0.13

Table 4. Variance of principal components explained before and after rotation (cut-off Eigen value = 1)

Principal Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.070	13.6%	13.6%	2.910	9.7%	9.7%

2	3.500	11.7%	25.2%	2.775	9.3%	19.0%
3	3.335	11.1%	36.4%	2.557	8.5%	27.5%
4	1.901	6.3%	42.7%	2.375	7.9%	35.4%
5	1.793	6.0%	48.7%	2.058	6.9%	42.3%
6	1.624	5.4%	54.1%	1.857	6.2%	48.4%
7	1.482	4.9%	59.0%	1.838	6.1%	54.6%
8	1.377	4.6%	63.6%	1.691	5.6%	60.2%
9	1.171	3.9%	67.5%	1.614	5.4%	65.6%
10	1.132	3.8%	71.3%	1.386	4.6%	70.2%
11	1.041	3.5%	74.8%	1.366	4.6%	74.8%

Main agricultural livelihood types

Livelihood types

Based on the PCA and k-means cluster analysis, the study identified three types of agricultural livelihoods in the study site. Based on results given in the later table, the following types of agricultural livelihoods can be characterized.

Livelihood type 1: *Land per capita rich and cattle dominant*. 26 households (26% of sample size) belong to this livelihood type. This livelihood type has relatively higher landholdings with average land area of 2938 m^2. Households in this group have higher number of livestock unit and most of which is cattle. Beyond the major discriminating factors, these households are richer in housing assets, have higher social capital and better welfare. Watermelons and fodder crops are more cultivated by this type of households rather than in other types.

Livelihood type 2: *Relatively labor rich, land per capita poorer and lower dependency ratio.* This type includes 31 households (31% of sample size). In this type, households have bigger family size with more labor, where an average family size is around 7 people and household labor amount is around 5 people. Land possession per capita is smaller than in other types (189 m^2 per family member). Despite the big family size, the dependency ratio is much lower than in other types. Vegetables are the main type crop that is cultivated by the households.

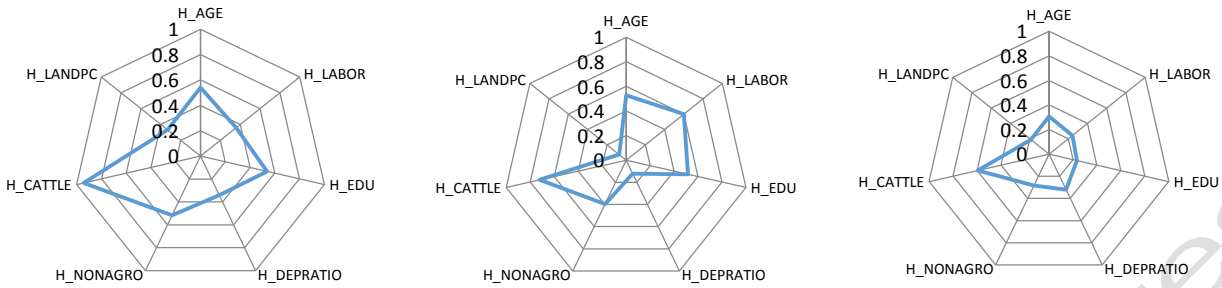
Livelihood type 3: *Relatively young, fewer members with non-agro income and labor poorer.* The major share from the sample (43 households or 43%) were assigned into this group. Households that belong to this group have younger household heads and, hence, should be younger families. Most of the household members have only agricultural income and a few have non agricultural income. Considering that their family sizes are smaller, they have less labor as well. Households with no higher education are more prevalent in this type.

Interestingly, in all livelihood types there are more household members that have non-agricultural income. Additionally, major share of the household's income comes from non-agricultural activities. This might indicate that most of agricultural products that produced by the households are not marketed, but produced for self-subsistence.

Table 5. Descriptive statistics of key agricultural livelihood variables of three identified smallholder types with ANOVA tests.

Variable	Agricultural livelihood type 1: 26 observations		Agricultural livelihood type 2: 31 observations		Agricultural livelihood type 3: 43 observations	
	Mean	$CI_{0.05}$	Mean	$CI_{0.05}$	Mean	$CI_{0.05}$
Human asset						
H_{AGE}	55^{a}	±4.499	54^{a}	±3.142	43^{b}	±2.398
H_{EXP}	29^{a}	±4.010	29^{a}	±4.045	16^{b}	±2.854
H_{SIZE}	6^{a}	±0.542	7^{b}	±0.613	5^{c}	±0.369
H_{EDU}	0.54^{a}	±0.205	0.52^{a}	±0.186	0.23^{b}	±0.131
H_{LABOR}	3^{a}	±0.422	5^{b}	±0.541	2^{c}	±0.254
H_{FLABOR}	1^{a}	±0.200	2^{b}	±0.315	1^{a}	±0.090
$H_{PWORKERS}$	3^{a}	±0.548	5.19^{b}	±0.458	2^{c}	±0.239
$H_{DEPRATIO}$	0.86^{a}	±0.277	0.31^{b}	±0.116	0.80^{a}	±0.181
Financial asset						
$H_{ONFARMINC}$	11.27	±7.485	12.52	±6.495	17.09	±8.841
$H_{OFFFARMINC}$	2.69	±4.206	5.00	±5.208	7.33	±6.735
$H_{NONAGROINC}$	86.04	±8.441	79.26	±9.121	71.63	±11.130
$H_{LVSTUNIT}$	9^{a}	±2.926	3^{b}	±1.627	2^{b}	±1.061
H_{CATTLE}	0.94^{a}	±0.015	0.72^{b}	±0.147	0.60^{b}	±0.143
$H_{RUMINANT}$	0.03	±0.012	0.02	±0.018	0.02	±0.014
$H_{POULTRY}$	0.03^{ab}	±0.014	0.10^{bc}	±0.090	0.20^{c}	±0.118
$H_{NONAGRO}$	0.39^{a}	±0.073	0.30^{a}	±0.065	0.21^{b}	±0.042
H_{AGRO}	0.61^{a}	±0.073	0.70^{a}	±0.065	0.79^{b}	±0.042
Natural asset						
H_{LAND}	2938^{a}	±423.326	1238^{b}	±356.595	1527^{b}	±257.69
$H_{LANDIRR}$	0.63	±0.100	0.59	±0.096	0.50	±0.095
H_{LANDPC}	555^{a}	±119.214	189^{b}	±54.029	351^{c}	±65.039
$H_{IRRIGATION}$	0.58	±0.203	0.35	±0.178	0.47	±0.155
Physical asset						
H_{ASSET}	16.72^{a}	±5.236	8.96^{b}	±4.523	4.49^{b}	±1.939
$H_{WELFARE}$	12.56^{a}	±3.491	7.93^{b}	±1.631	5.84^{b}	±1.345
Social asset						
H_{SOCIAL}	3.19^{a}	±0.636	2.03^{b}	±0.291	2.12^{b}	±0.278
Production orientation						
$H_{VEGETABLES}$	0.15^{a}	±0.058	0.40^{b}	±0.123	0.17^{a}	±0.075
$H_{WATERMELONS}$	0.07^{a}	±0.042	0.02^{b}	±0.016	0.01^{b}	±0.011
H_{FODDER}	0.29^{a}	±0.109	0.03^{b}	±0.033	0.09^{b}	±0.056
H_{FRUIT}	0.03	±0.024	0.02	±0.031	0.01	±0.010
Geographical variables						
$H_{LVSTDIST}$	15.17	±3.188	18.95	±3.154	14.57	±3.059
$H_{FOODDIST}$	18.19	±3.018	14.54	±3.943	17.25	±2.747

Note: the mean values that have the same alphabet superscript letter have no significant difference at $p < 0.05$ (95%); key variables identified in PCA are given in bold.



(a) Livelihood type 1 (b) Livelihood type 2 (c) Livelihood type 3

Figure 2. Spider/radar diagram showing livelihood indicators (standardized score) of the three identified smallholder types

Table 6. Livelihood type-specific Shannon diversity indices with ANOVA tests

	Agricultural livelihood type 1: 26 observations		Agricultural livelihood type 2: 31 observations		Agricultural livelihood type 3: 43 observations		ANOVA
Variable	Mean	$CI_{0.05}$	Mean	$CI_{0.05}$	Mean	$CI_{0.05}$	Prob > F
H_income	0.26	±0.119	0.32	±0.108	0.23	±0.092	0.3978
H_crop	0.61[a]	±0.123	0.33[b]	±0.100	0.28[b]	±0.088	0.0000
H_livestock	0.21[a]	±0.052	0.17[ab]	±0.070	0.11[b]	±0.051	0.0513

Note: the mean values that have the same alphabet superscript letter have no significant difference at $p < 0.05$ (95%).

Type-specific and overall drivers of production and livelihood diversification

The results from regression analysis on determinants of crop production diversification are provided in Table 7. The model is statistically significant for total ALs, AL type 1 and type 2 at 5 percent level. The estimates for AL type1 is weakly significant at 10 percent. R-squared varies between 0.50-0.71, indicating that our variables explain more than half of the variation in the model. Only significant drivers per group are reported in the table with their statistical significance levels (stars).

Results for total AL types show that household head's agricultural experience has very small positive impact on households' crop diversification, but it is weakly significant at 10 percent. Households that have members with higher education show positive effect on crop diversification and it is strongly significant at 1 percent level. Contrary to our hypothesis, another factor that drives households to diversify their crop production is the cattle share in total livestock. Share of in farm income turns to have positive effect on crop diversification but weakly significant. Landholding of the household shows its positive and statistically

significant impact on crop diversification. Lastly, distance to food market shows its negative impact on crop diversification.

The regression results for Type 2 AL show households with highly educated members still have a significant positive impact on crop diversification and its range is higher for this AL type. The share of cattle and landholding of the household still have positive impact, but their statistical significance levels are weaker than for total ALs. Additional driver that turns to have negative impact on crop diversification is share of small ruminants but statistically significant at 10 percent level. Agricultural experience of household head, share of on-farm income and distance to food market become insignificant for this AL type.

The results for AL type 3 shows that number of household's potential workers has positive effect on crop diversification but statistically significant at 10 percent level. Interestingly, contrary to AL type 2, share of small ruminants becomes strongly significant and has positive impact. Share of cattle becomes weaker in terms of statistical significance. The positive impact of landholding of household becomes insignificant for this AL type.

Irrigation water quality access, social capital and distance to livestock market show no statistically significant impact on any of the AL type and total AL. Interestingly, share of small ruminants has different impact in different AL types, negative in AL type 2 and positive in AL type 3. Overall, households with educated members, share of cattle and distance to food market are the common drivers that influence on crop diversification decision of households.

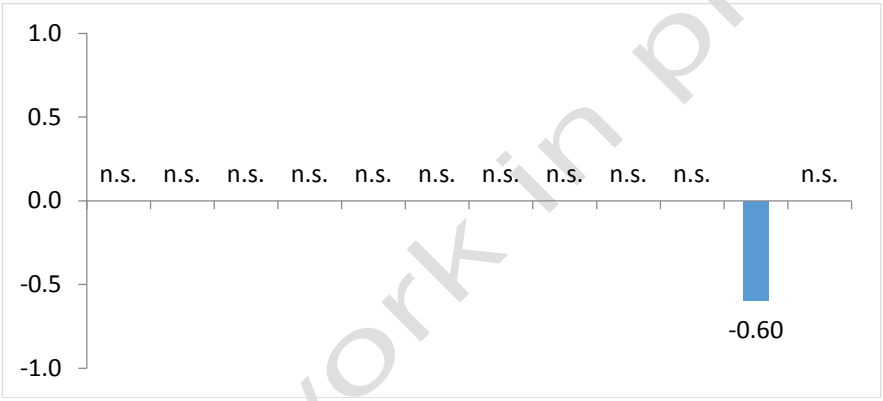
Table 7. Determinants of diversification of crop production by AL types

	Total	Type 1	Type 2	Type 3
Human asset				
H_{EXP}	0.005*	n.s.	n.s.	n.s.
	(0.002)			
$H_{PWORKERS}$	n.s.	n.s.	n.s.	0.137*
				(0.052)
H_{EDU}	0.191***	n.s.	0.301**	n.s.
	(0.052)		(0.087)	
$H_{DEPRATIO}$	n.s.	n.s.	n.s.	n.s.
Financial asset				
H_{CATTLE}	0.216**	n.s.	0.279*	0.186*
	(0.067)		(0.118)	(0.074)
$H_{RUMINANT}$	n.s.	n.s.	-1.967*	3.199***
			(0.914)	(0.738)
$H_{ONFARMINC}$	0.002*	n.s.	n.s.	n.s.
	(0.001)			
Natural asset				
$H_{LAND\ (ha)}$	1.029***	n.s.	1.228*	n.s.

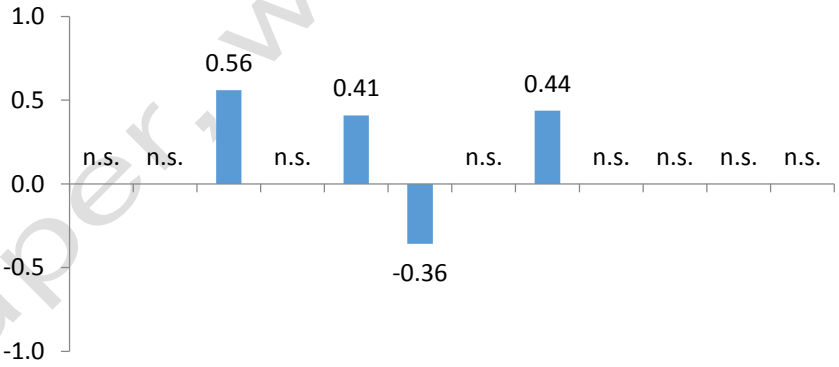
	(0.230)		(0.503)	
$H_{IRRIGATION}$	n.s.	n.s.	n.s.	n.s.
Social asset				
H_{SOCIAL}	n.s.	n.s.	n.s.	n.s.
Geographic				
$H_{FOODDIST}$	-0.009**	-0.024*	n.s.	-0.012**
	(0.003)	(0.008)		(0.003)
$H_{LVSTDIST}$	n.s.	n.s.	n.s.	n.s.
constant	n.s.	n.s.	n.s.	n.s.
Observations (n)	100	26	31	43
Prob > F	0.000	0.097	0.042	0.000
R-squared	0.507	0.662	0.621	0.717
Adj R-squared	0.439	0.350	0.368	0.604

Standard errors in parentheses; * p<0.05, ** p<0.01, *** p<0.001

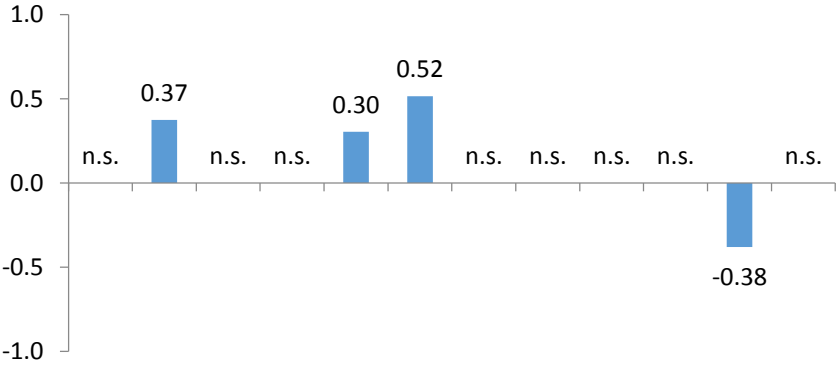
(a) ALS type 1



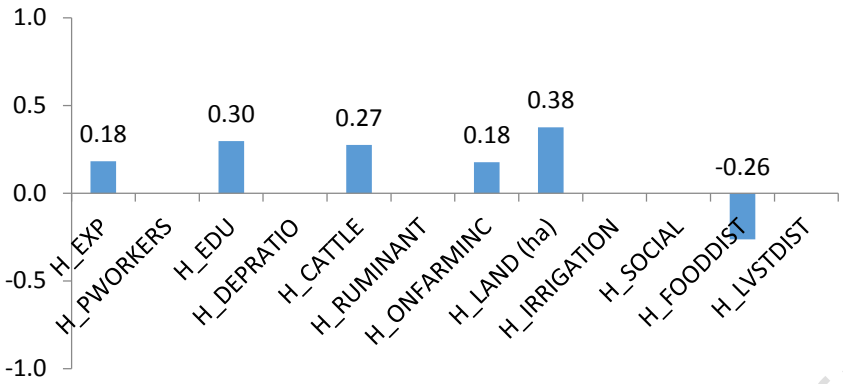
(b) ALS type 2



(c) ALS type 3



(d) Total sampled population



Note: n.s. stands for "not significant"; Standardized beta coefficients are given in the figure.

Figure 3. Bar charts showing significant drivers, their affecting directions and magnitudes of production diversification by AL types.

4. Conclusions

In presence of climatic variability and risks involved in agricultural production for rural people in Aral Sea region, current research extends the sustainable livelihoods framework to investigate the factors that discriminate agricultural livelihoods at village level and determine type-specific factors of households' production and livelihood diversifications, compared to the treatment of all household as a group.

Consequently, in two rural villages of Karauzyak district that have different climatic conditions, this study differentiates three types of agricultural livelihood types that are significantly distinct between each other.

First livelihood type is found to be rich in land per household member and cattle dominant. Households in this livelihood type possess on average relatively higher landholdings per household member compared to other livelihood types. Additionally, households in this group breed higher number of livestock and most of which is cattle. Beyond the major discriminating factors, these households are also richer in housing assets, have higher social capital and better welfare. Watermelons and fodder crops are more cultivated by this type of households rather than in other types. With respect to crop diversification, households in this group are significantly more diverse in crop production. Within this group, the study also finds that distance to food market from household's house has negative influence on decision to diversify its crop production, but its significance is statistically weak.

Second type of agricultural livelihood in Karauzyak district is relatively labor rich, land per household member poorer and has lower dependency ratio. In this type, households have bigger family size with more labor. Land possession per household member is smaller than

in other types. Despite the big family size, the dependency ratio is much lower than in other types. With respect to crop production, these households mainly cultivate vegetables and, hence, less diversified crops. Moreover, the regression analysis reveals major drivers that influence on decision to diversify its crop production. Education is found to be one of the driving forces that positively affect on the diversification in livelihood type two, implying that households with educated members are prone to diversify its crop production. Additionally, higher share of cattle in total livestock and landholding of the household showed also positive impact on the diversification.

The last livelihood type three has relatively younger household heads, with fewer labor and fewer household members with income outside of agriculture. Households without higher education are more prevalent in this type. This livelihood type is also less diversified in crop production as in livelihood type two. With respect to the type three, the study found that the number of potential workers in households, cattle and small ruminants amount positively influence on decision to diversify its crop production, but distance to food market has negative influence on the diversification.

Overall, our analysis for total sampled population found that agricultural experience of household head, households with educated members, share of cattle, share of on farm income, landholding per household member and distance to food markets are drivers that influence on household's decision to diversify its crop production.

Acknowledgements

This work was undertaken as part of, and funded by, the CGIAR Research Program on Dryland Systems led by the International Center for Agricultural Research in the Dry Areas (ICARDA). The opinions expressed here belong to the authors, and do not necessarily reflect those of Dryland Systems, ICARDA, or CGIAR.

References

DFID 1999. Sustainable Livelihoods Guidance Sheets. [accessed on 27.12.2016: http://www.eldis.org/vfile/upload/1/document/0901/section2.pdf]

Grote, U. 2014. Can we improve global food security? A socio-economic and political perspective. *Food Security 6*: 187-200.

Mitter, H., Heumesser, C., Schmid, E. 2015. Spatial modeling of robust crop production portfolios to assess agricultural vulnerability and adaptation to climate change. *Land Use Policy* 46: 75-90.

Nguyen, T. T., Nguyen, L. D., Lippe, R. S., & Grote, U. 2017. Determinants of Farmers' Land Use Decision-Making: Comparative Evidence From Thailand and Vietnam. *World Development*, *89*, 199-213. *Submitted paper* [accessed on 28.12.2016: https://www.researchgate.net/publication/307932140_Determinants_of_Farmers%27_Land_Use_Decision-Making_Comparative_Evidence_From_Thailand_and_Vietnam]

Robinson, L. W., J. de Leeuw, S. Homann-Kee Tui, K. A. Snyder. 2014. Framework for a systems approach in the CGIAR Research Program on Dryland Systems. Working paper.

Rutten, M., van Dijk, M., van Rooij, W., Hilderink, H., 2014. Land use dynamics, climate change, and food security in Vietnam: A global-to-local modeling approach. *World Development* 59: 29-46.

Thulstrup, A.W. 2015. Livelihood resilience and adaptive capacity: Tracing changes in household access to capital in central Vietnam. *World Development* 74: 352-362.

CGIAR

RESEARCH PROGRAM ON
Dryland Systems

The CGIAR Research Program on Dryland Systems aims to improve the lives of 1.6 billion people and mitigate land and resource degradation in 3 billion hectares covering the world's dry areas.

Dryland Systems engages in integrated agricultural systems research to address key socioeconomic and biophysical constraints that affect food security, equitable and sustainable land and natural resource management, and the livelihoods of poor and marginalized dryland communities. The program unifies eight CGIAR Centers and uses unique partnership platforms to bind together scientific research results with the skills and capacities of national agricultural research systems (NARS), advanced research institutes (ARIs), non-governmental and civil society organizations, the private sector, and other actors to test and develop practical innovative solutions for rural dryland communities.

The program is led by the International Center for Agricultural Research in the Dry Areas (ICARDA), a member of the CGIAR Consortium. CGIAR is a global agriculture research partnership for a food secure future.

For more information, please visit

drylandsystems.cgiar.org

Led by:

ICARDA
Science for Better Livelihoods in Dry Areas

In partnership with:

ICRISAT
Science with a human face

Bioversity International

CIAT

CENTRO INTERNACIONAL DE LA PAPA
CIP

World Agroforestry Centre

ILRI
INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

IWMI
International Water Management Institute