Typology analysis of Egyptian agricultural households reveals increasing income diversification and abandonment of agricultural activities

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Introduction

Agriculture is an important sector within the Egyptian economy, accounting for an average of 13.7% of the gross domestic product (GDP) between 2010 and 2014 (e.g. Bertini & Zouache, 2021). Additionally, it provided employment to more than 17% of the population in 2018 (Assaad et al., 2020). Meanwhile, Egyptian agriculture faces challenges that have been developing over decades. Rapid population growth coupled with limited water availability has reduced Egypt's renewable water from 1,750 $m^3.capita^{-1}.year.^{-1}$ in 1970 to 590 $m^3.capita^{-1}.year.^{-1}$ in 2019 (Tutwiler, 2021), well below the 1000 $m^3.capita^{-1}.year.^{-1}$ threshold of water scarcity (Falkenmark et al., 1989). Additionally, urban encroachment on agricultural land and desertification threaten the limited arable land (Abd-Elmabod et al., 2019). Climate change will exacerbate the already constrained water and land resources in the coastal region through salination of groundwater resources and loss of agricultural land due to sea-level rise, increased crop water demand due to increasing temperatures, and more severe and more frequent extreme weather events, to name but a few (Abutaleb et al., 2018).

Egypt has been increasingly dependent on imports of key staples to meet growing demand and compensate for stagnant domestic production. Egypt imports over half of all of the wheat it consumes, the staple which constitutes a third of total calorific intake and nearly half of all protein (Veninga & Ihle, 2018). This makes Egypt very vulnerable to global food price shocks. The years preceding the significant political instability of 2011 were characterised by low domestic yields due to extreme weather, followed by global food price rises (Soffiantini, 2020).

Most Egyptian farming households are categorised as smallholders, with more than 80% of households holding less than 2 hectares (Abdalla et al., 2022). Because of a warm winter climate and access to year-round Nile River waters, farmers can grow a variety of field crops, fruit and vegetables over three seasons (Abdalla et al., 2022; Abdelaal & Thilmany, 2019). Although Egyptian farmers enjoy some of the highest yields globally (Nikiel & Eltahir, 2021), the dominance of smallholder farming has resulted in farming households becoming dependent on mixed livestock-crop farming systems and secondary incomes (Abdelaal & Thilmany, 2019; El Nour, 2015).

Policy has played a major role in farming choices in Egypt. For decades, strong top-down governance has characterised agricultural policy (Bush, 2007). Since the 1980s, market liberalisation attempted to reduce state interventions while maintaining cheap inputs for key staple crops, limiting the production of 'thirsty' crops such as rice and cotton, and, at times, restricting exports of key staples (Fuglie et al., 2020). These governmental policies have been inconsistent, however, with rapidly changing agricultural policy priorities creating instability for farmers and limiting policy impact (Abdalla et al., 2022). One policy priority of the 1990s was the liberalisation of land rental laws, which allowed landlords to set land rents (previously constrained to no more than 7-times the land tax rate) based on free market prices. Furthermore, liberalisation removed the 'tenancy in perpetuity' provided under previous laws. These changes resulted in more than 900,000 tenants losing tenancy (El Nour, 2015). Large headline-grabbing projects have dominated agricultural policy at the expense of investment in low-income farming households (Bush, 2022). The 1.5 Million Feddan Project, a project to reclaim 1.5 million feddan[1] of desert land in the Western Desert and bring it under cultivation, is typical in focusing on large private or state investments. Additionally, it is predominantly operated by either large state or commercial enterprises. The main aim of the 1.5 Million Feddan Project is to reduce Egypt's dependence on imports for key grains, with a minor focus on providing land and income to the low-income, landless, and underemployed section of the population (Bush, 2022; Nour, 2020).

The Egyptian context presents a number of complex social, environmental, and policy challenges. Farm and farmer typology analyses are widely used to support policy design for such challenges through the identification of important socio-environmental, farmer, and farm structural characteristics (Huber et al., 2024). Typologies reveal commonalities within farmer populations, summarise large groups into representative types (Hammond et al., 2020; Shukla et al., 2019), and help in the development and ex-ante analysis of policy options (Nyambo et al., 2019; Rega et al., 2022). They can also focus on relatively neglected aspects such as roles, desires, and goals (Blanco et al., 2015) alongside environmental and structural resources (Huber et al., 2024).

Typology analysis has been widely used to understand and summarise the diversity within smallholder farmers in various contexts (Guarín et al., 2020; Nin-Pratt et al., 2018; Shukla et al., 2019; Sinha et al., 2022), and is a common tool in the assessment of technology adoption (Nin-Pratt et al., 2018; Rega et al., 2022; Sarker et al., 2021; Shukla et al., 2019). Farm household typology analysis would enable a greater understanding of the key characteristics and needs within Egyptian farming households while developing common archetypes, which can be used to define and assess the impact of policy, maximise the benefit derived from positive characteristics of the system, and respond to challenges of climate change.

Several farmer typologies have been developed for the Egyptian context. Most examples in Egypt are limited to small spatial areas (e.g. Aboul-Naga et al., 2022; Alary et al., 2014; Alary et al., 2020) or address a single socioeconomic level (e.g. Martin et al., 2020). These studies usually develop and implement local surveys to delineate typologies, but national-level market panel surveys have been used to produce national typologies (Helmy, 2020; Nin-Pratt et al., 2018). For example, Nin-Pratt et al.

[1] Feddan is the standard unit of agricultural area utilised in Egypt. 1 feddan = 1.038 acres = 4,200 m^2 = 0.42 hectares

(2018) conducted a farming household typology analysis based on 2012 labour market panel survey data. This analysis utilised continuous variables to develop typologies based on resource and environmental characteristics and used these typologies to analyse the impact of different climate change scenarios on agricultural production. Helmy (2020) used the complete labour market panel survey series (1996, 2006, 2012, 2018) to analyse the evolution of livelihood diversification in Egypt. Farming, salaried agricultural labour, and livestock activities were included within diverse livelihood strategies, but the diversity and characteristics of the farmer and farm structures were not specifically investigated. Together, these past studies provide an overview of agriculture's role in Egypt, but do not trace developments within the sector over recent years or their dependencies on contextual factors. In particular, a typology analysis including household economic and social characteristics, for example levels of education, dwelling type and ownership status, is so far lacking.

This study identifies farming household types utilising structural and functional characteristics and determines how these types evolve over time. This is achieved by addressing the following research questions: 1. What are the key structural and functional characteristics that explain variability in Egyptian agricultural households? 2. How can agricultural households be classified from a multivariate analysis? 3. How have these farming typologies evolved through time? 4. What are the possible causes of such changes?

Data

The most recent Egypt Labour Market Panel Surveys (ELMPS), carried out in 2012 and 2018 (Krafft et al., 2021), were used to determine the farmer typology. The 2012 survey was the first year in which detailed enquiries into the specifics of farming households were included. The ELMPS data were reinforced with data from annual governmental statistical reports (CAPMAS - Central Agency for Public Mobilization and Statistics, 2021). These reports included annual, governorate-level agricultural area and production bulletins and water use reports per crop type, and national crop and livestock incomes. These reports were used to calculate values for regional water use per unit area for each crop, crop-specific yields for each governorate, and national income per tonne of crop produced.

The 2012 and 2018 ELMPS included both individual and household questions relating to the socioeconomic conditions of the survey participants. The individual questionnaire included questions on demographic details, such as employment and education. Additionally, a household questionnaire included details of household income and capital, such as off-farm and farm enterprises, remittance, and other household income (Economic Research Forum & Central Agency For Public Mobilization and Statistics (CAPMAS), 2013, 2019).

A summary of the total and farming individuals and households of ELMPS 2012 and 2018 surveys are included in Table 1.

Table 1: Summary of 2012 and 2018 Egypt Labour Market Panel Survey details.

Property	ELMPS 2012 (% of total)	ELMPS 2018 (% of total)
Total number of individuals	49,186	61,231
Total households	12,060	15,746
Farming individuals	9,210 (18.72%)	8,197 (13.39%)
Farming households	1,821 (15.10%)	1,772 (11.25%)

Methodology

We undertook a multivariate analysis on a mixed categorical-continuous dataset of structural and functional characteristics of farming households in Egypt utilising a longitudinal labour market panel survey with datasets for 2012 and 2018. The analysis included removing highly correlated variables, and completing a data reduction approach using a Factor Analysis on a Mixed Dataset to identify variables which describe most of the variation. The key variables were then used to undertake a cluster analysis. Taking advantage of the longitudinal nature of the dataset, it was possible to determine how households present in both surveys changed between clusters.

The first stage of the analysis was data preparation. This included utilising 2012 and 2018 ELMPS and complementary data from various national statistical reports to estimate missing responses and standardise units where necessary, summarising individual responses across each household, and rebasing 2018 monetary values to 2012. Data preparation details are provided in Appendix 1. Variables were chosen from those available to capture functional and structural characteristics of the households, and for consistency with similar typology analyses (e.g. Huber et al., 2024; Nin-Pratt et al., 2018; Sarker et al., 2021; Shukla et al., 2019).

Subsequently, outliers were identified by defining rational limits on certain variables, to account for missing and incorrect data, – see Appendix 1 for more details – reducing the original 3593 cases to 3526. Histograms, given in Appendix 1, were used to visualise the distributions of the continuous variables.

The skewness of all continuous variables was calculated, with skewness greater than 1 and below -1 considered highly skewed and transformed to satisfy normality assumptions in subsequent methods. Box-Cox transformations were carried out using the *'MASS'* R package (Venables & Ripley, 2002). Due to the nature of the agricultural system in Egypt, many variables are highly positively skewed, representing the dominance of subsistence farming.

Correlated variables were identified using the '*hetcor'* function of the *'polycor'* R package (Fox, 2022), which provides Pearson product-moment correlation coefficients between continuous variables, polyserial correlations between continuous and categorical variables, and polychoric correlations between categorical variables. Correlations greater than an absolute value of 0.7 were deemed high and the variables were removed. Variable reduction was then carried out using the Factor Analysis on Mixed Data (FAMD) technique using the *'FAMD'* function of the *'clustMixType'* R package (Szepannek, 2018). FAMD is a combination of Principal Component Analysis and Multi Correspondence Analysis that reduces the number of variables in a mixed dataset whilst maintaining key variability (Nyambo et al., 2019).

To determine the number of clusters, hierarchical clustering on principal components was used. The defined number of clusters were used in the 'kproto' function of the 'clustMixType' R package (Shukla et al., 2019). K-Protoypes is an unsupervised clustering on a mixed data that partitions the data into k clusters, where each data point belongs to the cluster with the nearest centroid (van de Velden et al., 2018). K-prototypes uses a combination of the Euclidean distance for numerical features and the dissimilarity measure for categorical features (Foss et al., 2018).

Results

A total of 43 variables were included in the analysis: 10 nominal variables, 2 ordinal variables and 31 continuous variables. Table 2 gives the mean and standard deviation of the continuous variables and the frequency and percentage of each response for the categorical variables. Figure 1 in Appendix 1 shows the distribution of each continuous variable and the count of each response for categorical variables. Skewness is detailed in Table 5 in Appendix 1. Most continuous variables were highly skewed (-1 > skewness > 1), indicating unequal distribution of resources between households. The most highly skewed variables were the total agricultural area, with a skewness of 59, and total off-farm capital, with a skewness of 50. This high positive skewness is an indication of many very low values for both variables and a small number of very high values. There were two negatively skewed variables – cropping intensity and ratio of owned to rented land – which had a skewness of -0.27 and -0.79, respectively – indicating a prevalence of multiple harvests per year and of land ownership respectively. Categorical variables are in line with expectations for farming households in Egypt, with 87% being male-headed households, higher rates of illiteracy among the heads of households than in the household, and 88% of households being rural.

Table 2: Data summary of typology analysis dataset. This includes the description, variable code, and data type for each variable. Additionally, the means and standard deviation for continuous variables, and count and percentage of each response for categorical variables, are also included.

Variable (unit)	Data Type	Response+	Mean (Standard Deviation)* / Count (%)+
Characteristics of head of household			
Age of head of HH (yr)	**Continuous**		51.07 (13.85)
Sex of head of HH	**Categorical (nominal)**	**1 (male)**	3073 (87.15)
		2 (female)	453 (12.85)
Level of education of head of HH	**Categorical (ordinal)**	**0 (none)**	1957 (55.50)
		1 (primary)	542 (15.37)
		2 (preparatory)	175 (4.96)
		3 (general secondary)	45 (1.28)
		4 (technical secondary -3 years)	531 (15.06)
		5 (technical secondary - 5 years)	23 (0.65)
		6 (middle institute)	36 (1.02)
		7 (higher institute)	18 (0.51)
		8 (university)	184 (5.22)
		9 (postgraduate)	15 (0.43)
HH characteristics			
Size of HH	**Continuous**		4.84 (2.30)
HH region	**Categorical (nominal)**	**Lower Egypt**	1669 (47.33)
		Middle Egypt	863 (24.48)
		Upper Egypt	994 (28.19)
Urban/rural	**Categorical (nominal)**	**1 (urban)**	413 (11.71)
		2 (rural)	3113 (88.29)
Housing type	**Categorical (nominal)**	**1 (apartment)**	1682 (47.70)
		2 (more than one apartment)	46 (1.30)
		3 (villa/house)	542 (15.37)
		4 (village house)	1063 (30.15)
		5 (one room or more in same unit)	140 (3.97)
		6 (one independent room or more)	49 (1.39)
		7 (cottage/tent)	2 (0.06)
		8 (cemetery)	1 (0.03)
		9 (other/basement)	1 (0.03)

Housing ownership or rental type	**Categorical (nominal)**	**1 (owned)**	2868 (81.34)
		2 (condominium)	148 (4.20)
		3 (rent, unfurnished)	33 (0.94)
		4 (rent, furnished)	6 (0.17)
		5 (rent, new law)	20 (0.57)
		6 (fringe benefit/grant)	451 (12.79)
Highest level of education within HH	**Categorical (ordinal)**	**0 (none)**	1369 (38.83)
		1 (primary)	455 (12.90)
		2 (preparatory)	256 (7.26)
		3 (general secondary)	71 (2.01)
		4 (technical secondary -3 years)	820 (23.26)
		5 (technical secondary - 5 years)	30 (0.85)
		6 (middle institute)	64 (1.82)
		7 (higher institute)	32 (0.91)
		8 (university)	399 (11.32)
		9 (postgraduate)	30 (0.85)
Type of internet access	**Categorical (nominal)**	**1 (dsl)**	177 (5.02)
		2 (usb modem)	30 (0.85)
		3 (dial-up)	107 (3.03)
		4 (through neighbours)	59 (1.67)
		5 (none)	3147 (89.25)
		6 (other)	6 (0.17)
Total HH income per capita (2012 EGP)	**Continuous**		11695 (29964)
Agricultural details			
Agricultural capital			
Area of agricultural land (feddan)	**Continuous**		3.15 (106.11)
Advanced agricultural equipment	**Categorical (nominal)**	**1 (yes)**	642 (18.21)
		2 (no)	2884 (81.79)
Intermediate agricultural equipment	**Categorical (nominal)**	**1 (yes)**	876 (24.84)
		2 (no)	2650 (75.16)
Basic agricultural equipment	**Categorical (nominal)**	**1 (yes)**	562 (15.94)
		2 (no)	2964 (84.06)
Number of cattle	**Continuous**		0.91 (1.29)
Number of sheep and goat	**Continuous**		0.77 (3.47)
Total livestock capital (2012 EGP)	**Continuous**		16430 (20583)
Agricultural income and expenses			
Total income from crops (2012 EGP)	**Continuous**		17138 (41848)

Income from animal products e.g. poultry, honey, dairy (2012 EGP)	**Continuous**		130.75 (1347)
Income from rent of land (2012 EGP)	**Continuous**		734.02 (3784)
Cost of land rental (2012 EGP)	**Continuous**		1101 (5995)
Total agricultural income (2012 EGP)	**Continuous**		18032 (41870)
Agricultural resource use			
Cropped area (feddan)	**Continuous**		1.53 (2.75)
Total agricultural water use (m^3)	**Continuous**		5189 (10147)
Number of HH agricultural workers	**Continuous**		1.76 (1.27)
Number of hired agricultural workers	**Continuous**		0.59 (3.21)
Agricultural efficiency			
Cropping intensity	**Continuous**		1.31 (0.82)
Ratio of crop earnings to crop income	**Continuous**		0.32 (0.34)
Cropping income per unit area (2012 EGP/feddan)	**Continuous**		9743 (11115)
Ratio of high-value to field crop	**Continuous**		0.06 (0.20)
Ratio of crop production sold at market	**Continuous**		0.30 (0.32)
Ratio of owned to rented land	**Continuous**		0.68 (0.45)
Water use per unit area (m^3/feddan)	**Continuous**		2666 (1974)
Livestock capital per unit area (2012 EGP/feddan)	**Continuous**		26951 (51420)
Ratio of hired agricultural workers to household workers	**Continuous**		0.09 (0.24)
Ratio of agricultural to total income	**Continuous**		0.49 (0.37)
Non-agricultural income and capital			
Total HH income from off-farm employment (2012 EGP)	**Continuous**		7000 (22004)
Income from remittance (2012 EGP)	**Continuous**		936.41 (6527)
Other income (2012 EGP)	**Continuous**		12339 (56589)
Total non-agricultural income (2012 EGP)	**Continuous**		18032 (41870)
Total non-agricultural capital (2012 EGP)	**Continuous**		2362 (41180)
Survey year	**Categorical (nominal)**	**12** **18**	1806 (51.22) 1720 (48.78)

* Mean and standard deviation for continuous variables.

+ Response, count and percentage for categorical variable

Correlation

After the transformation of the highly skewed continuous variables, a correlation analysis was carried out on the transformed variables. Figure 1 shows the correlation plot for all variables. Eight variables had a correlation greater than 0.9. The ratio of hired agricultural workers to household workers had a correlation of 0.99 with the number of hired agricultural workers. Additionally, the cropped area and total water use were also highly correlated (0.95). Similarly, the total crop income and total water use showed a high degree of correlation (0.91). Finally, the total capital from livestock and livestock capital per unit area returned a high correlation value (0.96). Four variables had a negative correlation: the cost of land rental and ratio of owned to rented land had a correlation of -0.75; the ratio of agricultural income to total income and off-farm income had a correlation of -0.77. A further 11 variable pairs had correlations between 0.7 and 0.9. A full list of correlated variables and the degree of correlation has been included in Table 6 in Appendix 1.

For each correlation pair, a single variable was removed. The following 10 variables were removed, leaving a total of 33 variables for the factor analysis and clustering activities: total water use; total income from cop production; number of cattle; total off-farm income; income from crop production per unit area; total livestock capital; number of hired farm workers; level of education of head of household; cost of land rental; total cropped area.

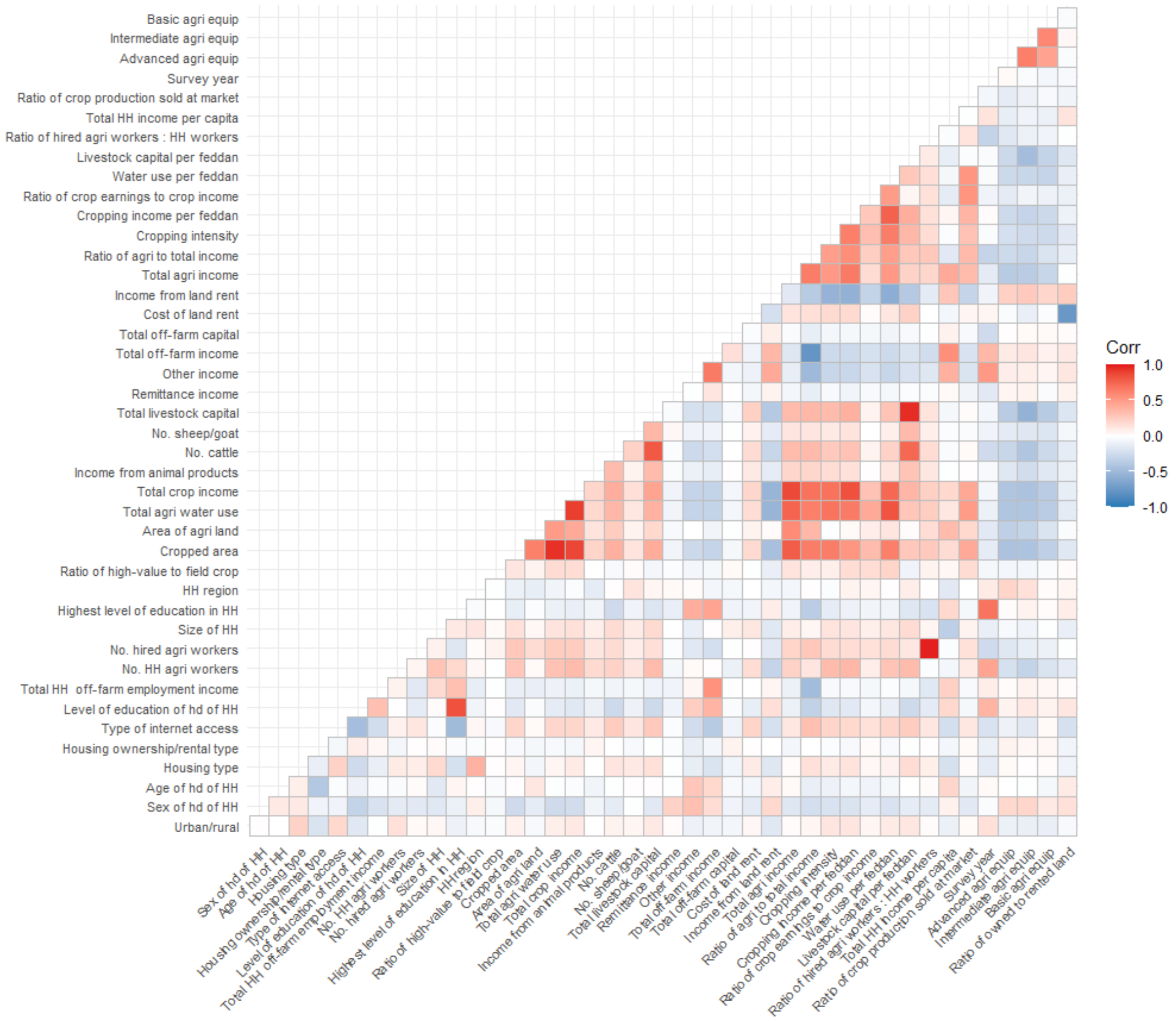


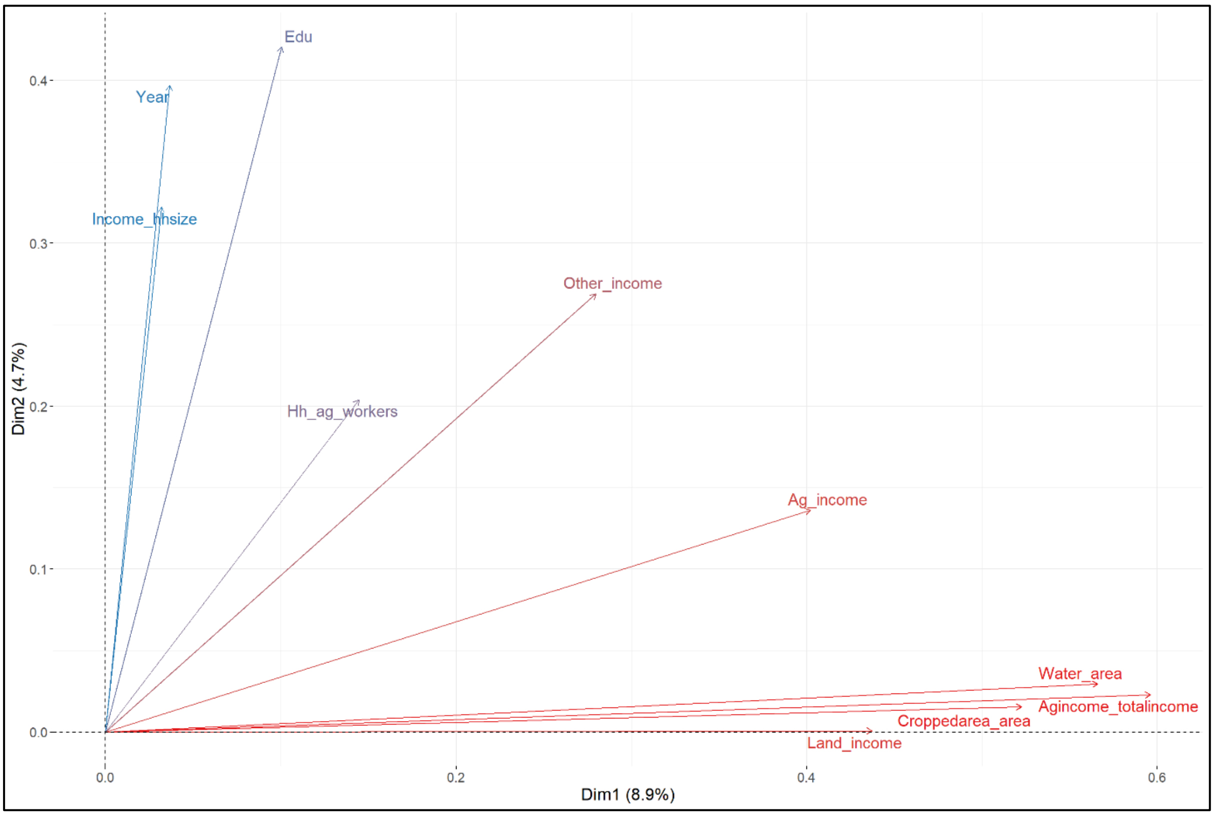
*Figure 1: **Correlation plot**: The heterogenous correlation between all variables after transformation of highly skewed variables. The darkness of the colour represents the degree of correlation, with darker colours representing a greater degree of correlation. Red represents positive correlation and blue represents negative correlation. White is a correlation of zero. Key: HH=household, hd=head, agri=agricultural, equip=equipment, No.= number of, feddan=0.42 hectares.*

Factor Analysis on Mixed Data

The factor analysis was carried out on the reduced set of transformed variables and returned eigenvalues detailed in Table 7 of Appendix 2. As per the Kaiser criterion, dimensions with eigenvalues above 1 were retained. Therefore, 22 dimensions were retained, explaining a cumulative variance of 59%. Table 8, in Appendix 2, gives the contribution that each variable makes to the dimension of the FAMD. Contributions above 10% are highlighted in green, and the corresponding variables are highlighted in yellow. Figure 2 shows the eigenvectors for dimension 1 and 2, and 1 and 3 of the factor analysis, indicating the relative contributions of each variable to each of the dimensions. The total variance explained by dimensions 1 and 2 is 13.6%. Cropping intensity, water use per unit area, and the ratio of agricultural to total income have the highest loading for dimension 1, whilst year of survey, the highest level of education in the household, and total household income per capita were the largest contributors to dimension 2.

Based on the factor analysis, variables contributing less than 10% to the first 22 dimensions of the factor analysis were removed. A total of 13 variables were removed, leaving 20 variables for the cluster analysis. The remaining variables are those highlighted in yellow in Table 8 of Appendix 2.

a)


Edu
Year
Income_hhsize
Other_income
Hh_ag_workers
Ag_income
Water_area
Agincome_totalincome
Croppedarea_area
Land_income
Dim2 (4.7%)
Dim1 (8.9%)
0.4
0.3
0.2
0.1
0.0
0.0
0.2
0.4
0.6

b)

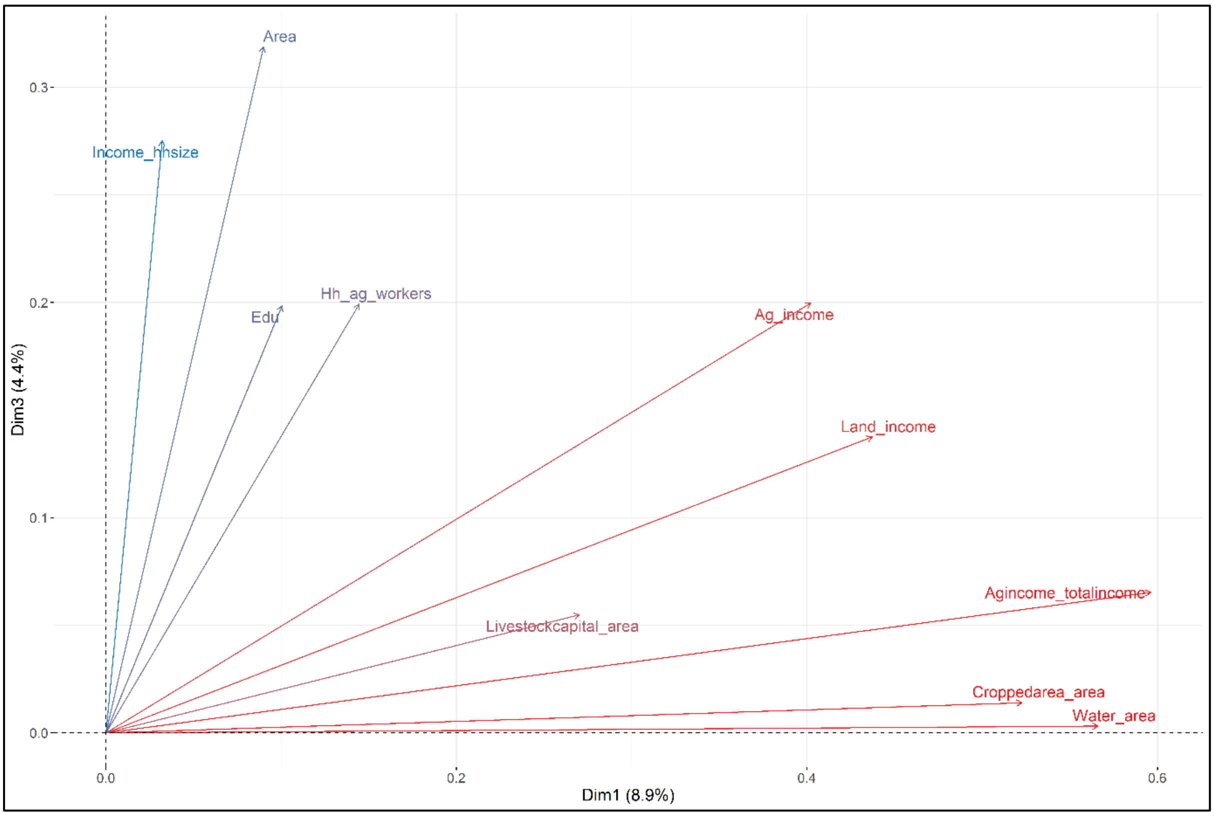
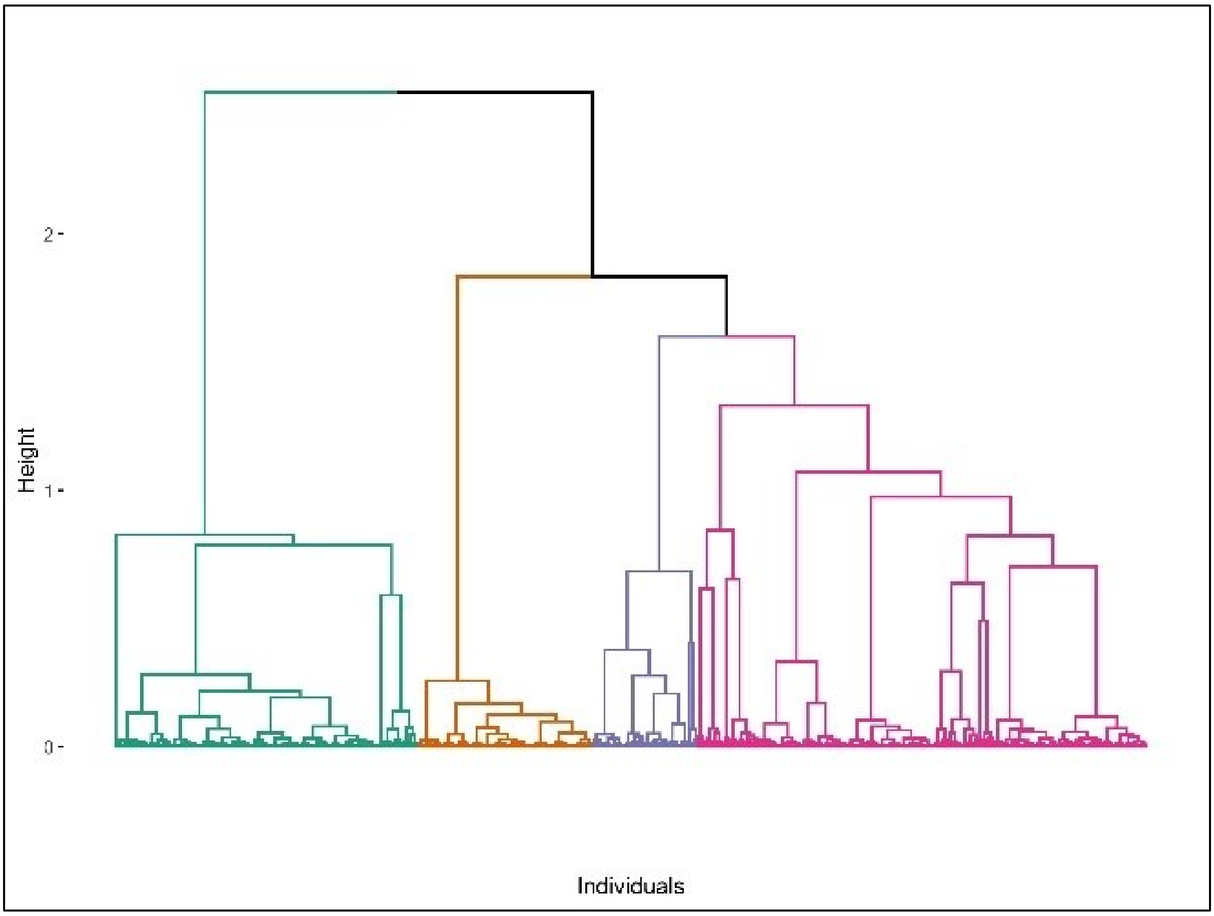

Area
Income_hhsize
Edu
Hh_ag_workers
Ag_income
Land_income
Agincome_totalincome
Livestockcapital_area
Croppedarea_area
Water_area
Dim3 (4.4%)
Dim1 (8.9%)
0.3
0.2
0.1
0.0
0.0
0.2
0.4
0.6

*Figure 2: **Results from the Factor Analysis on Mixed Data**: The ten variables which contribute the most to a) dimensions 1 and 2, b) dimensions 1 and 3. The length of the arrow shows the eigenvector, a degree of contribution. The colour of the arrow demonstrates the extent to which it contributes more to the dimension 1 (red) or the y-axis dimension (dimension 2 or 3) (blue).*

Hierarchical Clustering on Principal Components

The subsequent stage of the analysis entailed the completion of hierarchical clustering on principal components (HCPC), to determine the appropriate number of clusters for the cluster analysis. To make this possible, categorical variables were converted to binary coding, with each response becoming a new variable and zero or one used to identify which observation is included in this response. A principal component analysis (PCA) was carried out on the converted data. A total of 20 components met the Kaiser Criterion. Hierarchical clustering was carried out on the first 20 components of the PCA. Figure 3 shows the cluster dendrogram and inter-cluster inertia gain plot for the HCPC. A review of both diagrams in Figure 3 shows that there are between 2 and 5 appropriate clusters. Only utilising two clusters was deemed too coarse to allow for sufficient description of the variability within the sample population. The relative difference in inter-cluster inertia for 3, 4 and 5 clusters is similar, with 4 being slightly greater than 5 and 3. The "NbClust" R package was used to assess the appropriate number of clusters using 23 different indices (Charrad et al., 2014). Most indices returned 4 as the most appropriate number of clusters. Appendix 5 includes details of results for 3 and 5 clusters as a comparison to the results presented below.

a)



b)

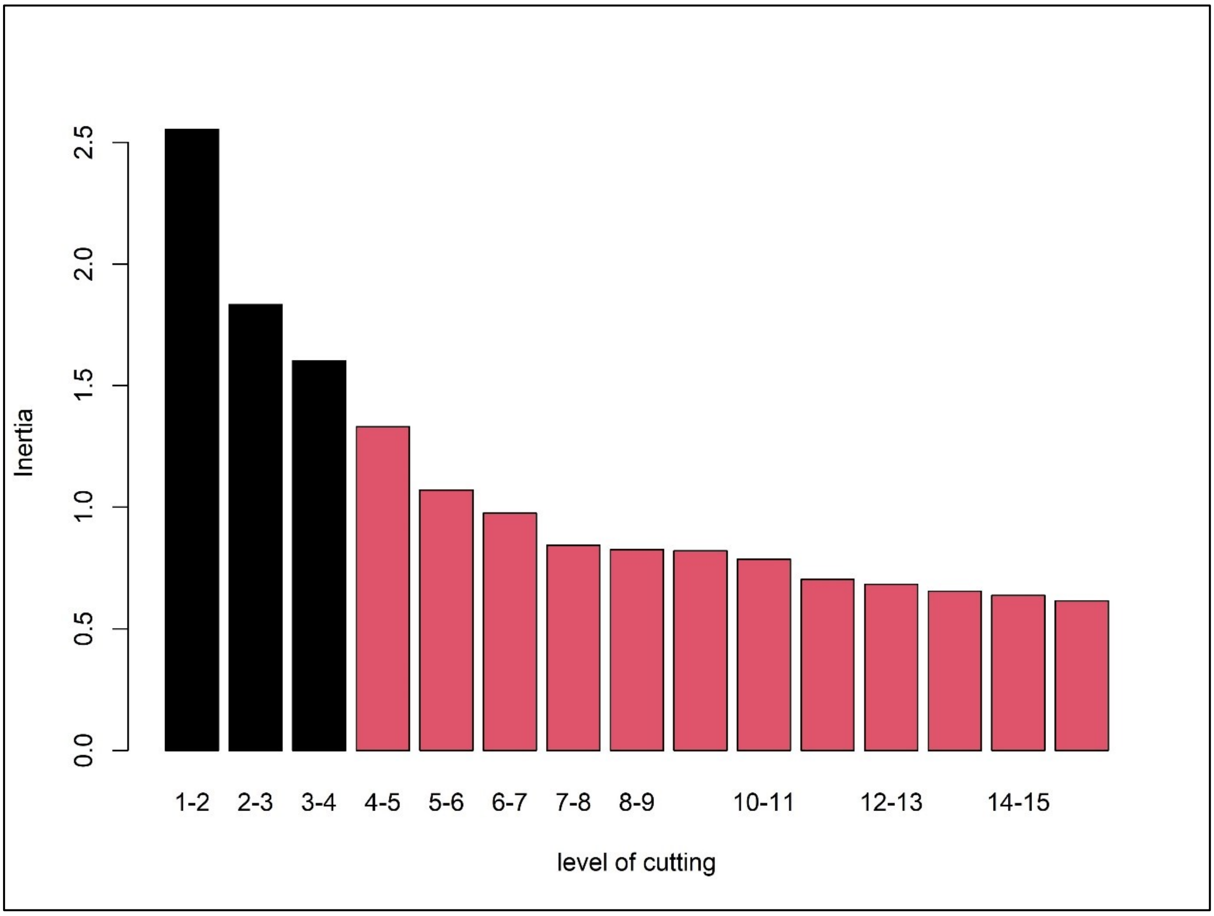


*Figure 3: **Hierarchical Clustering on Principal Components results**: a) Cluster dendrogram derived from the Hierarchical Clustering on Principal Components (HCPC) of survey individuals. This is derived by conducting a Principal Component Analysis of continuous variables and binary coded categorical variables, identified in the FAMD, using Ward's criterion. Four different clusters are highlighted in different colours. b) The inter-cluster inertia gain, showing the drop in inertia between each pair of cluster number. For example, the first bar shows the difference in inertia between having a single cluster and having two clusters. The difference in colour highlights the relative drop in inertia of 4 clusters.*

K-prototype clustering

The final stage of the analysis entailed the use of k-prototype clustering on the dataset post-FAMD to determine the final clusters. There is a need to stipulate the number of clusters for this methodology. As per the result of the HCPC, 4 clusters were used. Table 3 includes the number and percentage of households in each cluster. Figure 4 includes the percentage of each response for each cluster for categorical variables. Additionally, Figure 5 includes the constituent components and total value of agricultural and off-farm income for each cluster. Finally, Figure 6 is a radar chart of key efficiency indicators for each cluster. The efficiency indicators were scaled based on the range of each variable and the mean was calculated for all cases. The results are summarised in detail in the emergent clusters section below. The emergent cluster names were assigned based on their key differentiating attributes.

Table 3: Number of households in each cluster and percentage each cluster represents from the whole sample.

Cluster	Number of households	Percentage of households
1 - Specialised	650	18
2 - Village	1085	31
3 - Diversified	1130	32
4 - Landlord	661	19

Emergent clusters

Cluster 1: Specialised farming household

The **specialised farming household** type is highly specialised, generating 62% of their income from agricultural activity, compared to an overall mean of 49%. It exhibits the greatest profitability – 51% earnings to income - and has the highest average cropped area (2.37 feddan). This household type also has the highest ratio of high-value to field crops, with 15% of crops produced being high-value, (the mean across all households is 6%). Additionally, **specialised farming households** sell 49% of produced crops and use the remainder for household consumption. This household type also uses the most water per unit area at 5,406 m^3/feddan. Specialisation is focused on crop production, with livestock capital per feddan being the lowest of the three household types focused on agricultural activity (17,888 EGP). However, this household type generates the most income from the sale of animal products, with a mean annual income of 187 EGP.

The off-farm income of this household type is dominated by off-farm employment (6,335 EGP) and governmental support (5,874 EGP). The **specialised farming household** receives the second highest income from remittances (1,182 EGP), 26% higher than the overall mean of 936 EGP. However, the **specialised farming household** has lower levels of education, with 71% having no one with a secondary education, second only to the village farming household. Additionally, the household type has high rates of living in apartments (64%; compared to an average of 48%). This household type is also less likely to live in a village house (21% compared to the 30% average). The dwelling type may be due to a high geographical skew; 74% of **specialised farming households** reside in Lower Egypt which is more densely populated. This household type is the smallest, including only 18% of survey participants. Finally, 69% of **specialised farming households** are from the 2012 survey.

Cluster 2: Village farming household

This cluster is characterised by a very high rate of village-dwelling, with 60% living in village houses, compared to a mean of 30%. Agricultural income contributes 70% to the total household income, well above the survey average of 49%. However, the mean total agricultural income is 18,115 EGP, the second lowest of the four household types. The **village farming household** has the highest level of livestock capital (21,437 EGP). Although this household type has the highest cropping intensity (1.64), it has the lowest income per unit area (10,999 EGP per feddan). This can probably be explained, in part, due to the **village farming household** being less likely to grow high-value crops – 6% of crops grown are high-value on average – and the lowest water use per unit area between farming types that grow crops (2,454 m^3/feddan). This household type employs the most external workers compared to the number of household members who work on the household's farm (0.16), further highlighting the specialisation in agricultural activities.

The **village farming household** type has the lowest level of education, with 78% of heads of households not having completed primary education and 93% not having completed secondary education. For the household, levels of education are also the lowest amongst the household types, with 90% of households having no one who has completed a secondary education. The **village farming household** type has the lowest access to internet – 96% of households are without any internet access. This household type, with an average of 5.54 people, also has the largest average household size. In terms of off-farm income, off-farm employment and support and benefits from the government and other organisations contribute 4,291 EGP and 2,490 EGP annually to the total off-farm household income of 9,643 EGP. The lower income and high dependence on agricultural income contribute to this household type having the lowest household income per capita (5,987 EGP). The **village farming household** type was far more common in 2012 than 2018, with 84% of households in this household type coming from 2012. Geographically, the **village farming household** cluster is skewed towards Middle Egypt – 63% compared to an overall percentage of 24%.

Cluster 3: Diversified income household:

This household type has the most diversified income, with 46% of income from agricultural activities and the remainder from off-farm income. The 23,098 EGP annual agricultural income is mostly generated from crop production (22,778 EGP). The **diversified income household** type spends the most on land rental (1,341 EGP). Of the 3 household types which participate in crop production, this household type sells the least at market; only 32% of produced crops. However, the crop income per feddan is the highest of any household (13,343 EGP/feddan). The **diversified income household** type is most dependent on household labour and least on hired labour for farming activities, with 2.47 household farm workers and 0.26 hired workers per household. Additionally, this household type has more sheep and goats than cattle, with a mean of 0.78 head of cattle per household and 0.96 head of sheep or goats per household; a pattern that is unique among crop-producing household types.

The **diversified income household** type has the highest level of education, with 50% of households having at least one person who has completed a 3-year technical secondary education and 13% with university undergraduate or postgraduate education. Additionally, this household type has the lowest level of illiteracy among heads of household as only 37% have not completed primary education. Regarding off-farm income, the **diversified income household** type generates a total of 25,439 EGP per year. This is made up primarily from off-farm employment (8,280 EGP) and governmental support (8,062 EGP). This household type is much more common in 2018, with 88% coming from the 2018 survey.

The results, in Figure 5 and Figure 6, show that the **diversified income household** type is similar to the **village farming household** type in terms of income, and agricultural efficiency**.** However, the difference in degree of dependence on agricultural income, dwelling type, location, education level, and year of survey, are important differences which warrant maintaining two household types for these households.

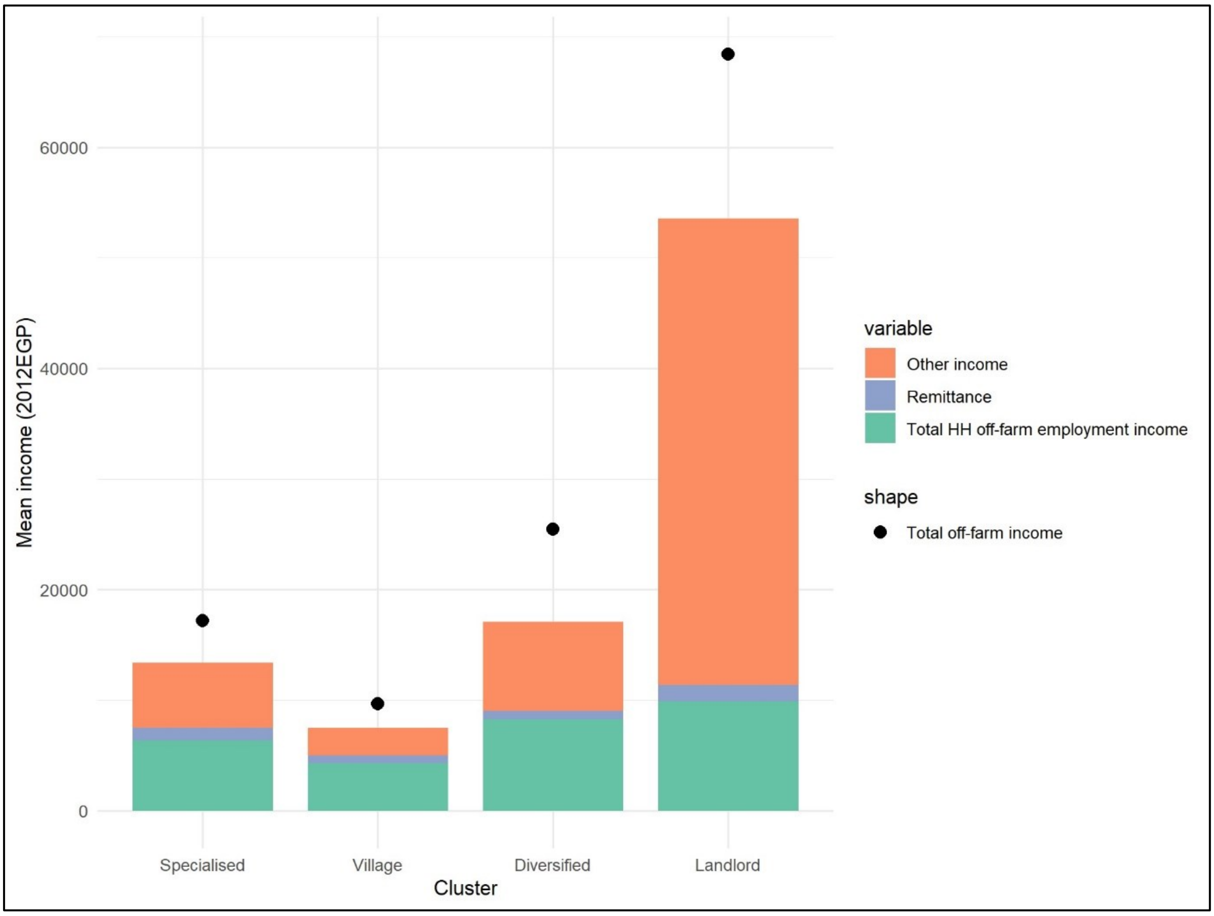
Cluster 4: Landlord household

This household type has a mean income per member of household of 21,118 EGP, the highest of any household. Additionally, the cluster generates 3,273 EGP per year from land rental, ten times that of any other household type. This is further highlighted by the absence of any cropped area and, therefore, no income from crop production and no crop water use. The 7% of income derived from agricultural activities comes from land rental and the sale of animal products. Additionally, this household type has low agricultural capital, with the lowest mean livestock capital of (5,266 EGP) and the lowest access to basic, intermediate, and advanced agricultural equipment – with 3.5%, 5.8%, and 2.9% having access to each of those levels of equipment, respectively. The **landlord household** is mostly dependent on government support, deriving 42,174 EGP of a total of 68,399 EGP of off-farm income from pensions and other governmental support. Additionally, this household type earns the most from household off-farm employment, with a mean income of 9,914 EGP.

The **landlord household** type is more likely than others to have a female head – 24% are female-headed compared to an overall survey percentage of 13%. Although this household type has the highest level of higher education – 14% of household heads have a university or postgraduate education and 22% of households have at least one person who has a university or postgraduate education – 50% of households have no one who has completed a secondary education. This appears high, but is the second-lowest among the household types. Furthermore, 61% of this household type live in apartments, compared to 48% of the overall surveyed households. The **landlord household** type has the highest access to the internet (23%). Additionally, this household type is the most likely to be from an urban area, with 18% coming from urban areas compared to an overall percentage of 11%. The temporal and geographic distribution of the households in this household type is similar to the overall sample.

*Figure 4: **A summary of categorical variables for each cluster:** The charts show the percentage of each response. Key: HH=household, agri=agricultural, equip=equipment.*

a)


60000
40000
20000
0
Mean income (2012EGP)
Specialised
Village
Diversified
Landlord
Cluster
variable
Other income
Remittance
Total HH off-farm employment income
shape
Total off-farm income

b)

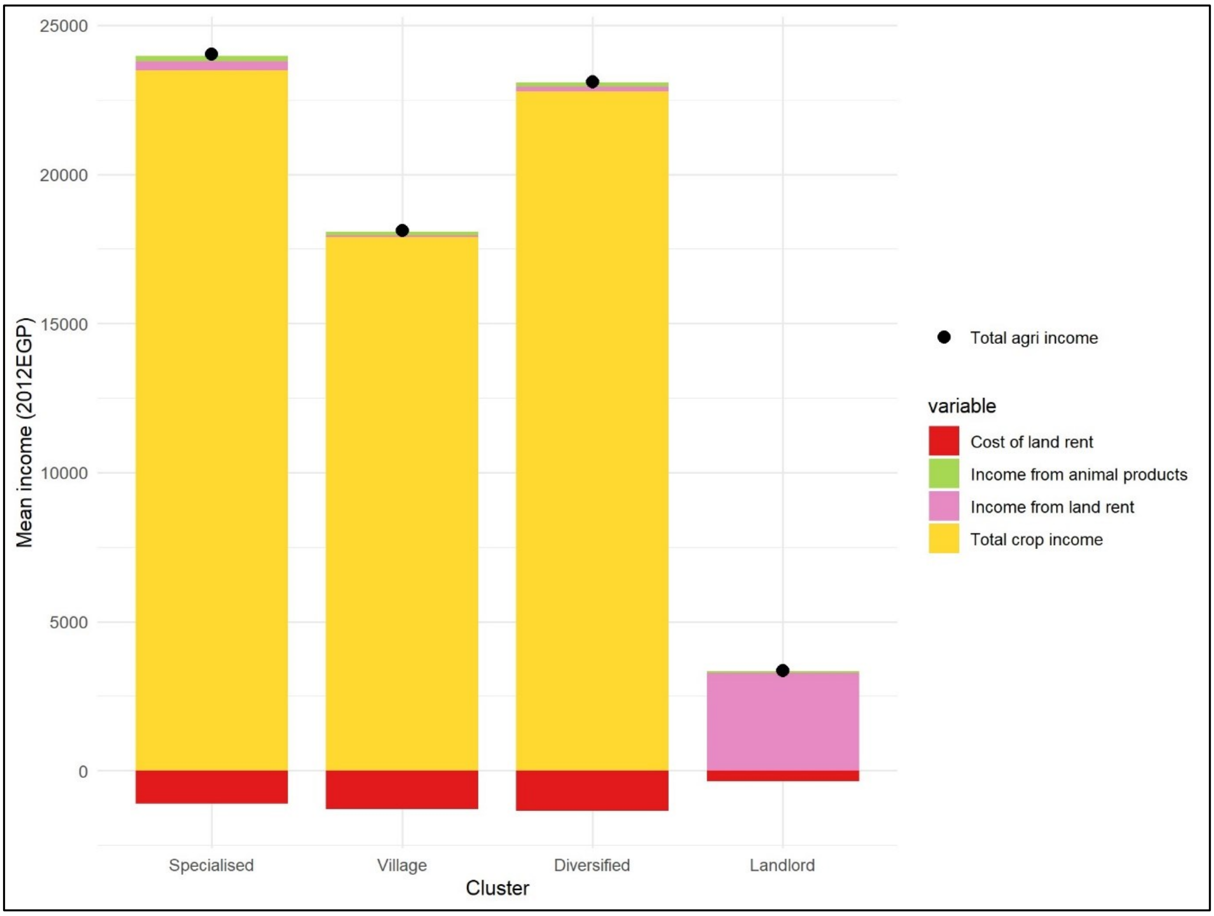


*Figure 5: **Breakdown of agricultural and off-farm income for each cluster:** a) The mean income per household type for agricultural income, including constituent parts and the overall mean. b) The mean income per household type for off-farm income, including constituent parts and the overall mean. Key: agri=agricultural, HH=household*

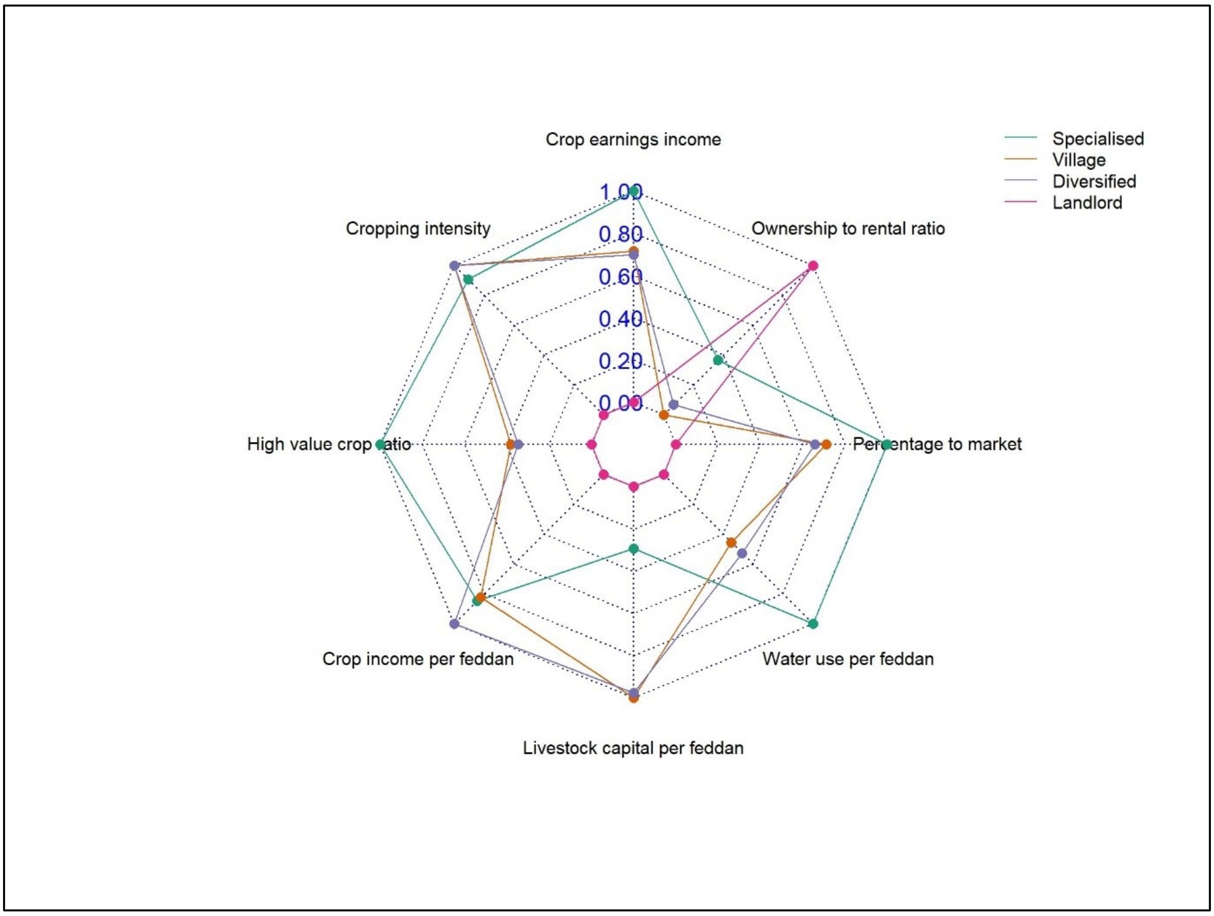


Figure 6: ***Radar chart of agricultural efficiency:*** *The ratio of crop earnings to crop income, the cropping intensity, ratio of high value to field crops, the crop income per unit area, livestock capital per unit area, water use per unit area, percentage of crop sold at market, ratio of ownership to rental of land. All variable have been standardised by range and the cluster mean for each variable is included in the chart.*

Cluster evolution

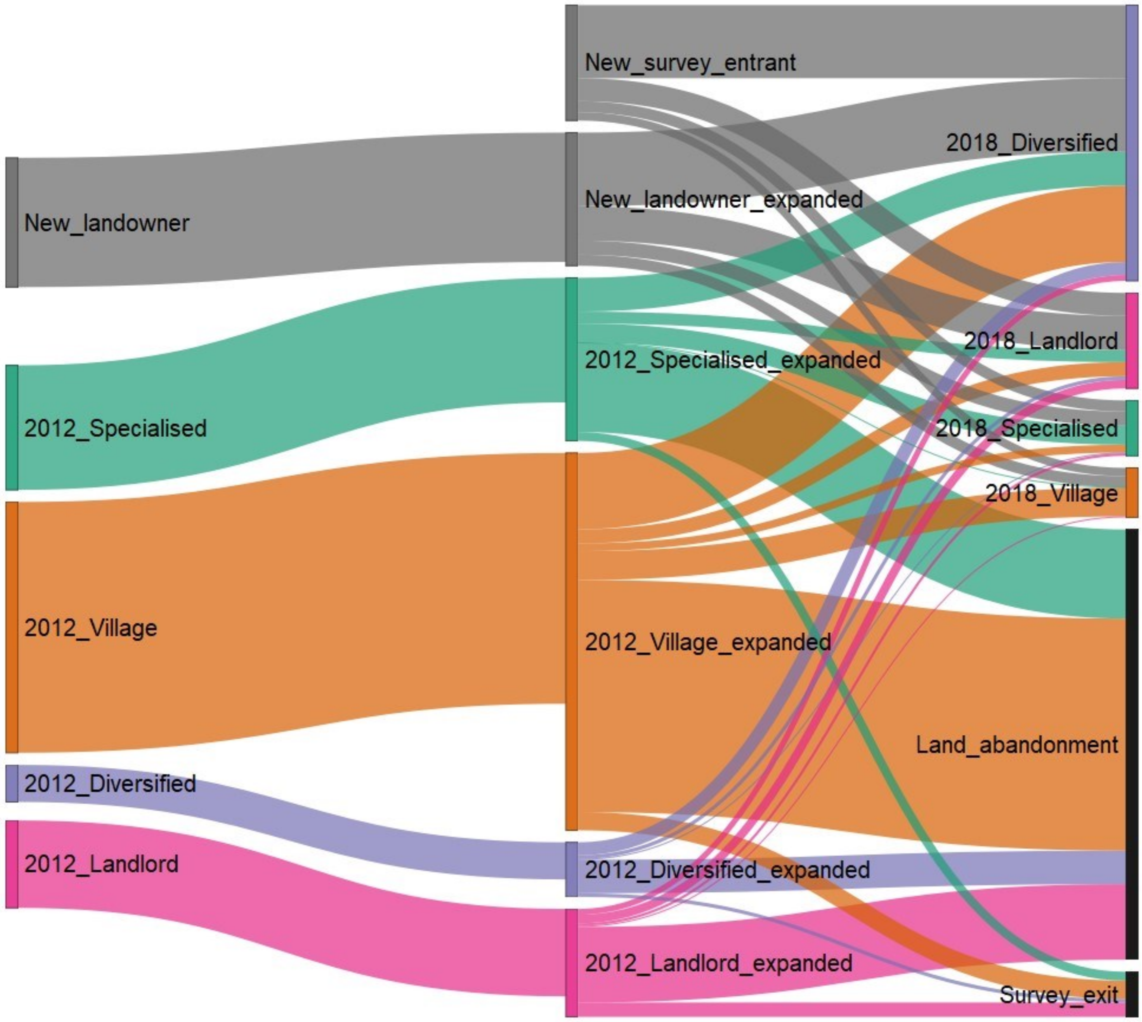


Figure 7: ***Sankey plot of the transition between household types:*** *The transition of household clusters from 2012 (left) through the expansion of the 2012 households due to household members establishing secondary households between 2012 and 2018 (middle) and the 2018 household types (right). "New_landowner" are 2012 participants in the ELMPS that only became farming households in 2018 ELMPS. "Survey_exit" refers to households which exited the survey after 2012. "Land_abandonment" are households which were farming households in 2012, remain in the ELMPS but are no longer farming. "Specialised" refers to* ***Specialised farming household,*** *"Village" refers to* ***Village farming household****, "Diversified" refers to* ***Diversified income household****, and "Landlord" refers to* ***Landlord household.***

Utilising the 2018 ELMPS, it was possible to identify the previous household IDs and determine how households transitioned between types. Figure 7 shows the Sankey diagram from this analysis. A total of 163 (4.7%) farming households participated in the 2012 ELMPS but did not in the 2018 round of the survey, while 417 (12%) were new entrants into the ELMPS in 2018 and did not participate in 2012. A further 481 of the 2018 households were not undertaking agricultural activities in 2012 but were in 2018. Abandonment of agricultural activities was high, with 45% (1,554) of households from 2018 abandoning agricultural activity having come from households that participated in them in 2012.

In terms of household type evolution, 59% (530) of all new landowners (both new entrants to the survey and those households which are new farming households) were part of the **diversified income household** type in 2018. Additionally, there was a marked reduction in the number of households in the **village farming household** type as this household type reduced from 50% of 2012 households to 10% of 2018 households. There was also a reduction in the **specialised farming household** type. This household type reduced from 25% of 2012 farming households to 12% of 2018 farming households.

Table 4 below and Figure 7 detail the expansion of households. It shows the number of households in each household type in 2012 and 2018. For example, the 906 households in the **village farming household** type in 2012 became 1363 households in 2018 due to household splitting as members of the household move out to, for example, begin families or for work. This explains, to some extent, the high level of abandonment of agricultural activity. The total number of unique 2012 households which had a subsidiary household in 2018 which abandoned agricultural activity is 1098. Of these 1098 unique households, 858 had no households in 2018 which carry out agricultural activities. The **village farming household** and the **diversified income household** types exhibit the greatest rate of household expansion at 50% and 47%, respectively. In addition to household expansion, household size appears to be reducing. The **village farming household**, which is predominantly from the 2012 survey, has the largest household size, whilst **landlord household** and the **diversified income household**, which are slightly and very skewed towards 2018 respectively, have the lowest household size.

*Table 4: Total number of households in each household type in 2012 and the households derived from those households in 2018. For example, the 712 households in the **Village farming households** in 2012 become 1104 households in 2018 due to the household splitting as members of the household began families or moved for work. The **new landowner** are households which were present in both the 2012 and 2018 surveys, did not have agricultural activity in the 2012 survey but did in 2018.*

	No. 2012 households	Household expansion
Specialised farming household	450	589
Village farming household	906	1363
Diversified income household	134	197
Landlord household	316	390
New landowner	467	481

Total	2273	3020

Discussion

Abandonment of agricultural activities

The abandonment of farming as a means of livelihood has been widely studied in developed countries but is relatively unstudied in developing country contexts (Ahmad et al., 2020). Examples where it has been studied for low-income, smallholder contexts (e.g. Helmy, 2020; Shukla et al., 2019; Valbuena et al., 2014) highlight lower resources and income as being a key driver for exiting farming. In Egypt, Helmy (2020) demonstrated that farming households were abandoning farming activity at a high rate: 40% of households included some farming activity in 2006 but only 14% in 2019. This trend is generally reflected in the work presented here, with a rate of abandonment of agricultural activities of 45% in the observations overall. Additionally, the ELMPS data reinforce this conclusion as the percentage of households participating in agricultural activities in the surveys went from 15%, in 2012, to 11%, in 2018 (Economic Research Forum & Central Agency For Public Mobilization and Statistics (CAPMAS), 2013, 2019). As this is representative of the labour market, it would suggest that 4% of the households stopped working in agriculture during this period. An analysis of farming household typologies in the Himalayas identified different climate change adaptation strategies (Shukla et al., 2019) and a clear trend that the least diversified and lowest-resourced household types were the most likely to abandon agricultural activities. This is represented in this analysis in the dramatic reduction of the **village farming household** type, the one most dependent on agricultural income and with the lowest income per capita, between 2012 and 2018. It is not clear from this analysis what was the extent of land abandonment, but it is clear that a large proportion of households no longer depended on agricultural activities for their livelihoods.

Subedi et al. (2022) conducted a systematic literature review of global land abandonment and identified biophysical, economic, regulatory, and socio-political characteristics to be key causes of abandonment. The most common causes discussed in the literature were accessibility of farm, migration and depopulation, farm income, and off farm employment. A review of land abandonment in the Mediterranean region identified similar causes for abandonment (Quintas-Soriano et al., 2022). The lowest income household type – **village household** – exhibited the highest rate of abandonment of agricultural activities, demonstrating that low farm income is a contributor to abandonment of agricultural activities.

The two surveys used here were conducted in the context of the post-Arab Spring era. There is evidence that this period of instability saw a rapid rise in urbanisation, potentially explaining the extent of the abandonment of agricultural activities in the results. An analysis of the satellite data for Lower Egypt showed an average rate of urban expansion between 2012 to 2017 of 60 km^2/year, with a loss of cropland between 2010 and 2011 – the period of the Arab Spring – of 1.63% (502.21 km^2) (Badreldin et al., 2019). This is mirrored in the review of land abandonment, which highlights political instability and collapse of political systems as a cause of abandonment of agricultural activities (Subedi et al., 2022).

Explanatory variables

Resource use efficiency, such as water use per unit area, cropping intensity, and the percentage of total income derived from agricultural activity, were the main variables contributing to the principal dimension of the FAMD. Additionally, household properties such as household education level, dwelling type, and total household income per capita are key to explaining the variability within the farming households. Resource endowment is commonly a key dimension in farming household typologies (Falconnier et al., 2015; Sarker et al., 2021; Shukla et al., 2019), with higher resource endowment resulting in greater efficiency and productivity. However, in this analysis, the **village farming household**, which has the greatest livestock capital, land area, and cropping intensity, has the lowest income per unit area.

Characteristics of the head of household, most notably their age and level of education, are key descriptors of variation between household types. Unlike (Shukla et al., 2019), for example, who demonstrates that household types with high resource endowment have older heads of household, this analysis does not identify age as a key descriptor of the differences between household types. However, a farming typology analysis in Bangladesh showed that age did not improve the adoption of technology (Sarker et al., 2021). However, the education level of the head of household is an important difference between the different household types in this analysis. This is similar to the results of the typology analysis in Beni Suef by Martin et al. (2020), which identified education as a key indicator of income diversification.

The degree of livelihood diversification is a key differentiator between the different household types. The results showed that **diversified income household** types had a high degree of diversification. Martin et al. (2020), who undertook a typology analysis of smallholder dairy farmers in Beni Suef (a governorate in Middle Egypt), identified the greatest income diversification among poor farming households, with the very poor and the rich diversifying less. This is similar to results here, where the **village farming household** and **landlord household** – the lowest and highest income household types, respectively – were highly dependent on farm and off-farm income, respectively. Martin et al. (2020) propose that low educational or material resources limit the ability for income diversification. This is similar to the results of the clusters identified in this analysis, where the **village farming household** type has the lowest level of education and is the most dependent on agricultural income. However, the household type with the lowest land resource – **diversified income household** – has the lowest dependence on agricultural income of the three household types which produce crops. The increase in the **diversified income household** in 2018 compared to 2012 would suggest that fewer households depend on agricultural income, with more utilising off-farm income, such as income from off-farm employment, to meet household needs.

Gender

This research considered gender by including the sex of the head of the household amongst the analysis variables. Female-headed households are not common in Egypt, as is seen in the results. The **landlord household** type, which has 24% female headed households, compared to around 10% in other household types, was less likely to participate in crop production, and was more dependent on income from land rental. This may be in part due to social norms about physical labour and single women participating in male only spaces. An investigation of female participation in irrigation activities in Egypt showed that women from lower-income female-headed households were likely to participate in irrigation activities out of necessity due to lack of alternative income and the absence of means or the support for someone else to do it (El Garhi et al., 2019). The higher representation of female-headed households in the **landlord household** type is notable because these households have a greater average income per capita. Most studies of female-headed households in Egypt suggest that the majority of female-headed households are less well-off than male-headed households, often with higher rates and deeper levels of poverty (AbdelLatif et al., 2019). This analysis suggests that this is not the case, at least amongst farming households.

Limitations

This analysis utilised a large, national labour market panel survey dataset. However, several typology analyses include more detailed questions on attitudes, views, and perceptions (Hien et al., 2014; Sarker et al., 2021). This can be particularly useful when trying to understand technology adoption or climate change adaptation strategies. Additionally, a long-term longitudinal survey enables the identification of clear trends in the evolution of household types (Falconnier et al., 2015). This analysis would benefit from being repeated using a longer time series and more survey responses relating to attitudes and perceptions to technology adoption and climate change adaptation. Another limitation of this study is that the survey is designed to be nationally representative of the labour market and demographic characteristics (Krafft et al., 2021; Nin-Pratt et al., 2018) and not necessarily of farming characteristics, such as the crops grown, and access to agricultural equipment. Due to the dataset size, it may be representative of the agricultural sector in Egypt, however, a dedicated survey that specifically attempts to represent the agricultural sector may provide more representative results. What is not specifically clear from these results is to what extent the abandonment of agricultural activities directly relates to abandonment of land.

Conclusion

Egyptian agriculture faces several resource constraints which are exacerbated by climate change and continued population growth. Farm and farmer typology analyses are a useful tool to identify key characteristics and describe the heterogeneity within a diverse population whilst maintaining a manageable number of archetypes. This work utilises labour market survey data for 2012 and 2018 to carry out a typology analysis. Measures of agricultural efficiency - such as the cropping intensity and water use per unit area, household characteristics, and the survey year were important for describing the variability within the survey population. The analysis identifies four household types: **specialised farming households**, **village farming households**, **diverse income households**, and **landlord households**. The analysis demonstrates a trend towards greater income diversification and reduced dependence on agricultural income. This is mirrored by high rates of abandonment of agricultural activities, and a strong move away from the agriculture-dependent village farming household type. This analysis provides the basis for targeted policy strategies and development interventions by identifying farm typologies, the key variables which describe the variation between them, and the evolution of the typologies. Targeted interventions can provide high returns, especially to smallholders. This could help stem the tide of land abandonment and empower smallholder farmers to become profitable enough to continue agricultural activities, whilst increasing resource use efficiency.

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Appendix

1. Detailed data preparation methodology

The 2012 and 2018 Egypt Labour Market Panel Survey (ELMPS) (Krafft et al., 2019), were used to determine the farmer typologies. The 2012 and 2018 ELMPSs comprised individual and household surveys. The 2012 ELMPS fieldwork was carried out between March and June 2012 (Assaad & Krafft, 2013) and the 2018 survey was conducted between April 2018 to November 2018 (Krafft et al., 2021). The first stage of the analysis included extracting survey responses from individuals within farming households. The following stage entailed extracting individual survey responses pertinent to the farming household. This included summing the total income from employment for each household member, including basic wage, bonuses, incentives, profits, and secondary employment. Subsequently, the total number of household members working within the family farm and the total time spent working on the family farm were summed up. For the 2012 survey, to determine the number of staff employed in farming activities, we used the number of people supervised in farming activities. Although this may include those supervised on non-family farms, this response was the only indication of non-household employees. The 2018 survey, included details of farm employment within the household survey (family members working within the farm, and the number of days and average daily rate paid to external employees). The total number of worker days was divided by 204 to estimate the number of hired labourers. This value was calculated by using the average number of days worked in the last 3 months for all survey respondents employed in agricultural activity in the 2018 ELMPS. This included permanent and temporary or informal labour for all survey respondents and not just those who were part of farming households. The highest level of education within the household was also extracted from each household and included in the analysis. As the analysis considers the household as a unit, the survey results were reduced to include a single row for each household, maintaining the details of the head of the household from the results of the individual survey.

The household survey included details of crops harvested within the last year. This included details of areas, quantity produced for household consumption and for sale, and the net income from each crop. Some crop quantities were measured in traditional volumetric units (qintar, ardab) and area (kirat). Where conversions were available, these quantities were converted into tonnes. Governorate-specific yield estimates – in tonnes per feddan – were derived from CAPMAS agricultural bulletins for the respective years (CAPMAS - Central Agency for Public Mobilization and Statistics, 2021), and used where a conversion was not possible or where the area was used as the unit of measurement for the quantity. The total production quantity (for consumption and sale) was used for the analysis. Heml (camel load), another volumetric unit, is used to measure crop residue (straw/stalks etc.). This unit is used in the 2018 ELMPS. It was not possible to find conversion from heml to tonnes or prices for straw, therefore, this was ignored where heml was identified as the unit of the crop produced.

Annual agricultural income reports (CAPMAS - Central Agency for Public Mobilization and Statistics, 2021), detailing the total income per crop each year (including total income from straw or stalk), were used to calculate the income per tonne for each crop. This was used to determine the income per tonne of crop by dividing the total national income by total national production for each crop type. This in turn was used to determine the income per household for each harvested crop. Sharecropping is sometimes practised in Egypt. These survey responses were included in the analysis so that actual household income from crop production could be calculated for the analysis. The survey included a question on the estimated net income for each produced crop. Furthermore, the income derived from the hiring of agricultural equipment was included in the analysis based on survey responses. This included details of equipment jointly shared with others; the percentage ownership was used to calculate the household's actual income from any hiring activities.

Water use was estimated using the governorate specific total water use per crop derived from CAPMAS annual irrigation bulletin for the respective years (2013 was used instead of 2012 as 2012 was not available) (CAPMAS - Central Agency for Public Mobilization and Statistics, 2021). As most crops are irrigated using flood irrigation from Nile water, most crops are irrigated in this way. The CAPMAS reports also include total water use from groundwater and waste water reuse for each crop per governorate. To estimate the annual water, use per unit area per crop per governorate, the flood irrigation, and groundwater and waste water reuse were summed and divided by the total area per governorate. The mean of the water use per feddan for each governorate and each crop was calculated by region – Lower, Middle, and Upper Egypt. This was used with the crop type and area of each crop to calculate the total water use per crop.

The surveys included details of additional agricultural income from the sale of dairy products, honey, eggs, and poultry. This was also included as it is an important contributor to incomes within many farmer households.

Livestock and equipment capital details were included in the survey. The valuer of the livestock was estimated, as described in Appendix 2. It was not possible to estimate the value of agricultural equipment capital. Therefore, different equipment was divided into basic, intermediate, and advanced agricultural equipment, as described in Appendix 3.

Non-farm income is an important feature of farm typologies (Nin-Pratt et al., 2018). Therefore, I included the value of non-agricultural enterprise income and capital in the analysis. The survey included details of partial ownership of enterprises. This was considered when calculating the capital and income from non-agricultural enterprises. Additionally, survey responses relating to remittances were included. Finally, the income from

In terms of household characteristics, the age of the household head and the size of the household have been widely used in typology analysis (e.g. Hien et al., 2014; Sarker et al., 2021; Shukla et al., 2019). These were extracted from the survey and included in the typology analysis. Additionally, several categorical variables, for the household and the head of household, were identified as potentially important for understanding the variability within the sample population. These included the highest level of education within the household, the level of education of the head of household, the type of dwelling, the ownership status of the dwelling, the region which the household is based, and the sex of the head of household.

2. Livestock prices

Livestock prices are calculated based on the price per head of livestock derived from the CAPMAS report on agricultural income – 2011/12 and 2017/18 – and the animal production report – 2012 and 2018 – (CAPMAS - Central Agency for Public Mobilization and Statistics, 2021). Horses and donkeys are estimated based on the price of a camel (horse=camel, donkey=camel/2). Table 5 and

Table 6 include these calculations and the price per head used in the multivariate analysis for 2012 and 2018, respectively.

Table 5: Total animals slaughtered (2012) and total value of sales of meat for each animal (2011/12) from CAPMAS reports. Calculated price per head.

Code	Description	Total animals slaughtered (1000s)	Total value of meat production (1000s EGP)	Price per head (EGP)

501	cows	1462	15686370	10,729
502	buffaloes	1205	13104981	10,875
503	goats	2663	2291126	860
504	sheep	2335	3133202	1,341
505	camels	35	329074	9,402
506	donkeys/mules			4,701
507	horses			9,402

Table 6: Total animals slaughtered (2018) and total value of sales of meat for each animal (2017/18) from CAPMAS reports. Calculated price per head.

Code	Description	Total animals slaughtered (1000s)	Total value of meat production (1000s EGP)	Price per head (EGP)
1	Cows	1145	33763188	29,488
2	Poultry	1163381	46813950	40
3	Goats	1473	2991889	2,031
4	Sheep	1496	4699365	3,141
5	Camels	21	502922	23,949
6	Donkeys/Mules			11,974
7	Horses			23,949
8	Buffaloes	1096	30053112	27,421
9	Other animals			

3. Capital equipment grouping

Capital equipment is grouped based on the whether it is advanced, intermediate, or basic. I have included the groupings for 2012 and 2018 in Table 7. The multivariate analysis includes a categorical variable for each level of capital equipment.

Table 7: Capital equipment grouping into advanced, intermediate, and basic.

2012		**2018**	
Code	**Description**	**Code**	**Description**
601	large tractor (>12 horse power)	1	large tractor (>12 horse power)
602	small tractor (<12 horse power)	2	small tractor (<12 horse power)
603	machine pulled plough or harrower	3	machine pulled plough or harrower
604	animal pulled plow	4	animal pulled plow
605	mechanical water pump	5	drip irrigation system
606	manually powered water pump	6	sprinkler
607	sprinkler	7	mechanical water pump
608	motorized thresher	8	manually powered water pump
609	hand thresher	9	motorized thresher
610	rice winnower	10	hand thresher
611	machine to process livestock feed	11	machine to process livestock feed
612	motorized insecticide pump	12	motorized insecticide pump
613	hand insecticide pump	13	hand insecticide pump
614	donkey cart	14	donkey cart
615	small cart pulled by person	15	small cart pulled by person
616	poultry battery	16	poultry battery

617	beehives	17	beehives
Key		18	office furniture
	Advanced capital equipment	19	boat
	Intermediate capital equipment	97	Other equipment (specify)
	Basic capital equipment	97_other	Please specify what the other equipment is:

4. Inflation calculation

The cumulative inflation from 2012 to 2017 is used to rebase 2018 financial information to 2012 values, and is included in Table 8. The inflation rate is extracted from the consumer prices inflation World Bank database (https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG).

Table 8: Annual and cumulative inflation 2012-2018.

Year	Annual inflation	Cumulative inflation from 2012
2012	7.11%	107.11%
2013	9.47%	117.25%
2014	10.07%	129.06%
2015	10.37%	142.44%
2016	13.81%	162.12%
2017	29.51%	209.96%
2018	14.40%	240.19%

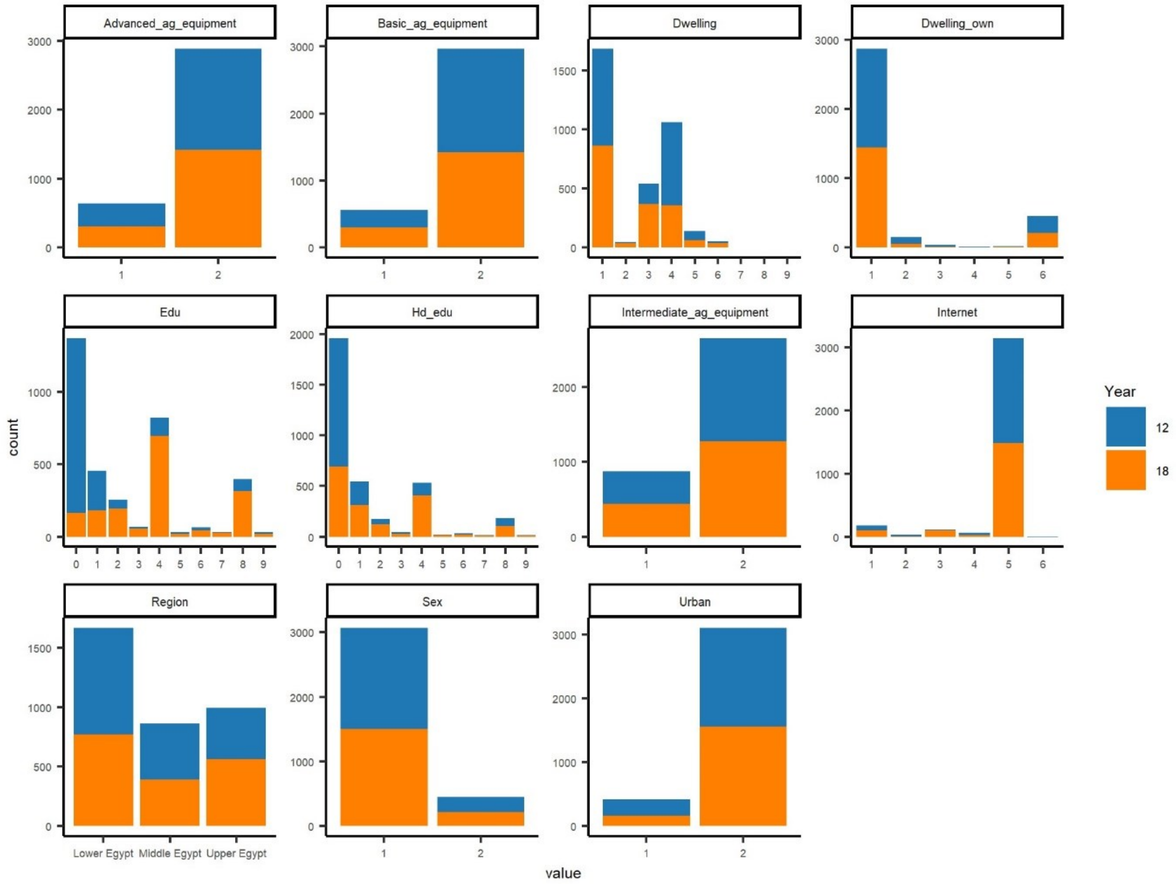
5. Outliers

Due to non-responses and missing responses, some outliers exist in the dataset. There were a number of responses that appeared to be non-responses but were not coded correctly (e.g. do not know response should be 99998, however the results included responses of 9999998, 9998 etc.). Non-responses were set to zero, where possible. Additionally, some logical outlier identification and removal rules were applied:

- Area equals zero whilst cropped area is greater than zero.
- Cropped area is zero and crop income is greater than zero.
- Cropping intensity is greater than 3. Cropping intensity greater than 3 is possible using intercropping, however this is not common. Results significantly higher than 3 must be as a result of missing or inaccurate responses.

6. Histograms plots pre-transformation

a)



b

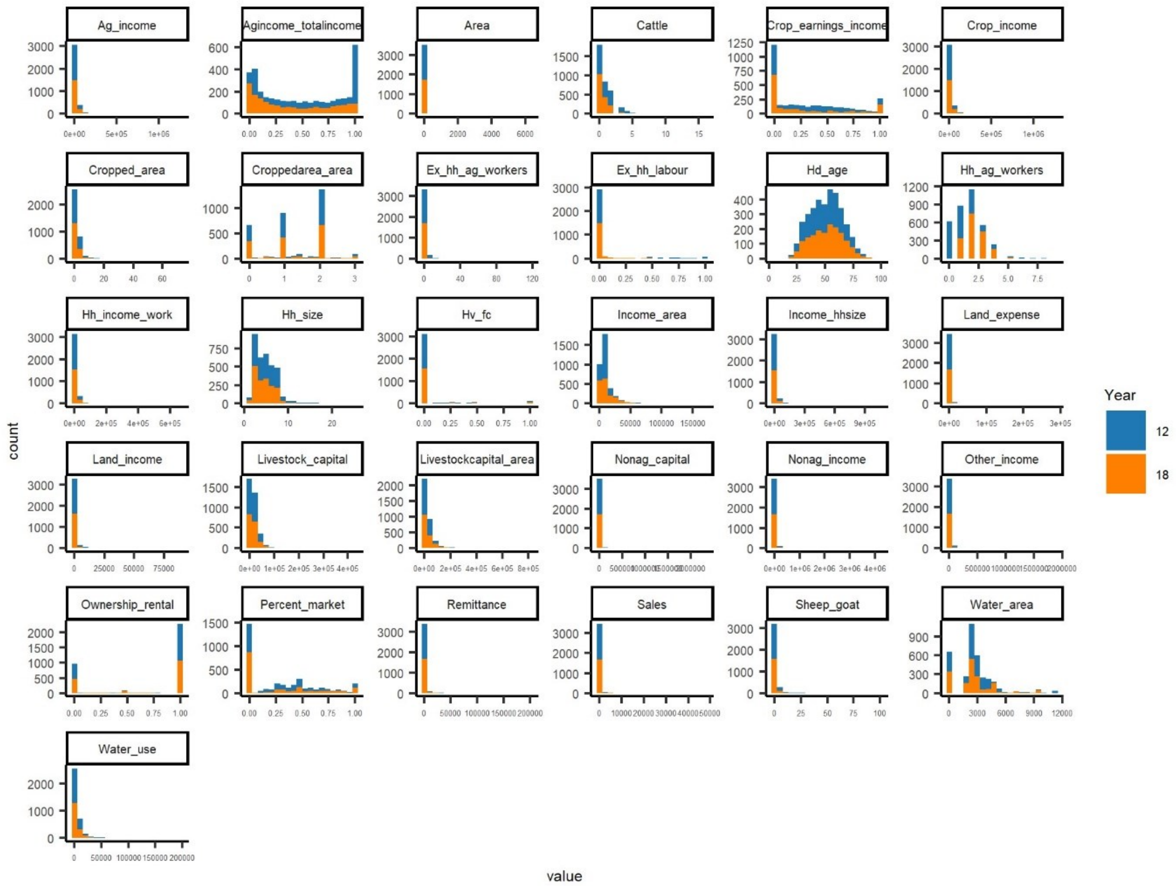


Figure 8: Histogram of variables used in analysis. 2012 and 2018 survey years are represented in red and green, respectively. a) Histogram of categorical variables. b) Histogram of each continuous variable.

7. Box-Cox transformation

Table 9 includes the calculated skewness of continuous variables prior to transformation, the Box-Cox lambda to normalise highly skewed variables (-1 < skewness > 1), and the skewness post transformation.

Table 9: Skewness of continuous variables before and after transformation and Box-Cox lambda transformation values.

Variable	Untransformed skewness	Lambda	Transformed skewness
Hd_age	0.057657	-	0.057657
Hh_income_work	15.61488	-0.18182	0.561398
Hh_ag_workers	0.688156	-	0.688156
Ex_hh_ag_workers	23.38536	-2	2.1259
Hh_size	1.354602	0.181818	0.015189
Hv_fc	3.703981	-2	2.893507
Cropped_area	9.746562	-0.66667	0.119182
Area	59.26281	-1.07071	0.18065
Water_use	7.832535	0.222222	-0.27387
Crop_income	13.24439	0.222222	-0.22027
Sales	27.3344	-1.07071	1.761553

Cattle	2.721348	-0.86869	0.265326
Sheep_goat	16.69052	-2	1.720424
Livestock_capital	4.002754	0.141414	-0.39092
Remittance	17.16487	-1.15152	2.50982
Other_income	17.8896	0.10101	-0.26114
Nonag_income	24.73504	0.181818	-0.33131
Nonag_capital	50.34889	-2	3.788658
Land_expense	33.80066	-0.42424	1.097774
Land_income	12.15978	-0.86869	2.008607
Ag_income	13.1941	0.222222	-0.01739
Agincome_totalincome	0.093641	-	0.093641
Croppedarea_area	-0.26882	-	-0.26882
Income_area	4.18218	0.343434	-0.47335
Crop_earnings_income	0.722729	-1.79798	0.722729
Water_area	1.381413	0.464646	-0.77999
Livestockcapital_area	5.90046	0.10101	-0.3295
Ex_hh_labour	2.703529	-2	2.307199
Income_hhsize	17.56299	0.141414	0.205081
Percent_market	0.685254	-	0.685254
Ownership_rental	-0.78622	-	-0.78622

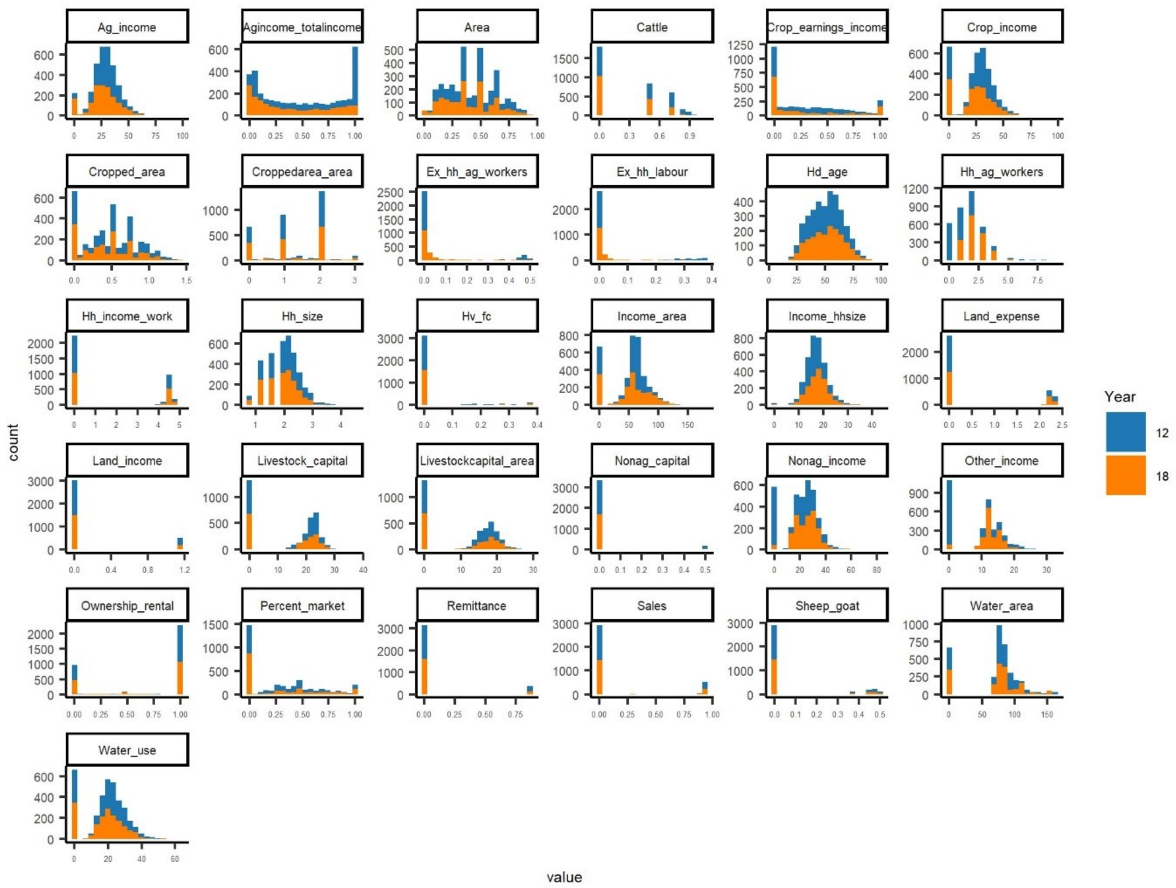


Figure 9: Histograms of transformed continuous variables.

8. Heterogenous correlation

Table 10: Correlated variables, with correlation greater than 0.7 or less than -0.7.

Variable to be removed	Correlated variables	Correlation
[Water_use]	[Cropped_area] [Water_area] [Crop_income] [Ag_income]	0.95 0.83 0.91 0.76
[Crop_income]	[Ag_income] [Income_area] [Water_area] [Cropped_area] [Agincome_totalincome]	0.87 0.84 0.74 0.88 0.70
[Cattle]	[Livestockcapital_area] [Livestock_capital]	0.74 0.81
[Nonag_income]	[Agincome_totalincome]	-0.77
[Income_area]	[Water_area]	0.77
[Livestock_capital]	[Livestockcapital_area]	0.96
[Ex_hh_ag_workers]	[Ex_hh_labour],	0.99
[Hd_edu]	[Edu]	0.84
[Land_expense]	[Ownership_rental]	-0.75
[Cropped_area]	[Ag_income]	0.79

9. Factor analysis on mixed data

Table 11: Eigenvalues, variance, and cumulative variance of each dimension in FAMD.

	Eigenvalue	**Variance (%)**	**Cumulative variance (%)**
Dim.1	5.084121	8.919511	8.919511
Dim.2	2.68393	4.70865	13.62816
Dim.3	2.500844	4.387445	18.01561
Dim.4	1.976886	3.468221	21.48383
Dim.5	1.747132	3.065143	24.54897
Dim.6	1.571333	2.756724	27.30569
Dim.7	1.359046	2.384291	29.68998
Dim.8	1.304613	2.288795	31.97878
Dim.9	1.198353	2.102374	34.08115
Dim.10	1.172255	2.056588	36.13774
Dim.11	1.149446	2.016572	38.15431
Dim.12	1.138347	1.997099	40.15141
Dim.13	1.114551	1.955352	42.10677
Dim.14	1.082599	1.899297	44.00606
Dim.15	1.072012	1.880723	45.88679
Dim.16	1.065119	1.868629	47.75542
Dim.17	1.043094	1.82999	49.58541

Dim.18	1.037525	1.82022	51.40563
Dim.19	1.032668	1.811698	53.21732
Dim.20	1.022399	1.793683	55.01101
Dim.21	1.019523	1.788637	56.79964
Dim.22	1.013242	1.777617	58.57726
Dim.23	0.996934	1.749007	60.32627
Dim.24	0.988707	1.734573	62.06084
Dim.25	0.981784	1.722427	63.78327
Dim.26	0.965909	1.694578	65.47785
Dim.27	0.959842	1.683933	67.16178
Dim.28	0.944439	1.656911	68.81869
Dim.29	0.935046	1.640432	70.45912
Dim.30	0.930308	1.63212	72.09124
Dim.31	0.921078	1.615927	73.70717
Dim.32	0.892064	1.565024	75.27219
Dim.33	0.884226	1.551274	76.82347

The eigenvalues for each dimension of the factor analysis of mixed data (FAMD) is included in Table 11. As per the Kaiser criterion, dimensions with eigenvalues above 1 are retained. Therefore, 22 dimensions are retained, explaining a cumulative variance of 58.6 %. Table 12 is the contribution each variable makes to the dimension of the FAMD. I highlighted in green contributions above 10 % and highlighted in yellow variables that contribute 10 % or more to the first 22 dimensions; the other variables were removed from the clustering analysis due to their limited contribution.

Table 12: Contribution of variables to each dimension in factor analysis on mixed data

	Dim.1	Dim.2	Dim.3	Dim.4	Dim.5	Dim.6	Dim.7	Dim.8	Dim.9	Dim.10	Dim.11	Dim.12	Dim.13	Dim.14	Dim.15	Dim.16	Dim.17	Dim.18	Dim.19	Dim.20	Dim.21	Dim.22
Edu	1.976353	15.67118	7.934134	3.931083	2.509682	10.01348	5.098026	11.31264	10.62948	11.91196	16.95149	14.59168	16.98242	26.37449	26.21187	42.56541	48.43154	32.18765	35.39957	23.38299	58.53166	7.356058
Dwelling_own	0.567421	0.778784	1.571052	1.848957	11.24117	3.411285	1.772128	18.93075	23.23302	14.50955	14.86687	17.92477	8.855041	22.85877	29.09361	11.80147	10.844	1.20078	14.6235	10.14993	2.750195	4.39725
Dwelling	1.233438	5.252084	4.40961	4.554964	14.65075	17.00486	5.020331	9.968218	16.54176	15.48284	17.29207	19.82344	20.00096	17.47307	22.14637	25.41408	15.78415	23.93592	22.48343	10.65442	21.12306	42.41221
Internet	1.824633	2.646423	1.948548	1.724795	1.707107	8.933577	4.684565	8.053117	1.085775	2.648961	17.63821	12.98857	10.1038	11.36475	6.0285	8.290892	13.51447	33.2968	16.3711	39.25987	6.158461	20.9713
Urban	0.293528	0.008221	1.143765	0.531891	0.827201	3.492111	2.753282	3.926499	12.77267	4.575959	4.509128	2.889471	1.584227	0.233053	0.471463	1.231806	1.103473	0.182721	0.090879	1.275213	0.071918	6.26E-06
Region	0.754572	1.397821	4.760787	2.227989	13.89128	8.941572	14.78378	10.31962	0.571548	0.476274	9.946198	2.037637	4.641129	2.870465	0.826269	1.854477	0.096583	0.283178	0.039503	1.017145	0.546703	0.210263
Hd_age	0.401517	1.998151	1.755639	2.62412	12.73899	0.134837	0.004726	11.11634	1.913532	0.018932	0.000332	0.103296	0.020374	0.534325	0.009468	0.070018	0.065229	0.069658	2.063664	0.108075	0.540272	0.196189
Remittance	0.163027	0.746108	0.098322	0.81292	0.849155	0.278265	10.78204	3.558992	5.258421	8.064864	2.916512	2.497508	0.367509	0.486181	0.045621	2.530689	0.513809	0.157999	1.023023	0.109561	0.129396	3.990779
Basic_ag_equipment	1.379269	2.951077	0.447691	3.644333	0.517083	0.482414	13.28167	1.92333	3.734506	1.608497	0.099817	0.119626	0.19721	0.754595	0.002356	0.20486	0.004186	0.026422	0.182807	0.653579	1.279174	0.055543
Hh_size	1.194648	0.007623	5.562196	0.129084	1.357911	22.24842	0.01279	0.006406	2.645636	0.014452	0.110624	0.037073	0.91669	3.035187	1.688701	0.008015	0.683455	0.063117	0.324592	0.099682	0.000169	0.601771
Crop_earnings_income	4.467555	0.012919	0.06068	11.86597	1.909673	0.003238	1.047252	0.047509	0.559179	0.066627	0.560619	0.915104	1.544722	0.153782	0.002041	0.185533	0.448363	1.303243	0.123673	1.963669	0.050125	0.007901
Livestockcapital_area	5.312948	0.131048	2.192943	11.57688	0.759983	0.041057	0.391492	0.1008	0.037667	2.407465	0.072486	0.361259	3.043108	0.833856	0.030369	0.225919	0.000716	0.02912	0.180685	0.137871	0.011097	0.162244
Percent_market	5.052146	0.172406	0.257068	14.05059	2.192334	0.115052	0.107366	0.139036	0.019394	0.042716	0.677649	1.201352	0.886656	0.013807	0.000422	0.009674	0.096894	1.545892	7.70E-05	1.822405	0.036428	0.509772
Income_hhsize	0.630773	12.00461	11.00194	0.017284	0.403001	0.010869	0.046238	0.005525	3.337401	5.042353	0.008699	0.635991	3.493308	0.087457	1.700954	0.241443	0.112683	0.062061	0.27323	0.14074	0.096467	0.231547
Area	1.767531	3.292638	12.74625	0.26035	0.127555	1.014312	4.533257	0.372968	1.023963	0.055866	0.131476	1.165529	0.022571	2.88777	0.389457	0.471219	1.002197	0.567048	0.145959	0.133049	0.06758	0.0326
Other_income	5.503589	10.01968	0.000468	0.685231	3.368482	0.29507	2.002145	0.272302	0.249293	0.454246	1.024628	0.693583	0.241518	0.058144	0.005296	0.002798	0.000417	0.147421	0.233945	0.949459	0.095543	0.003682
Year	0.721151	14.79343	9.289156	0.156469	0.509741	4.039487	2.765319	0.970319	0.262129	0.697865	0.002914	0.14089	0.115096	0.104517	0.015675	0.029858	0.075947	0.001851	0.055732	0.059621	0.038934	0.073397
Agincome_totalincome	11.72513	0.852738	2.611628	0.007945	0.515502	0.551098	3.921338	0.74021	0.175074	0.65925	0.598913	2.250369	0.153183	0.628461	0.681211	0.010601	0.055018	0.191862	0.363171	0.788857	0.088001	0.002731
Croppedarea_area	10.27862	0.577025	0.557589	0.920766	0.062267	0.266334	0.381467	0.540729	0.381061	3.120827	0.071529	1.756608	0.655813	0.363684	0.09901	0.047381	0.290697	0.546931	0.091657	0.127408	0.082639	0.599329
Water_area	11.13453	1.099909	0.125885	6.135504	1.129173	0.259041	2.389064	0.167904	0.012449	1.385216	0.091429	0.421438	0.081253	0.144131	0.00813	0.101338	0.045058	0.003017	0.003419	0.17835	0.042277	0.04848
Hh_income_work	0.929806	3.717559	1.388474	2.469692	5.434071	7.346395	5.380853	5.108999	1.887156	2.353998	0.716508	2.074588	1.261837	0.031768	0.882768	0.862926	0.454717	0.154684	1.170768	0.03113	0.017638	0.23906
Hh_ag_workers	2.842738	7.601417	7.965729	1.178138	0.094709	0.137541	0.631966	0.023581	0.402813	0.310406	0.126531	0.605864	0.528361	0.014983	0.049208	0.095165	0.156581	0.063654	0.006862	0.158743	0.19051	0.316126
Hv_fc	0.593898	0.065181	0.408189	4.76476	0.510386	1.361616	0.882169	1.912037	0.032339	0.513476	5.741716	2.219776	2.076696	2.394203	1.29356	0.221601	0.8813	1.086755	0.004948	0.001001	1.642392	5.307665
Sales	1.914908	0.41891	0.092005	3.806241	5.269211	0.012144	1.132411	0.017557	0.950884	0.192479	0.416363	1.606204	0.027248	0.334086	0.630239	0.955415	0.041494	0.107562	0.040521	1.407912	1.24694	2.964081
Sheep_goat	1.20657	0.007599	0.18138	8.50363	0.157135	2.028092	1.279882	1.531581	0.225184	1.672846	0.015971	0.071671	4.919857	0.278852	0.944739	1.019903	0.002952	0.014594	0.91283	0.087258	1.912632	0.001029
Nonag_capital	0.10959	0.675567	0.952032	0.002534	2.964674	3.625716	0.567207	0.035685	0.868578	1.578592	0.161085	1.596862	0.338945	2.147774	4.1872	0.128329	3.253927	2.150809	2.326513	2.611016	0.086264	5.625645
Land_income	8.601	0.024983	5.498729	0.878802	0.009279	0.424982	0.726962	0.808777	1.129158	0.065859	0.001998	0.72538	0.075973	0.91181	0.000615	0.191946	0.094378	0.192831	0.037297	0.00076	0.683188	0.274648
Ag_income	7.910992	5.077482	7.985762	0.002994	0.784963	0.542481	1.677605	0.345451	2.867401	1.665625	0.371635	0.162997	1.205683	0.740479	3.61E-06	0.251224	0.00114	0.15011	0.078542	0.554806	0.494543	0.441596
Ex_hh_labour	2.27923	0.659617	2.363686	0.112274	0.317249	0.914941	0.408526	0.172201	0.219677	3.67749	0.410274	0.49265	0.575871	0.06844	0.112432	0.00242	0.362607	0.090708	0.003058	0.138669	0.193939	0.0014
Ownership_rental	1.191782	0.209005	2.396154	7.42E-05	2.237076	0.816153	5.897879	1.507931	0.000808	3.560295	0.378482	0.587523	0.075172	1.125753	0.371443	0.689104	0.455015	0.000175	0.791367	0.707872	0.404806	2.767021
Sex	1.023618	0.28034	0.105153	1.19478	5.458993	0.985615	1.036511	5.094752	3.750439	3.384415	2.561577	2.665766	6.311222	0.544311	1.801233	0.106491	1.080442	0.164947	0.35532	0.988049	0.147719	0.161822
Advanced_ag_equipment	2.091978	2.951825	1.620065	2.753758	2.518032	0.011822	1.888261	0.353454	1.733089	5.024584	1.322141	3.175737	6.145238	0.138463	0.243821	0.038165	0.045033	0.009098	0.119238	0.229422	1.08004	0.022164
Intermediate_ag_equipment	2.921517	3.896637	0.567291	6.625199	2.976185	0.256127	2.71149	0.614782	1.488521	2.755221	0.204126	1.459791	2.551308	0.00859	0.025941	0.139832	0.001516	0.011378	0.079125	0.071461	0.159288	0.014696

10. Cluster results

Table 13: Cluster means and standard deviations

Variable (unit) [variable code]	Response	Specialised	Village	Diversified	Landlord
Number of households		650 (18.43)	1085 (30.77)	1130 (32.05)	661 (18.75)
Characteristics of head of household					
Age of head of HH (yr) [Hd_age]		51.88 (13.41)	49.50 (13.61)	50.86 (13.33)	53.19 (15.17)
Sex of head of HH [Sex]	**1 (male)** **2 (female)**	587 (90.31) 63 (9.69)	976 (89.95) 109 (10.05)	1007 (89.12) 123 (10.88)	503 (76.10) 158 (23.90)
Level of education of head of HH [Hd_edu]	**0 (none)** **1 (primary)** **2 (preparatory)** **3 (general secondary)** **4 (technical secondary -3 years)** **5 (technical secondary - 5 years)** **6 (middle institute)** **7 (higher institute)** **8 (university)** **9 (postgraduate)**	392 (60.31) 94 (14.46) 31 (4.77) 7 (1.08) 73 (11.23) 3 (0.46) 10 (1.54) 3 (0.46) 37 (5.69) 0 (0.00)	846 (77.97) 139 (12.81) 32 (2.95) 9 (0.83) 42 (3.87) 2 (0.18) 3 (0.28) 0 (0.00) 11 (1.01) 1 (0.09)	422 (37.35) 215 (19.03) 82 (7.26) 16 (1.42) 308 (27.26) 9 (0.80) 11 (0.97) 8 (0.71) 56 (4.96) 3 (0.27)	297 (44.93) 94 (14.22) 30 (4.54) 13 (1.97) 108 (16.34) 9 (1.36) 12 (1.82) 7 (1.06) 80 (12.10) 11 (1.66)
HH characteristics					
Size of HH [Hh_size]		4.53 (1.97)	5.54 (2.64)	4.79 (2.09)	4.11 (2.01)
HH region [Region]	**Lower Egypt** **Middle Egypt** **Upper Egypt**	479 (73.69) 20 (3.08) 151 (23.23)	241 (22.21) 559 (51.52) 285 (26.27)	593 (52.48) 181 (16.02) 356 (31.50)	356 (53.86) 103 (15.58) 202 (30.56)
Urban/rural [Urban]	**1 (urban)** **2 (rural)**	74 (11.38) 576 (88.62)	118 (10.88) 967 (89.12)	100 (8.85) 1030 (91.15)	121 (18.31) 540 (81.69)
Housing type [Dwelling]	**1 (apartment)** **2 (more than one apartment)** **3 (villa/house)** **4 (village house)** **5 (one room or more in same unit)** **6 (one independent room or more)** **7 (cottage/tent)** **8 (cemetery)** **9 (other/basement)**	416 (64.00) 9 (1.38) 72 (11.08) 138 (21.23) 8 (1.23) 6 (0.92) 0 (0.00) 0 (0.00) 1 (0.15)	211 (19.45) 9 (0.83) 132 (12.17) 649 (59.82) 71 (6.54) 13 (1.20) 0 (0.00) 0 (0.00) 0 (0.00)	653 (57.79) 18 (1.59) 237 (20.97) 159 (14.07) 38 (3.36) 23 (2.04) 1 (0.09) 1 (0.09) 0 (0.00)	402 (60.82) 10 (1.51) 101 (15.28) 117 (17.70) 23 (3.48) 7 (1.06) 1 (0.15) 0 (0.00) 0 (0.00)

Housing ownership or rental type [Dwelling_own]	**1 (owned)** **2 (condominium)** **3 (rent, unfurnished)** **4 (rent, furnished)** **5 (rent, new law)** **6 (fringe benefit/grant)**	530 (81.54) 35 (5.38) 7 (1.08) 2 (0.31) 2 (0.31) 74 (11.38)	890 (82.03) 35 (3.23) 8 (0.74) 3 (0.28) 0 (0.00) 149 (13.73)	930 (82.30) 37 (3.27) 3 (0.27) 0 (0.00) 5 (0.44) 155 (13.72)	518 (78.37) 41 (6.20) 15 (2.27) 1 (0.15) 13 (1.97) 73 (11.04)
Highest level of education within HH [Edu]	**0 (none)** **1 (primary)** **2 (preparatory)** **3 (general secondary)** **4 (technical secondary -3 years)** **5 (technical secondary - 5 years)** **6 (middle institute)** **7 (higher institute)** **8 (university)** **9 (postgraduate)**	322 (49.54) 93 (14.31) 47 (7.23) 9 (1.38) 69 (10.62) 5 (0.77) 12 (1.85) 5 (0.77) 83 (12.77) 5 (0.77)	758 (69.86) 156 (14.38) 58 (5.35) 11 (1.01) 48 (4.42) 5 (0.46) 6 (0.55) 3 (0.28) 36 (3.32) 4 (0.37)	73 (6.46) 137 (12.12) 108 (9.56) 32 (2.83) 563 (49.82) 14 (1.24) 30 (2.65) 15 (1.33) 151 (13.36) 7 (0.62)	216 (32.68) 69 (10.44) 43 (6.51) 19 (2.87) 140 (21.18) 6 (0.91) 16 (2.42) 9 (1.36) 129 (19.52) 14 (2.12)
Type of internet access [Internet]	**1 (dsl)** **2 (usb modem)** **3 (dial-up)** **4 (through neighbours)** **5 (none)** **6 (other)**	25 (3.85) 7 (1.08) 15 (2.31) 10 (1.54) 591 (90.92) 2 (0.31)	23 (2.12) 6 (0.55) 7 (0.65) 5 (0.46) 1044 (96.22) 0 (0.00)	51 (4.51) 3 (0.27) 57 (5.04) 16 (1.42) 1003 (88.76) 0 (0.00)	78 (11.80) 14 (2.12) 28 (4.24) 28 (4.24) 509 (77.00) 4 (0.61)
Total HH income per capita (2012 EGP) [Income_hhsize]		11133 (16083)	5987 (10112)	11987 (20828)	21118 (59058)
Agricultural details					
Agricultural capital					
Area of agricultural land (feddan) [Area]		1.70 (2.33)	6.95 (191.24)	1.29 (3.14)	1.52 (3.76)
Advanced agricultural equipment [Advanced_ag_equipment]	**1 (yes)** **2 (no)**	142 (21.85) 508 (78.15)	237 (21.84) 848 (78.16)	240 (21.24) 890 (78.76)	23 (3.48) 638 (96.52)
Intermediate agricultural equipment [Intermediate_ag_equipment]	**1 (yes)** **2 (no)**	185 (28.46) 465 (71.54)	311 (28.66) 774 (71.34)	342 (30.27) 788 (69.73)	38 (5.75) 623 (94.25)
Basic agricultural equipment [Basic_ag_equipment]	**1 (yes)** **2 (no)**	137 (21.08) 513 (78.92)	170 (15.67) 915 (84.33)	236 (20.88) 894 (79.12)	19 (2.87) 642 (97.13)
Number of cattle [Cattle]		1.01 (1.43)	1.38 (1.43)	0.78 (1.11)	0.25 (0.74)
Number of sheep and goat [Sheep_goat]		0.44 (1.59)	1.07 (2.88)	0.96 (5.16)	0.28 (1.40)
Total livestock capital (2012 EGP) [Livestock_capital]		15414 (18734)	21437 (22525)	18739 (20250)	5266 (14375)
Agricultural income and expenses					

Total income from crops (2012 EGP) [Crop_income]		23480 (37433)	17896 (32577)	22788 (58445)	0.00 (0.00)
Income from animal products e.g. poultry, honey, dairy (2012 EGP) [Sales]		186.99 (1985)	122.79 (727.93)	142.24 (1533)	68.86 (954.35)
Income from rent of land (2012 EGP) [Land_income]		304.76 (1813)	52.13 (505.01)	150.50 (1304)	3273 (7869)
Cost of land rental (2012 EGP) [Land_expense]		1107 (5510)	1295 (2799)	1341 (8843)	365.22 (3841)
Total agricultural income (2012 EGP) [Ag_income]		24021 (37672)	18115 (32691)	23098 (58499)	3346 (7939)
Agricultural resource use					
Cropped area (feddan) [Cropped_area]		2.37 (2.94)	1.72 (2.15)	1.76 (3.51)	0.00 (0.00)
Total agricultural water use (m3) [Water_use]		11730 (16054)	4362 (6181)	5258 (9778)	0.00 (0.00)
Number of HH agricultural workers [Hh_ag_workers]		1.49 (1.16)	1.83 (1.44)	2.47 (0.94)	0.72 (0.58)
Number of hired agricultural workers [Ex_hh_ag_workers]		1.16 (5.46)	0.95 (3.66)	0.26 (1.25)	0.00 (0.09)
Agricultural efficiency					
Cropping intensity [Croppedarea_area]		1.49 (0.56)	1.64 (0.58)	1.64 (0.60)	0.00 (0.00)
Ratio of crop earnings to crop income [Crop_earnings_income]		0.51 (0.34)	0.36 (0.30)	0.36 (0.34)	0.00 (0.00)
Cropping income per unit area (2012 EGP/feddan)[Income_area]		11295 (10456)	10999 (8274)	13343 (13628)	0.00 (0.00)
Ratio of high-value to field crop [Hv_fc]		0.15 (0.33)	0.06 (0.16)	0.05 (0.17)	0.00 (0.00)
Ratio of crop production sold at market [Percent_market]		0.49 (0.34)	0.35 (0.28)	0.32 (0.32)	0.00 (0.00)
Ratio of owned to rented land [Ownership_rental]		0.70 (0.44)	0.62 (0.47)	0.64 (0.45)	0.84 (0.36)
Water use per unit area (m3/feddan) [Water_area]		5406 (2224)	2454 (450.26)	2853 (751.46)	0.00 (0.00)
Livestock capital per feddan (2012 EGP/feddan) [Livestockcapital_area]		17888 (41082)	34692 (51004)	34101 (59195)	10931 (40880)
Ratio of hired agricultural workers to household workers [Ex_hh_labour]		0.13 (0.29)	0.16 (0.30)	0.05 (0.16)	0.00 (0.04)
Ratio of agricultural to total income [Agincome_totalincome]		0.62 (0.34)	0.70 (0.31)	0.46 (0.32)	0.07 (0.14)
Non-agricultural income and capital					
Total HH income from off-farm employment (2012 EGP) [Hh_income_work]		6335 (15714)	4291 (13950)	8280 (25602)	9914 (29640)
Income from remittance (2012 EGP) [Remittance]		1182 (10271)	685.54 (4193)	739.96 (4420)	1442 (7810)

Other income (2012 EGP) [Other_income]		5874 (14575)	2490 (9368)	8062 (25620)	42174 (120431)
Total non-agricultural income (2012 EGP) [Nonag_income]		17186 (35020)	9643 (24771)	25439 (58344)	68399 (209784)
Total non-agricultural capital (2012 EGP) [Nonag_capital]		2184 (19047)	1495 (10553)	1054 (11137)	6198 (91030)
Survey year [Year]	**12** **18**	450 (69.23) 200 (30.77)	906 (83.50) 179 (16.50)	134 (11.86) 996 (88.14)	316 (47.81) 345 (52.19)

11. Cluster evolution

Table 14: Cluster transitions between 2012 and 2018

2012 cluster	No. of households in 2012	2018 cluster	No. of households in 2018
Specialised	68	Specialised	69
Specialised	1	Village	1
Specialised	117	Diversified	122
Specialised	42	Landlord	43
Specialised	241	Land_abandonment	322
Village	28	Specialised	28
Village	100	Village	104
Village	267	Diversified	276
Village	49	Landlord	51
Village	556	Land_abandonment	838
Diversified	3	Specialised	3
Diversified	46	Diversified	47
Diversified	13	Landlord	13
Diversified	84	Land_abandonment	121
Landlord	9	Specialised	9
Landlord	4	Village	4
Landlord	20	Diversified	21
Landlord	31	Landlord	31
Landlord	217	Land_abandonment	273
New_landowner	51	Specialised	51
New_landowner	40	Village	40
New_landowner	257	Diversified	266
New_landowner	122	Landlord	124
Specialised	32	Survey_Exit	32
Village	66	Survey_Exit	66
Diversified	13	Survey_Exit	13
Landlord	52	Survey_Exit	52
New_survey_entrant	0	Specialised	40
New_survey_entrant	0	Village	30
New_survey_entrant	0	Diversified	264
New_survey_entrant	0	Landlord	83

12. Alternative number of clusters

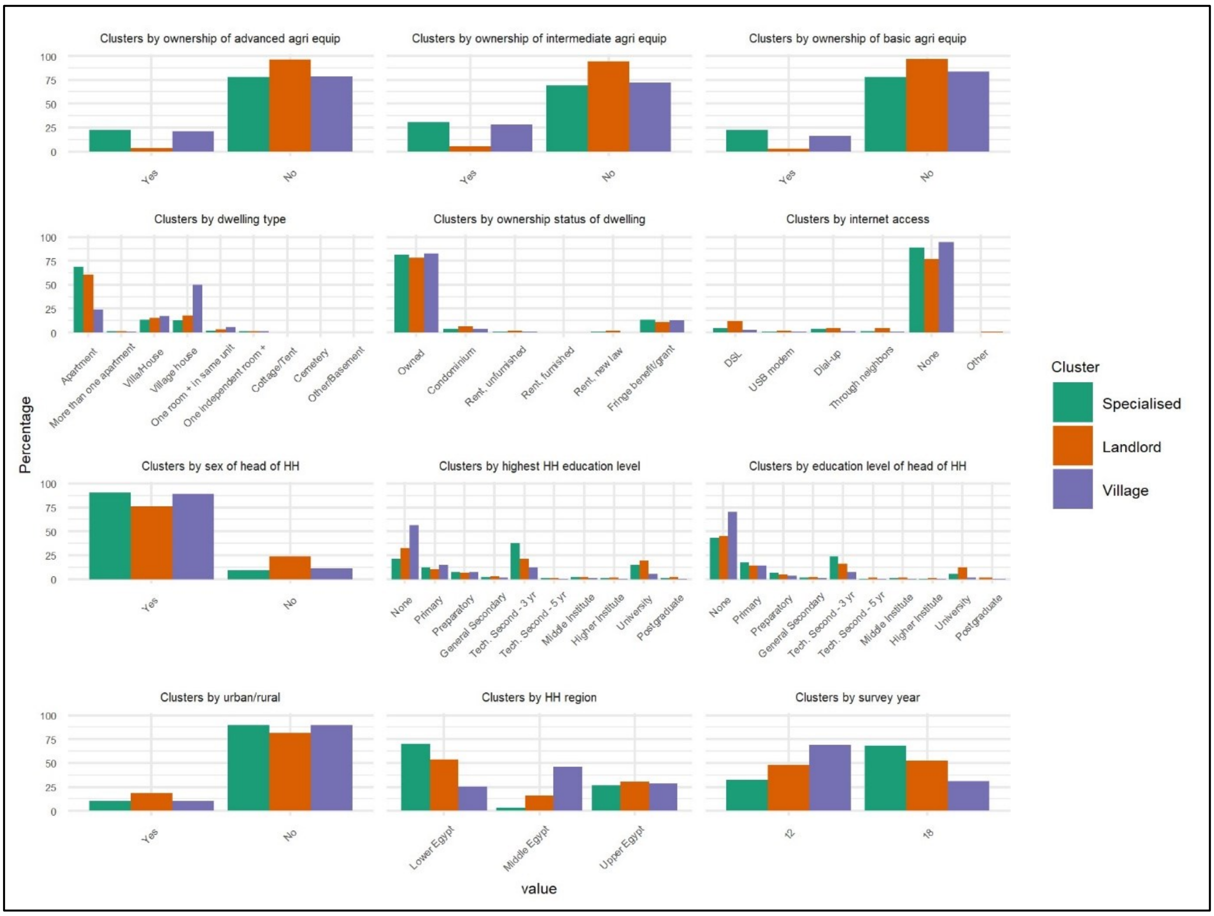
13. Three clusters

Table 15: Number of households in each cluster and percentage each cluster represents from the whole sample.

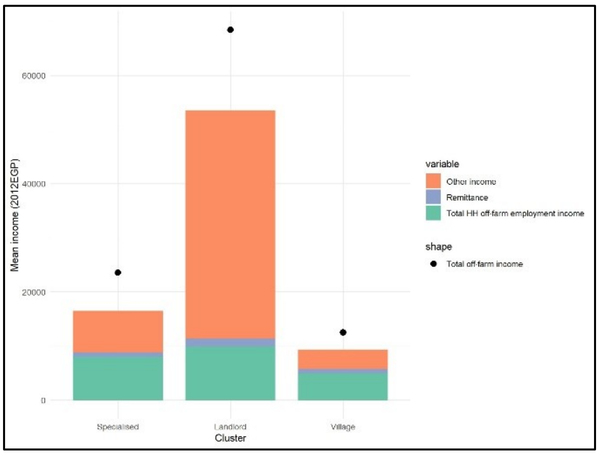
Cluster	Number of households	Percentage of households

1 - Specialised	1313	37.2
2 - Landlord	661	18.7
3 - Village	1552	44.0

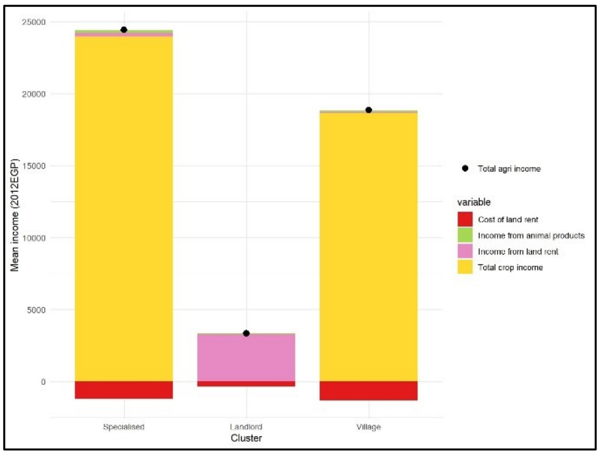
a)



b)



c)



d)

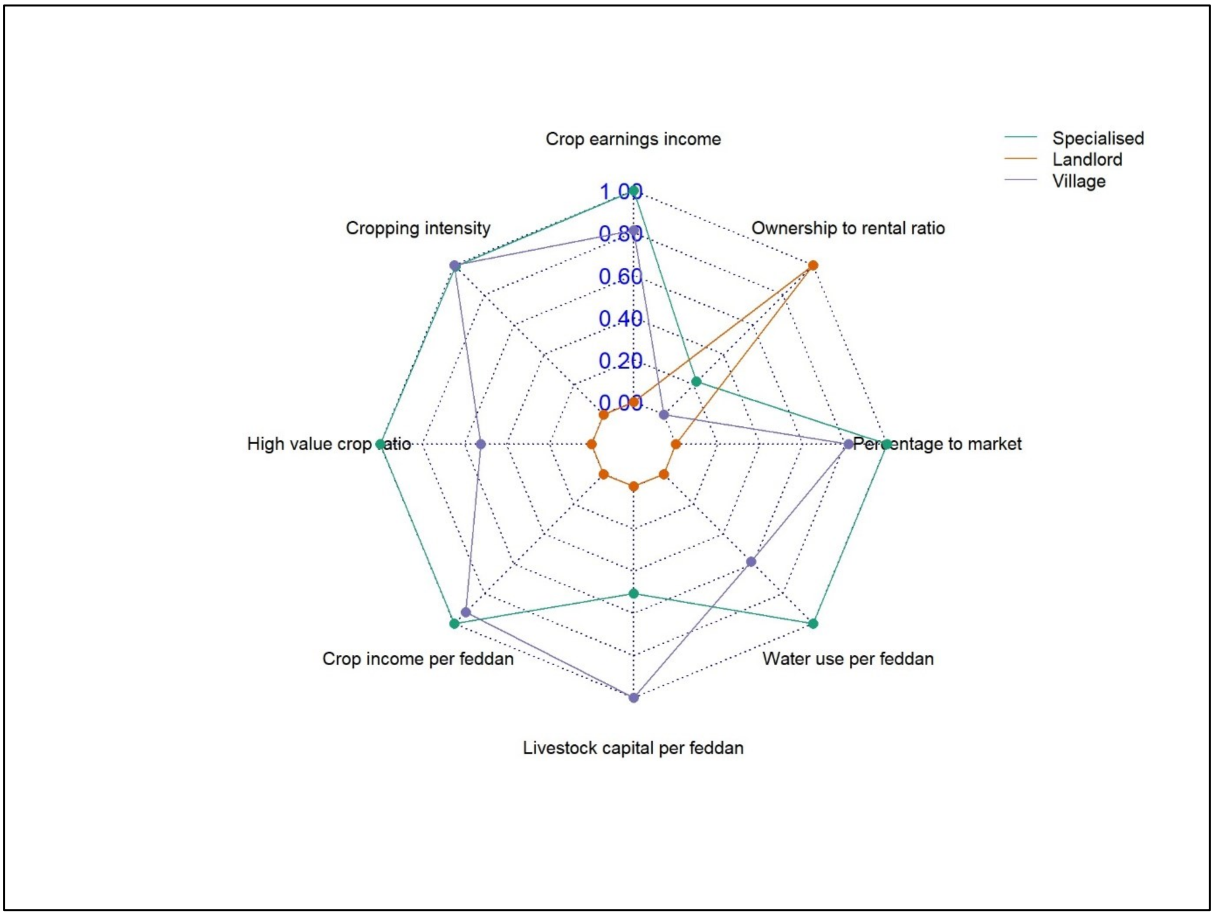


Figure 10: Summary of results by cluster for 3 clusters, including: a) percentage each response for categorical variables; b) total mean agricultural income and mean constituent components of agricultural income; c) total mean off-farm income and mean constituent components of off-farm income; d) radar chart of mean range standardised efficiency metrics.

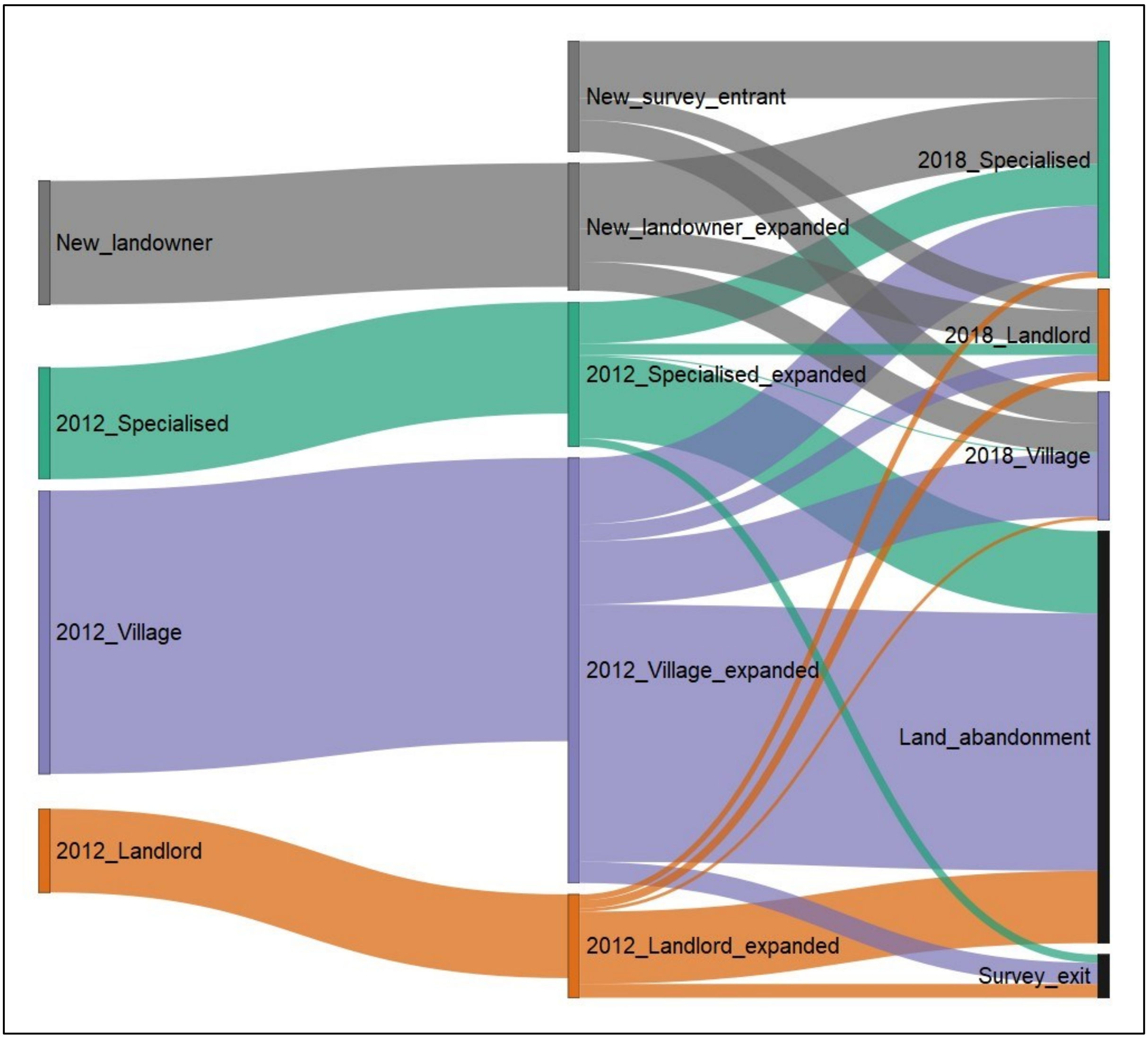


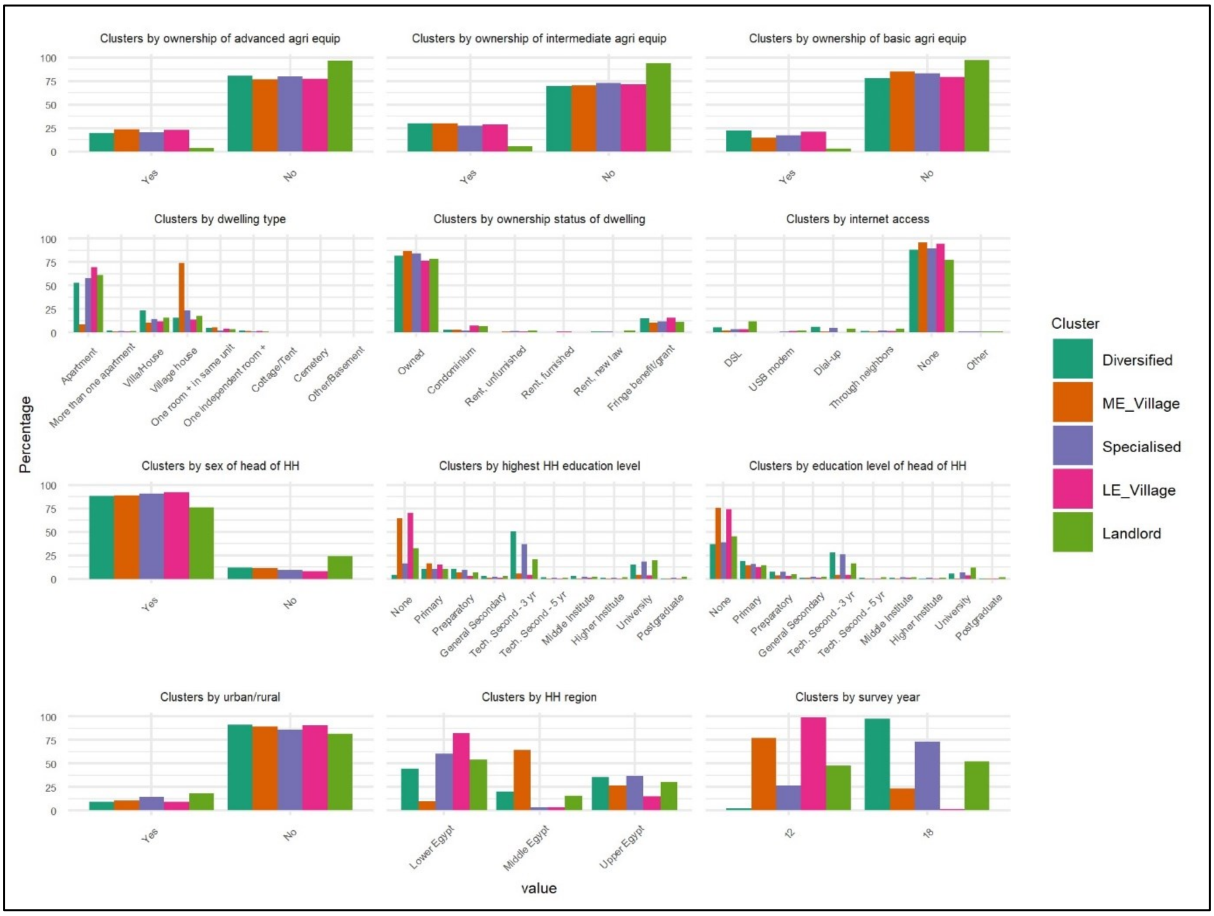
Figure 11: Sankey plot showing the transition of household clusters, for 3 clusters, from 2012 (left) through the expansion of the 2012 household types (middle) and the 2018 household types (right).

14. Five clusters

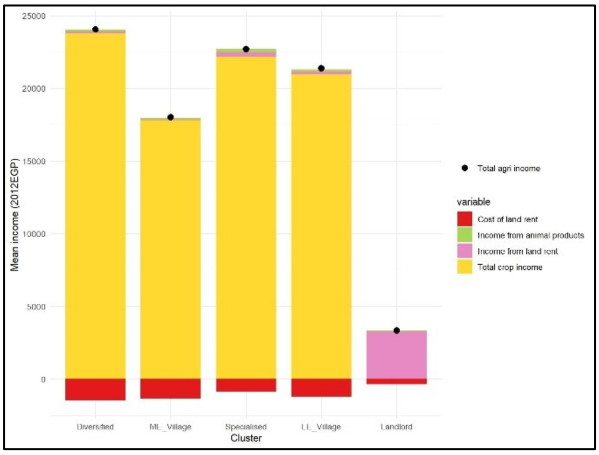
Table 16: Number of households in each cluster and percentage each cluster represents from the whole sample.

Cluster	Number of households	Percentage of households
1 - Diversified	911	25.8
2 - ME_Village	837	23.7
3 - Specialised	386	10.9
4 - LE_Village	731	20.7
5 - Landlord	661	18.7

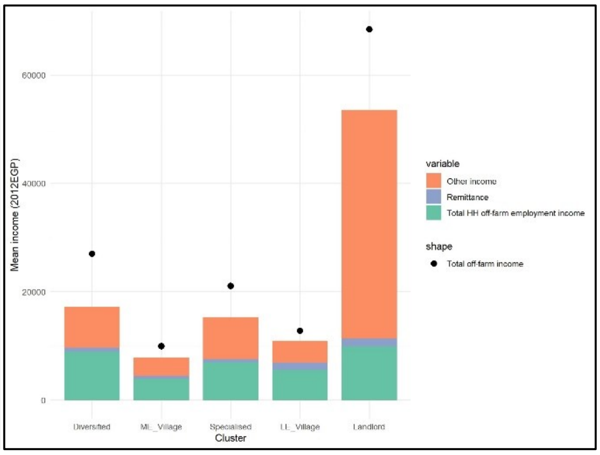
a)


Clusters by ownership of advanced agri equip
Clusters by ownership of intermediate agri equip
Clusters by ownership of basic agri equip
Yes
No
Clusters by dwelling type
Apartment
More than one apartment
Villa/House
Village house
One room + in same unit
One independent room +
Cottage/Tent
Cemetery
Other/Basement
Clusters by ownership status of dwelling
Owned
Condominium
Rent, unfurnished
Rent, furnished
Rent, new law
Fringe benefit/grant
Clusters by internet access
DSL
USB modem
Dial-up
Through neighbors
None
Other
Percentage
Clusters by sex of head of HH
Clusters by highest HH education level
Clusters by education level of head of HH
None
Primary
Preparatory
General Secondary
Tech. Second - 3 yr
Tech. Second - 5 yr
Middle Institute
Higher Institute
University
Postgraduate
Clusters by urban/rural
Clusters by HH region
Lower Egypt
Middle Egypt
Upper Egypt
Clusters by survey year
12
18
value
Cluster
Diversified
ME_Village
Specialised
LE_Village
Landlord

b)


Mean income (2012EGP)
Total agri income
variable
Cost of land rent
Income from animal products
Income from land rent
Total crop income
Diversified
ME_Village
Specialised
LE_Village
Landlord
Cluster

c)


Mean income (2012EGP)
variable
Other income
Remittance
Total HH off-farm employment income
shape
Total off-farm income
Diversified
ME_Village
Specialised
LE_Village
Landlord
Cluster

d)

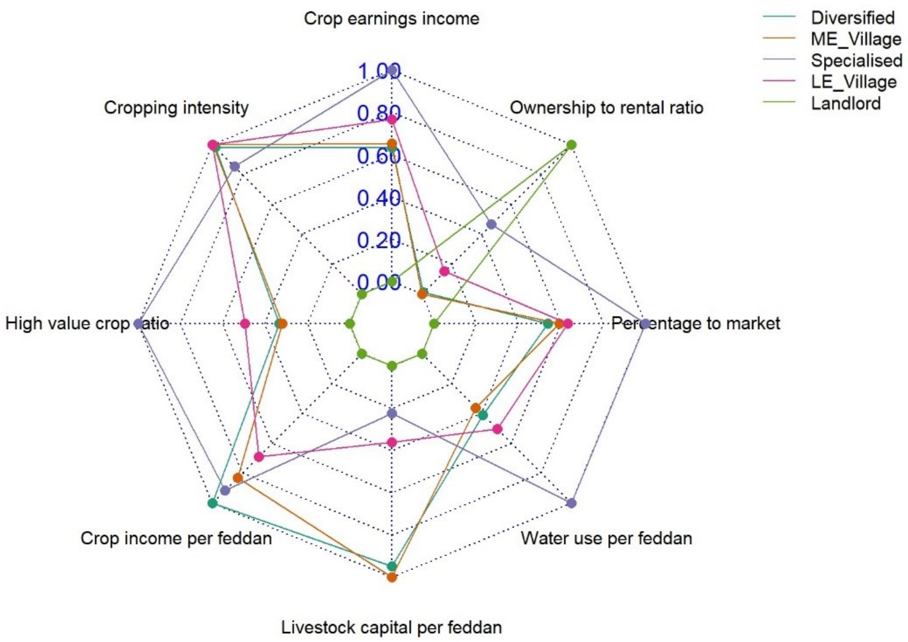


Figure 12: Summary of results by cluster for 5 clusters, including: a) percentage each response for categorical variables; b) total mean agricultural income and mean constituent components of agricultural income; c) total mean off-farm income and mean constituent components of off-farm income; d) radar chart of mean range standardised efficiency metrics.

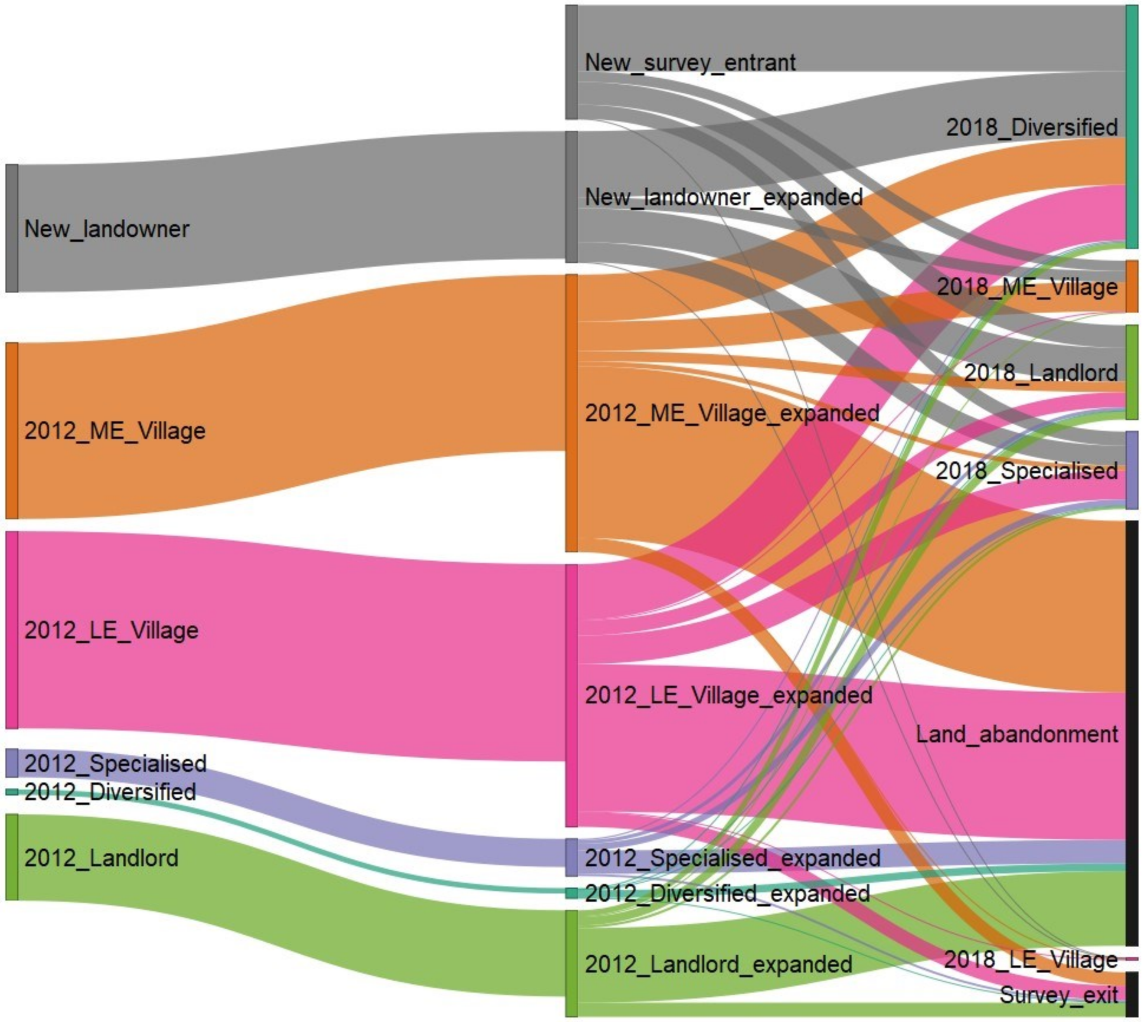


Figure 13: Sankey plot showing the transition of household clusters, for 3 clusters, from 2012 (left) through the expansion of the 2012 household types (middle) and the 2018 household types (right).

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