

**STRENGTHENING THE RESILIENCE OF FAMILY
FARMERS AND SMALL-SCALE PRODUCERS IN THE
AGRICULTURE AND FOOD SECTOR IN
OIC MEMBER COUNTRIES**

**STANDING COMMITTEE FOR ECONOMIC AND
COMMERCIAL COOPERATION OF
THE ORGANIZATION OF ISLAMIC COOPERATION**

AGRICULTURAL WORKING GROUP

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Executive Summary

Family farmers and small-scale producers in the agriculture and food sector in the Organization of Islamic Countries (OIC) member countries are critical for food security and rural livelihoods. The objective of this study is to measure the resilience and identify the factors that influence the resilience of the family farms and small-scale producers in the OIC member countries. With the identified factors policy recommendations are provided to strengthen the resilience of the family farmers and small-scale producers. While proposing recommendations to improve resilience, environmental and social sustainability are also considered.

Resilience of farmers can be defined as ability of farmers to continue to produce agricultural products and continue to support their livelihoods after an economic, environmental or a social shock has occurred. We measure the continuation of agricultural production and generating income from this production with total value of agricultural production and the value of agricultural production per hectare at the national level. We specifically use the yearly percentage change of total value of agricultural production and the yearly percentage change of value of the agricultural production per hectare to see if the system is resilient. Non-negative changes in the face of shocks imply resilience.

Desk based case studies of resilience of family farmers and small-scale producers in the agriculture and food sector in Senegal, Türkiye, and the United States was conducted. Percentage change in total value of agricultural production in Senegal, Türkiye, and the United States were analyzed. The positive and zero values during the external shocks indicated that the agricultural production system was resilient. On the other hand, the negative values during the external shocks indicated the non-resilience of the system. For Senegal, we saw both positive and negative values, especially between 1990 and 2010. Hence, resilience of farmers can show

variation from one year to another. Farmers can be resilient to external shocks in one year and non-resilient in the following year. Hence, the resilience of the farmers to external shocks should be checked regularly.

Regression analysis was conducted to identify the factors that influence the resilience of farmers in Senegal, Türkiye, and the United States. In Senegal, it was found that as the fixed capital formation in agriculture increases, the resilience of farmers increase. Hence, as farmers have higher access to capital, such farm infrastructure, machines and equipment, farmers can generate higher agricultural production value, which strengthens their resilience to external shocks. It was also found that as the farmers access to arable land increases, farmers' resilience to external shocks increase. On the other hand, for the United States, off-farm income was found as an important factor that influence resilience of farmers. Hence, generating alternative sources income is an important factor to hence resilience of farmers.

In the second regression model, where the resilience was measured as the percentage change in value of agricultural production per hectare, in addition to capital and arable land variables, number of cattles variable is also statistically significant and has a positive coefficient for Senegal. Hence, as the number of cattles farmers have increases, farmers' resilience also increases. Raising cattle provides additional and higher income to farmers, which is like an income diversification and a safety net against external shocks.

Based on the regression results, we recommend the following policies to strengthening the resilience of family farmers and small-scale producers;

- Financial support programs, such as cost share programs, can be established for farmers to accumulate farm capital (e.g. building, equipment, machinery).

- Farmers access to arable land can be increased through government support programs, such as rent cost sharing, and long term rental contracts through leasing. Care should be taken for deforestation.
- Educational and financial support programs for livestock operators can be established to increase the number of cattle holdings.
- Off-farm income opportunities should be generated to provide alternative income sources for the farmers. Investment incentives can be given to private companies to invest in rural areas to generate employment opportunities to farmers.
- Entrepreneurship activities and education should be promoted among farmers to help farmers to generate alternative sources of income and protect themselves from negative economic shocks by better managing income and production risks.

I. Scope of the Project

The objective of this study is to measure the resilience and identify the factors that influence the resilience of the family farms and small-scale producers in the Organization of the Islamic Cooperation (OIC) member countries. With the identified factors policy recommendations are provided to strengthen the resilience of the family farmers and small-scale producers. While proposing recommendations to improve resilience, environmental and social sustainability are also considered.

The specific objectives of the project are;

- Doing a literature review on the factors those influence the resilience of family farmers and small-scale producers in the agriculture and food sector in the OIC member countries.
- Identify the well-functioning examples of the family farmers and small-scale producers around the world and in the OIC member countries by doing desk reviews, surveys, and field visits.
- Provide policy recommendations and a clear road map to the OIC member countries to strengthen the resilience of family farmers and small-scale producers systems, which can include legal arrangements, support programs, performance indicators.

II. Conceptual Framework and Methodology

Resilience of farmers can be defined as ability of farmers to continue to produce agricultural products and continue to support their livelihoods after an economic, environmental or a social shock has occurred (Meuwissen et al., 2019). We measure the continuation of agricultural production and generating income from this production with total value of agricultural products produced and the value of agricultural production per hectare at the national level. We

specifically use the yearly percentage change of total value of agricultural production and the yearly percentage change of value of the agricultural production per hectare to see if the system is resilient. Non-negative changes in the face of shocks imply resilience. We use the following formulas;

- % Change in the Value of Agricultural Production = $\frac{(y_t - y_{t-1})}{y_{t-1}} \times 100$

where y_t is the value of agricultural production in year t .

- % Change in the Value of Agricultural Production per Hectare = $\frac{(v_t - v_{t-1})}{v_{t-1}} \times 100$

where v_t is the value of agricultural production per hectare in year t .

- If % Change is Positive, then the system is “Resilient”
- If % Change is Zero, then the system is “Resilient”
- If % Change is Negative, then the system is “Non-resilient”

The factors that influence the resilience capacity of the farmers can be grouped as;

- Access to Credit and Productive Assets
- Access to Technology and Markets
- Demographic Factors and Adaptive Capacity (i.e. socio-economic factors)

Farmers access to credit, productive assets, technology and markets, which eventually influence the resilience of the farmers, are analyzed using the conceptual framework based on the behavioral agricultural economics that has been established since the study by Griliches (1957). The quantitative analysis is based on inferential statistics and econometrics (Wooldridge, 2010). The methodology and the data collection tools to be conducted in the study are:

Regression and Principal Component Analysis of Determinants of Resilience

We conduct regression analysis to determine the factors influencing resilience of the family farmers and the small-scale producers. In the current analysis we use the following econometric model;

$$Resilience = \beta_1 + \beta_2 Credit + \beta_3 Capital + \beta_4 Cattle + \beta_5 ArableLand + \varepsilon$$

where *resilience* is the dependent variable and measured as the percentage change in total value of agricultural production. We also used the percentage change in the value of the agricultural production per hectare as another dependent variable. For the independent variables, *credit* is credit to agriculture measured in million US\$, *capital* is the gross fixed capital formation in agriculture measure in million US\$, *cattle* is the number of cattle measured in livestock units (e.g. dairy cow is equal to one), and *arable land* is the amount of arable land measured in 1000 ha. β_k 's are the coefficients to be estimated and ε is the error term. We use principal component analysis for the highly correlated factors to determine the those that have high influence on the resilience capacity of a country. We also look at the sub-groups of these factors.

Econometric Model of Farmers' Behavior

A farmer's decision to adopt a new technology to enhance resilience will be analyzed using a random utility model (Wooldridge, 2010). Same model will also be used for access to markets and financial resources to enhance resilience capacity of the farmers. The farmer compares the utility gained from adopting a new technology U_a with the utility gained from not adopting the new technology U_{na} . The farmer adopts the new technology if U_a is bigger than U_{na} , otherwise the farmer does not adopt the conservation practice. As researchers we can't observe the random utility for the farmer, but we can observe the technology adoption decision as:

$$y_i = 1 \text{ (the new technology is adopted)} \quad \text{if } U_a > U_{na}$$

$y_i = 0$ (the new technology is not adopted) if $U_a \leq U_{na}$

Following the literature on technology adoption, the random utility from technology adoption $U(.)$ is a function of the farmer's and farm's characteristics; age, farm sales (size of the farm operation), perceptions of the farmer, off-farm income, education and farm physical properties. The random utility function also has a random component ϵ , which accounts for the factors not measured by the researcher. Based on the random utility specification of technology adoption, a binary response model can be used as the econometric model for the adoption decision. In the current study we will use a probit model as the binary response model. This model can be represented as (Wooldridge, 2010):

$$\Pr (y_i = 1|X_i) = G(X_i\beta_i) \text{ for } i = 1, \dots, N$$

where $y_i = 1$ if the farmer adopts the new technology and $y_i = 0$ if the farmer does not adopt the new technology. β_i is the vector of coefficients to be estimated and X_i is the vector of independent variables, which includes the variables that are included in the random utility function. $G(.)$ is the cumulative distribution function and for the probit model standard normal distribution is used (Wooldridge, 2010).

A. Resilience Analysis in OIC Member Countries Based on the International Databases and the Review of the Literature

Desk research was conducted with a review of the literature and analysis of the applications, reports, and procedures of the international and regional organizations on the resilience in agriculture and food sector. In addition to this an analysis was conducted based on the data available from internationally available databases. For the desk research, the data was collected from international and national data sources, such as the following sources;

- Statistical Database of the Food and Agriculture Organization of the United Nations
- World Bank Group World Development Indicators
- The Statistical, Economic and Social Research and Training Centre for Islamic Countries
- Organization for Economic Co-operation and Development
- United States Department of Agriculture Foreign Agricultural Services
- Food Systems Dashboard

B. Survey

An agricultural household survey was constructed to measure the resilience of the family farmers and small-scale producers in the OIC Member Countries. The survey was used to identify the factors those influence the resilience capacity of the family farmers, such as limited access to markets, technology, and financial resources. The survey was designed based on the literature review conducted and the surveying methodology developed by Dillman (2000). The survey was conducted through face-to-face interviews, phone interviews, and online-interviews with the identified farmers. The survey was designed in a way to provide a measure of the level of the resilience of family farmers and small-scale producers and the level of the determinants of the resilience. The survey was designed to cover specifically;

- Measuring the level of resilience
- Access to market and technology
- Access to financial resources
- Asset ownership

- Socio-economics factors those influence the strength of resilience of family farmers and small-scale producers
- Economic performance indicators for the resilience of family farmers and small-scale producers, such as yield and value of the agricultural production.

C. Field Visit Case Studies

Field visits to Morocco (African group) and Azerbaijan (Asian group) were conducted to conduct an in-depth analysis of the history and current situation of resilience of family farmers and small-scale producers. With the help of these visits in-depth policy related information was collected to develop effective policy recommendations on increasing the resilience of the family farmers and the small-scale producers. Detailed face-to-face interviews were conducted with stakeholders. At the end of each visit, an assessment of the resilience of family farmers and small-scale producers were conducted and applicable policy recommendations were developed. These policy recommendations were specific and targeted at increasing the resilience of family farmers and small-scale producers.

D. Desk-Based Case Studies

An analysis of one non-OIC (Unites States) and two OIC Countries (Türkiye and Senegal) as case studies, based on literature review and international databases, were conducted. These case studies address the resilience of family farmers and small-scale producers and cover the topics included in the survey designed. Overall, linkages were formed between field-visits and desk-based case studies to strengthen the resilience of the family farmers and small-scale producers in the OIC member countries.

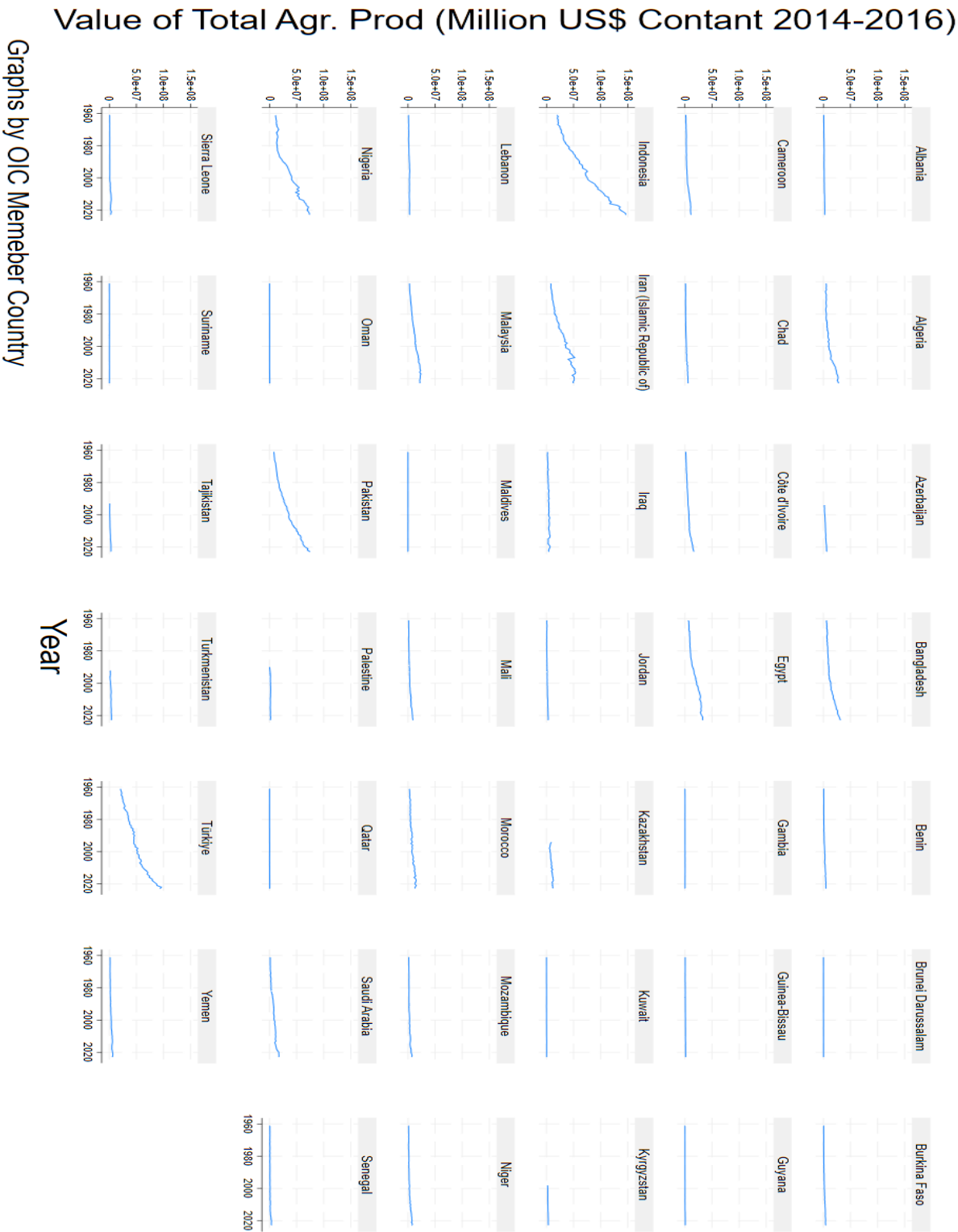
III. Overview of the Resilience in the OIC Member Countries

Family farmers and small-scale producers in the agriculture and food sector in the Organization of Islamic Countries (OIC) member countries are critical for food security and rural livelihoods. Resilience of farmers can be defined as the ability of farmers to continue to produce agricultural products and continue to support their livelihoods after an economic, environmental or social shock has occurred. We measure the continuation of agricultural production and generate income from this production with total value of agricultural production and the value of agricultural production per hectare at the national level. We specifically use the yearly percentage change of total value of agricultural production and the yearly percentage change of value of the agricultural production per hectare to see if the system is resilient. Non-negative changes in the face of shocks imply resilience.

We provide an overview of the total value of agricultural production of the OIC member countries, measured in 2014-2016 US\$, in figure 1 below. There has been an overall increase in agricultural production in some of the OIC member countries significantly higher than other member countries. Five member countries; Indonesia, Iran, Pakistan, Nigeria, and Türkiye show significant increase in total value of agricultural production since 1961. Whereas the other members, such as Benin, Chad, Qatar, and Suriname, show relatively smaller increases. We provide the total value of agricultural production in the OIC member countries, as a sum in the figure 2. There has been an overall increase in agricultural production in the OIC member countries together.

In figure 3, we present the change in total value of agricultural production in the OIC member countries. Overall, there are fluctuations in the aggregate agricultural production in the OIC member countries, but these are mostly positive fluctuations. Very few of the changes are

Figure 1: Total Value of Agricultural Production of the OIC Member Countries



negative at the aggregate agricultural production among the OIC member countries. With appropriate agreements among countries, there is significant potential among the OIC member countries support each other in agricultural commodities.

Figure 2: Total Value of Agricultural Production in the OIC Member Countries

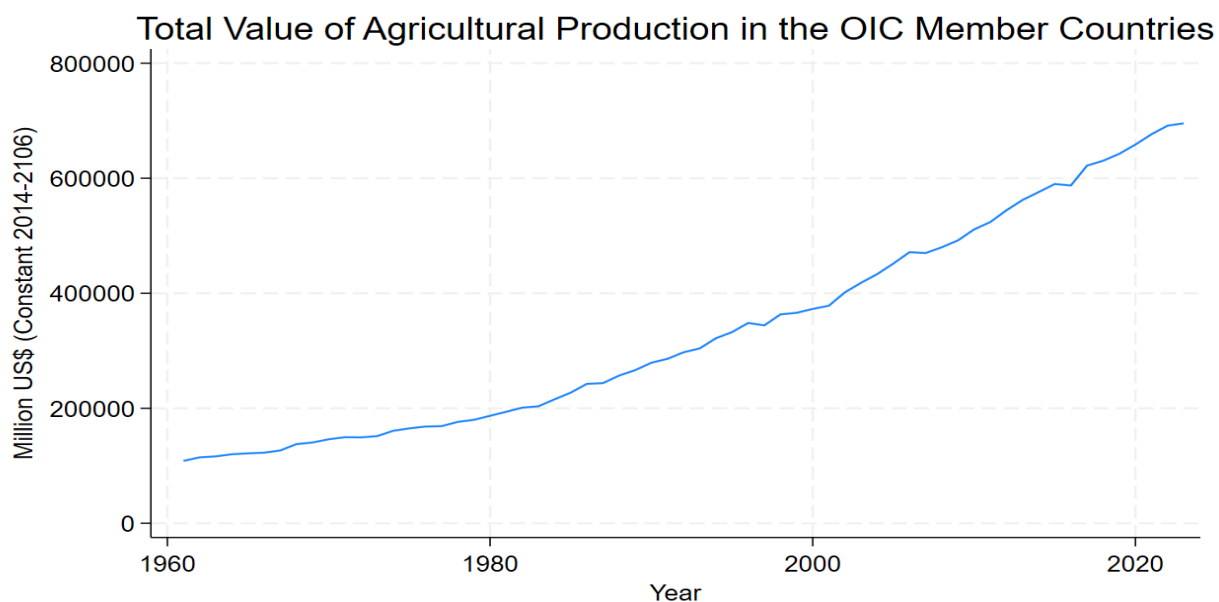
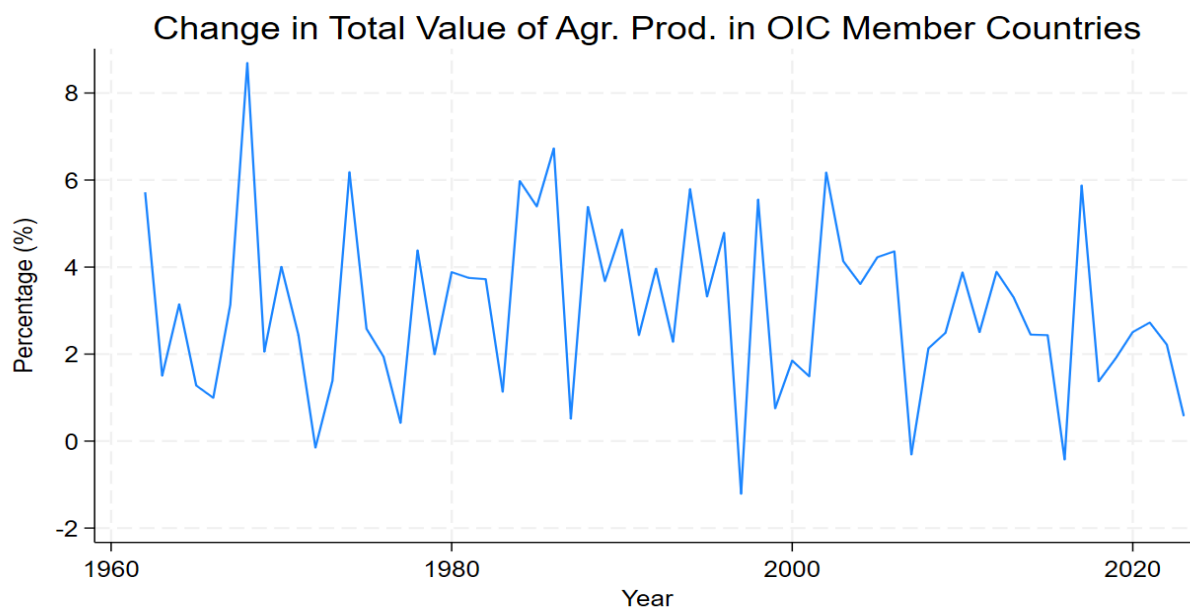


Figure 3: Change in Total Value of Agricultural Production in the OIC Member Countries



To further look at the resilience of the OIC member countries individually, we provide the percentage change in the value of total agricultural production at the member country level in figure 4 below. Based on figure 4, Indonesia, Malaysia, Pakistan, and Türkiye show relative less fluctuations in the total value of agricultural production, hence more resilience over the 1990-2023 period. To further look at the resilience of OIC member countries, we rank the member countries in number of negative percentage changes in total value of agricultural production since 1995. The results are given in table 1 below. We can see from the table that Indonesia had the smallest number of negative percentage changes in total value of agricultural production, which is three. Hence, based on this criteria Indonesia has more resilient agricultural production system than the rest of the member countries. Indonesia is followed by countries such as Azerbaijan, Bangladesh, Cameroon, and Pakistan with four negative percentage changes in total value of agricultural production since 1995. On the other hand, countries such as Maldives and Senegal had fourteen negative percentage changes in total value of agricultural production during the same period.

Figure 4: Change in Value of Total Agricultural Production in the OIC Member Countries

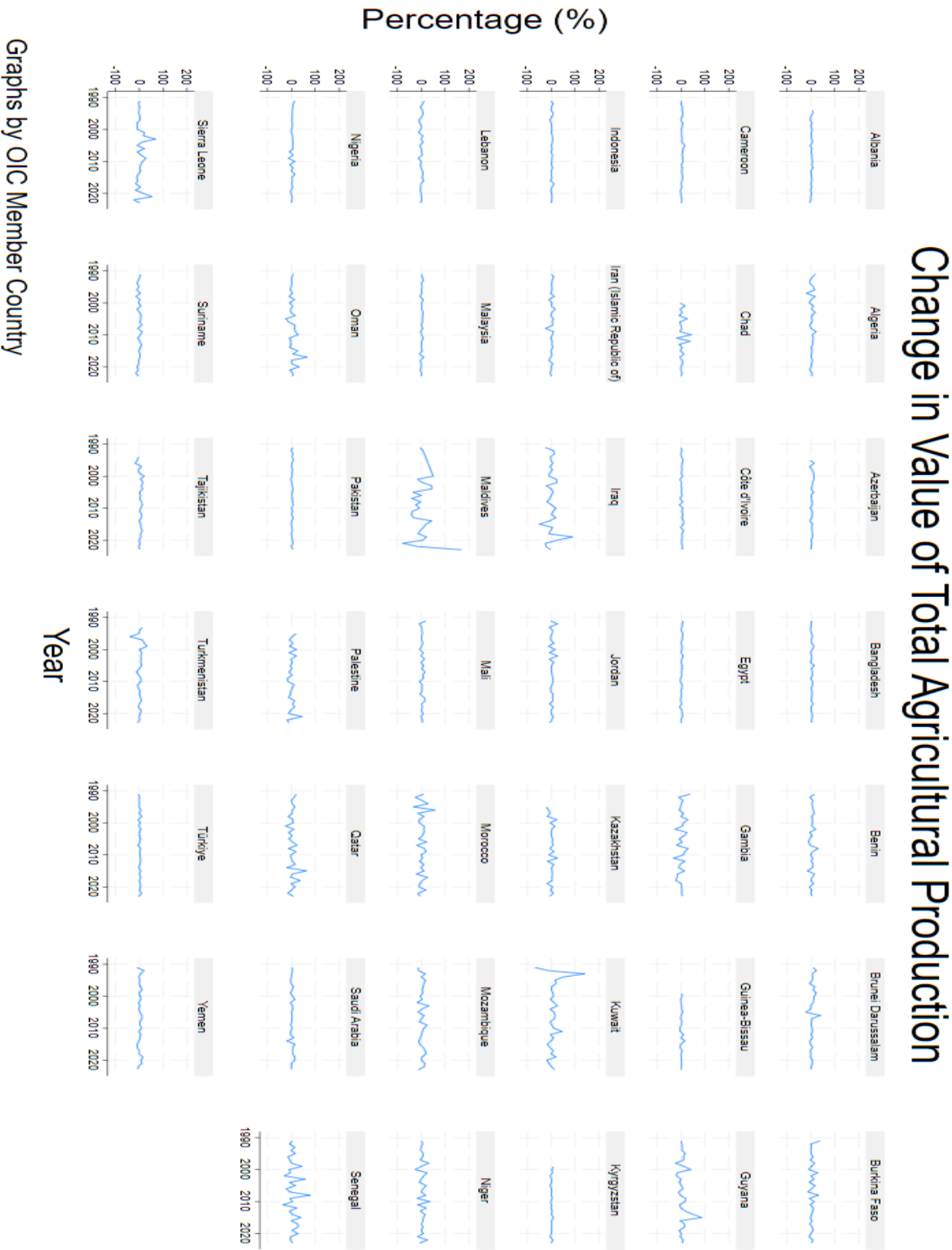


Table 1: Ranking of OIC Member Countries Based on Number of Negative Percentage Changes in Total Value of Agricultural Production since 1995

Ranking	Country	Number of Negative Changes (Total Value of Agr. Production)
1	Indonesia	3
2	Azerbaijan	4
3	Bangladesh	4
4	Cameroon	4
5	Cote d'Ivoire	4
6	Kyrgyzstan	4
7	Pakistan	4
8	Algeria	5
9	Mali	6
10	Tajikistan	6
11	Guinea Bissau	7
12	Nigeria	7
13	Türkiye	7
14	Benin	8
15	Mozambique	8
16	Turkmenistan	8
17	Egypt	9
18	Iran	9
19	Malaysia	9
20	Saudi Arabia	9
21	Albania	10
22	Brunei Darussalam	10
23	Burkina Faso	10
24	Gambia	10
25	Jordan	10
26	Kazakhstan	10
27	Kuwait	10
28	Niger	10
29	Qatar	11
30	Sierra Leone	11
31	Guyana	12
32	Oman	12
33	Yemen	12
34	Chad	13
35	Iraq	13
36	Morocco	13
37	Suriname	13
38	Maldives	14
39	Senegal	14
40	Lebanon	15
41	Palestine	15

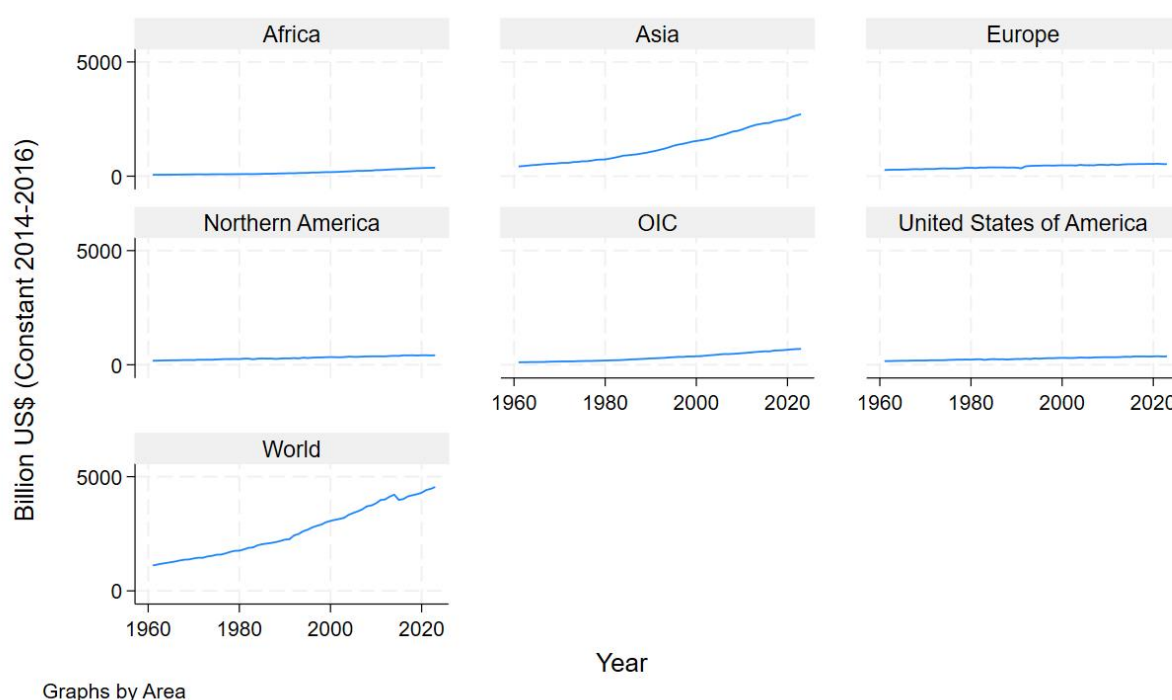
As an alternative measure, we give a ranking of the OIC member countries based on the “largest negative percentage change” in total value of agricultural production since 1995. The results are presented in table 2 below. Pakistan has the smallest negative percentage change in total value of agricultural production among OIC member countries since 1995. Hence, the largest negative change in total value of agricultural production has been -2%. Hence, the influence of a shock to the agricultural production system in Pakistan has been relatively lower than the other OIC member countries. Pakistan is followed by Kyrgyzstan with -4%. Indonesia, which had the smallest number of negative percentage changes in total value of agricultural production, has -6% as the largest negative percentage change and following Kyrgyzstan among with Azerbaijan, Cote d’Ivoire, and Egypt. Hence, Indonesia shows relatively resilient agricultural production system among OIC member countries including both ways of measurement. On the other hand, countries such as Iraq, Qatar, Kuwait, and Maldives had more -50% or more as the largest negative percentage changes in total value of agricultural production, which can be challenging to recover from such an influential shock to the agricultural production system. A food system buffer can be established among OIC member countries to support those that face big shocks. Also, farmers access to technologies to make agricultural production more resilient becomes more important for those countries facing big production shocks or shortages in their food supply. OIC member countries with more resilient agricultural production systems, such as Indonesia, can facilitate to generate more resilient agricultural production systems in member countries those face big production shocks in the food supply.

Table 2: Ranking of OIC Member Countries Based on Largest Negative Percentage Change in Total Value of Agricultural Production since 1995

Ranking	Country	Largest Negative Change (Total Value of Agr. Production)
1	Pakistan	-2%
2	Kyrgyzstan	-4%
3	Azerbaijan	-6%
4	Cote d'Ivoire	-6%
5	Indonesia	-6%
6	Egypt	-6%
7	Malaysia	-7%
8	Türkiye	-7%
9	Bangladesh	-9%
10	Albania	-10%
11	Cameroon	-10%
12	Burkina Faso	-13%
13	Mali	-13%
14	Yemen	-13%
15	Suriname	-14%
16	Nigeria	-14%
17	Benin	-15%
18	Mozambique	-16%
19	Tajikistan	-16%
20	Palestine	-17%
21	Guinea-Bissau	-18%
22	Chad	-19%
23	Kazakhstan	-20%
24	Lebanon	-20%
25	Brunei Darussalam	-22%
26	Sierra Leone	-22%
27	Iran	-23%
28	Oman	-23%
29	Niger	-26%
30	Guyana	-27%
31	Algeria	-31%
32	Gambia	-31%
33	Morocco	-32%
34	Saudi Arabia	-36%
35	Senegal	-37%
36	Turkmenistan	-38%
37	Jordan	-43%
38	Iraq	-50%
39	Qatar	-55%
40	Kuwait	-68%
41	Maldives	-78%

In figure 5 below, we provide a comparison of total value of agricultural production across regions and the OIC member countries. We can see especially in Asia there has been an significant increase in the total value of agricultural production starting 1980's. This could be a result of the “Green Revolution” during the 1960's, which introduced high yielding seed varieties and other technological improvements. OIC member countries, in aggregate, also see an increase in total value of agricultural production since 1980's, which can also be attributable to use of modern technology and mechanization in agriculture during the green revolution, especially among member countries in Asia.

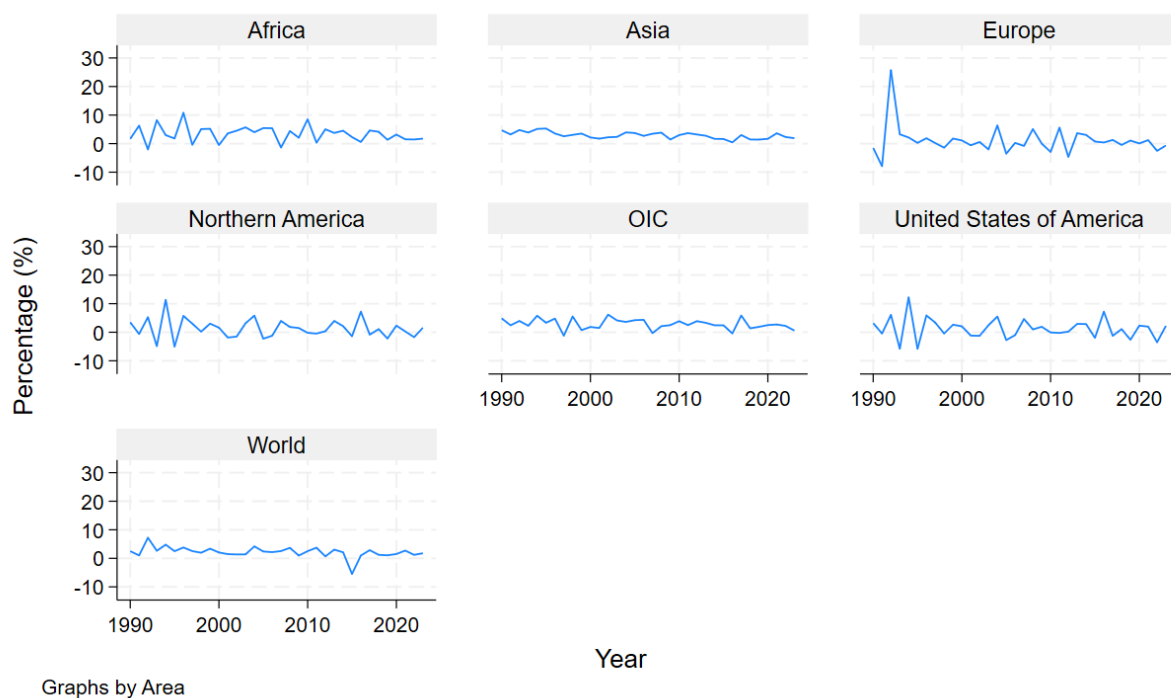
Figure 5: Total Value of Agricultural Production in the World and OIC Member Countries



We provide percentage change in total value of agricultural production across different regions in the World and the OIC member countries in figure 6. Overall, we see less fluctuations in Asia than the other regions. The OIC member countries, in aggregate, show some fluctuations, but generally positive percentage changes. Africa has more fluctuations than Asia and with some

negative percentage changes. As indicated previously, with certain trade agreements among OIC member countries, a support system can be established to provide buffer when there are negative shocks to the agricultural production at the member countries. We also see high fluctuations in the Europe and Northern American can in general be attributable climate related events.

Figure 6: Percentage Change in Total Value of Agricultural Production in the World and OIC Member Countries



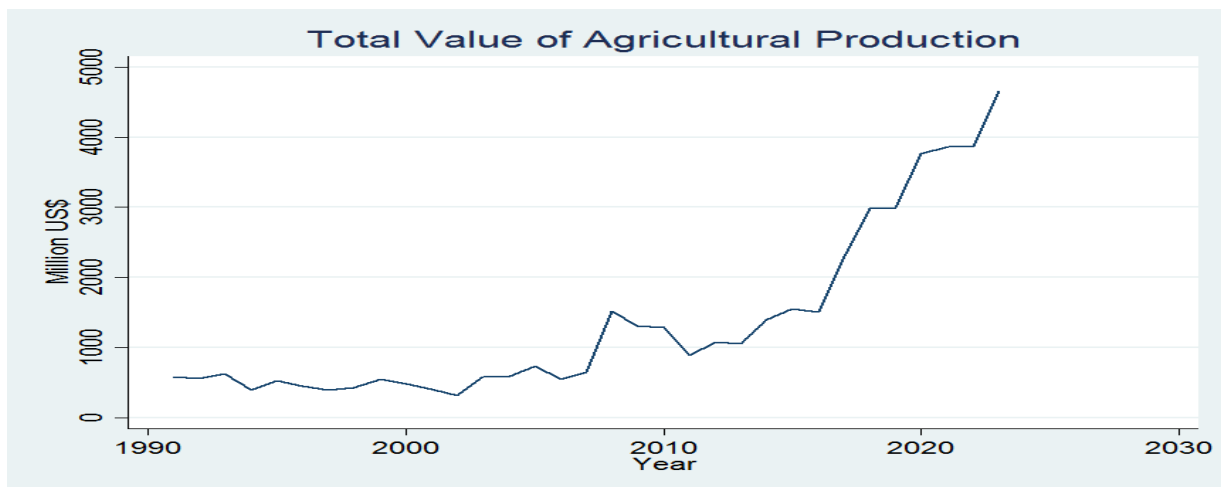
IV. Desk-Based Case Study: Senegal

In this part of the report, we study the resilience of family farmers and small-scale producers in Senegal. First we will analyze the resilience, then we will identify the factors that influence resilience of farmers in Senegal. With the identified factors policy recommendations will be provided to strengthening the resilience of the family farmers and small-scale producers in Senegal.

A. *Measurement of Resilience*

Total value of agricultural production measure in US\$ is given in figure 4 below. Total value of agricultural production is around the same level between 1990 and 2005 with some fluctuations. We see some decrease around year 2000. However, the total value agricultural production starts to increase especially after 2010. Senegal has seen increases in infrastructure though out the country, especially after 2010 (FAO, 2024). This could also influence the value created from agricultural production. We see some stability during the COVID-19 era, but then the total value of agricultural production increases to around 4,5 billion US\$ in 2023.

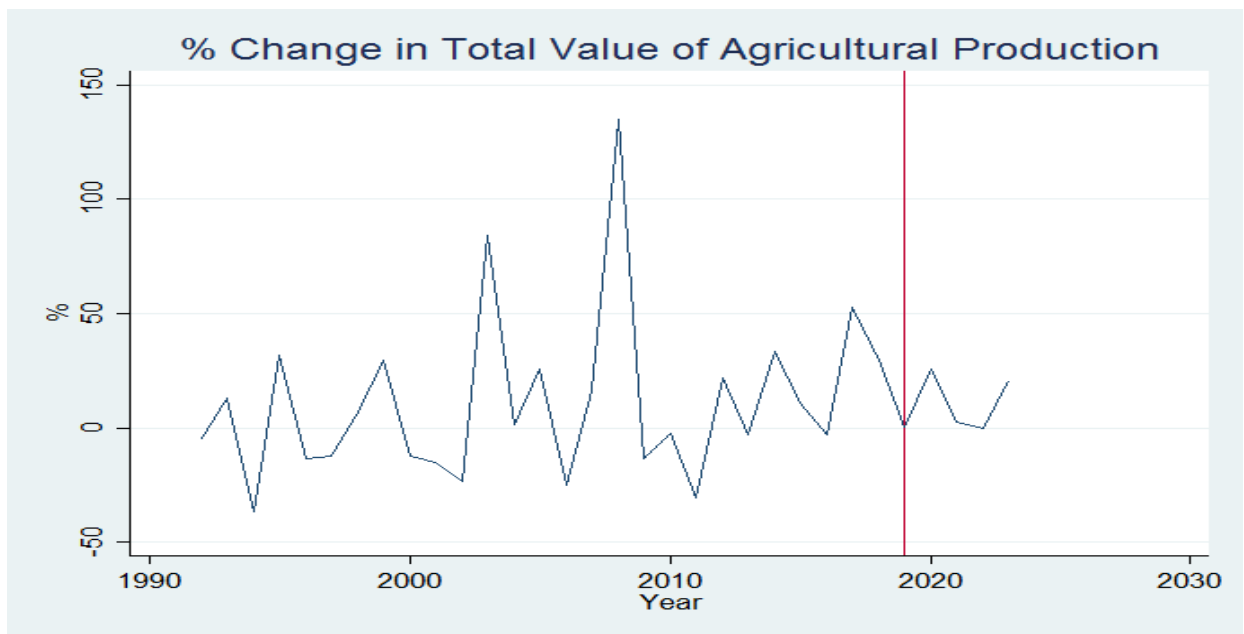
Figure 1: Total Value of Agricultural Production in Senegal



Source: FAOStatistics (2025)

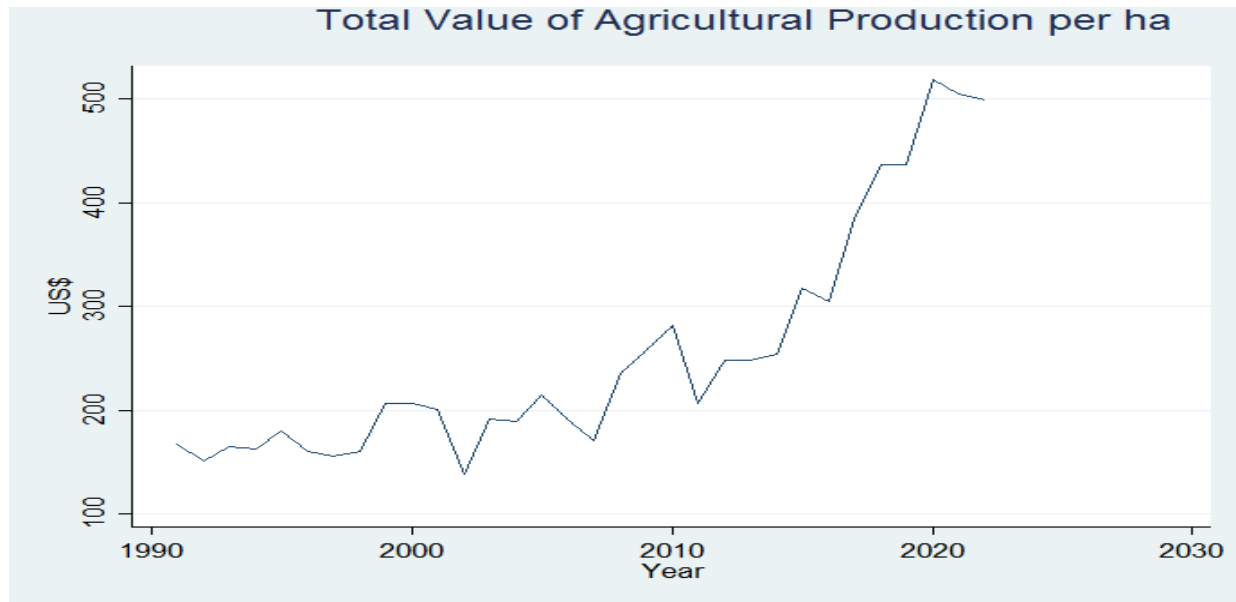
Percentage change in total value of agricultural production in Senegal, which is used as a measure of resilience of farmers, is given in figure 2 below. The positive and zero values during the external shocks indicate that the agricultural production system is resilient, as the value generated from agricultural production continued without a decrease. On the other hand, the negative values during the external shocks indicate the non-resilience of the system, as the value generated from agricultural production decreased. We see both positive and negative values, especially between 1990 and 2010. Hence, resilience of farmers can show variation from one year to another. Farmers can be resilient to external shocks in one year and non-resilient in the following year. Hence, the resilience of the farmers to external shocks should be checked regularly. In Senegal, resilience of farmers shows less fluctuations after 2010 and farmers look more resilient post 2010 period.

Figure 2: % Change in Total Value of Agricultural Production in Senegal



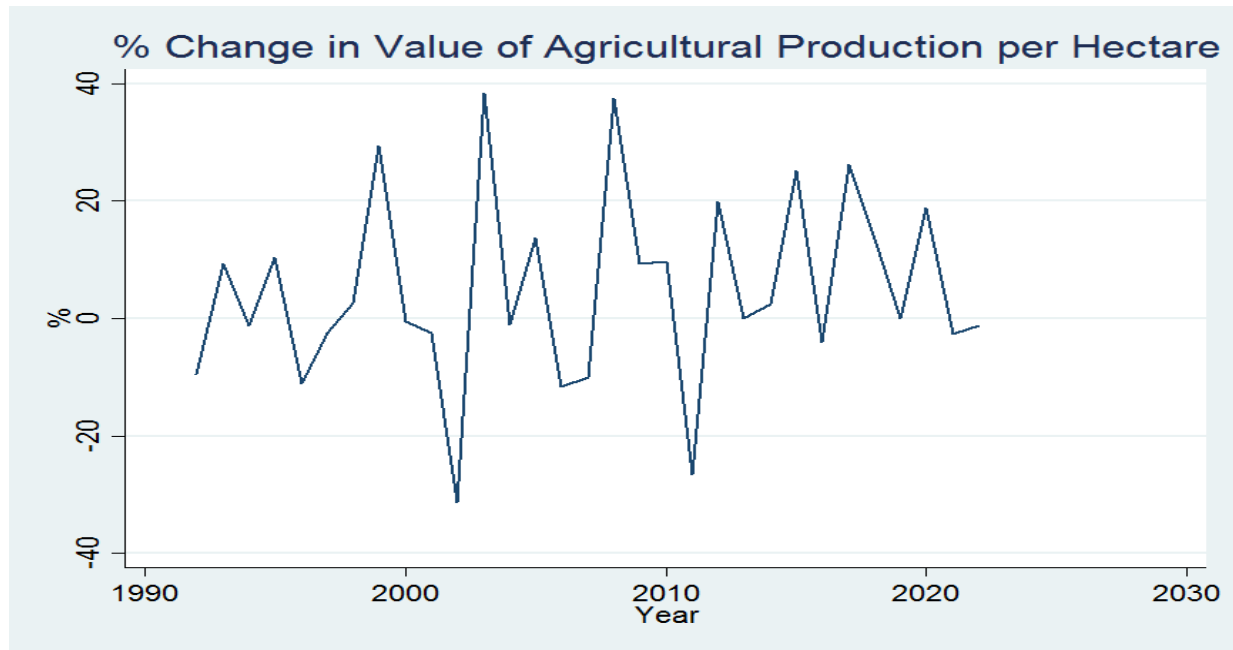
Total value of agricultural production per hectare is shown in figure 3 below. Overall, we see yearly fluctuations, especially between 1990 and 2010. This could be due to hostile economic

Figure 3: Total Value of Agricultural Production per Hectare in Senegal



conditions during this period. After 2010, there is a positive trend and the value reaches to 510 US\$ per ha in 2020. We then see a decrease in the total value of agricultural production per hectare in the recent years. The percentage change in the total value of agricultural production per hectare, which is also used as measure of resilience of farmers, is shown in figure 4. We see both positive and negative values between 1990 and 2023. There are seems to be more negative values before 2010, but there are also negative values in the recent years. Hence, based on the percentage change in total value of agricultural production per hectare, farmers lost their resilience in the recent years. This could be due to the import depend inputs, such as fertilizer use in Senegal, for which Ukraine and Russian was has been highly influential. The decrease in resilience could also be due to the draught occurred in Senegal, as the country is highly vulnerable to the effects of climate change (<https://www.copernicus.eu/et/node/10014>).

Figure 4: % Change in Total Value of Agricultural Production per Hectare in Senegal

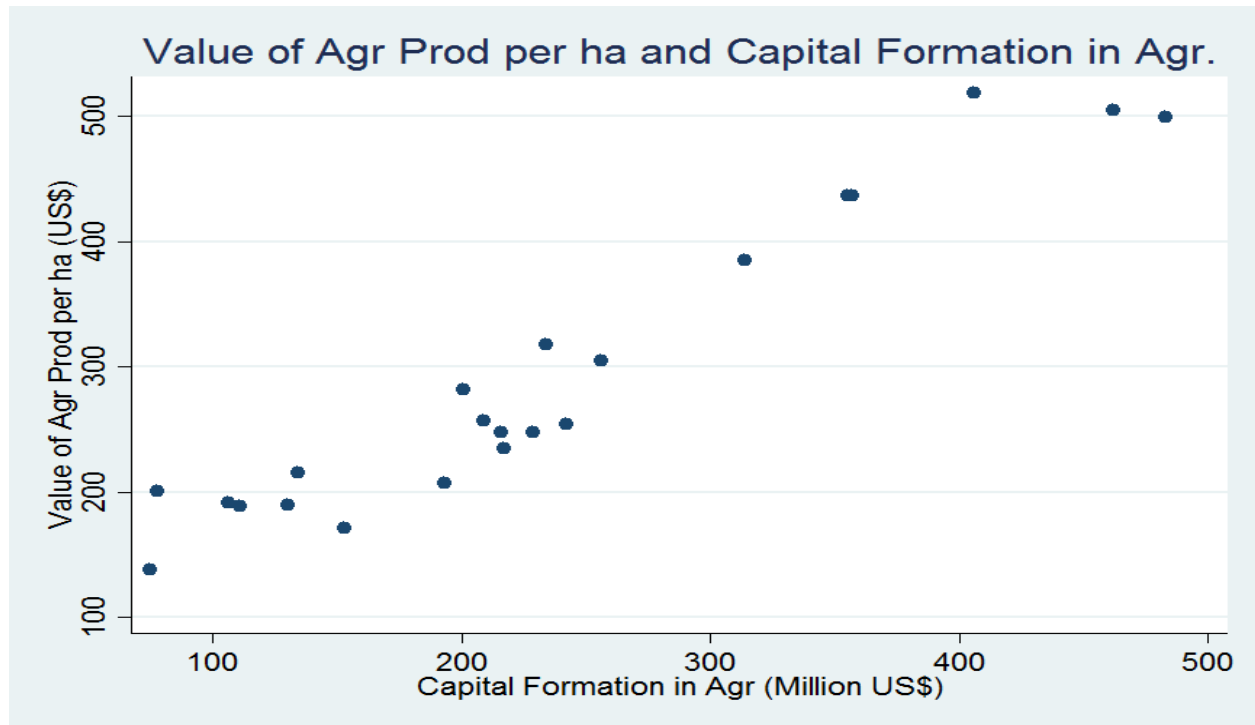


Source: FAOStatistics (2025)

B. Determinants of Resilience in Senegal

In this section of the report we analyze the factors that influence resilience of family farmers and small-scale producers in Senegal. With the identified factors policy recommendations will be developed to strengthening the resilience of farmers. In figure 5 below, the relationship between the value of agricultural production per hectare and capital formation in agriculture is presented. A positive association is seen between the two. As the value of capital formation in agricultural increases, we see an increase in the value of agricultural production per hectare. Farmers' access to higher agricultural capital, such as equipment and farm structure, can be influential on the value generated per hectare. To analyze the casual relationship between the two, regression analysis will be used in the next sub-section.

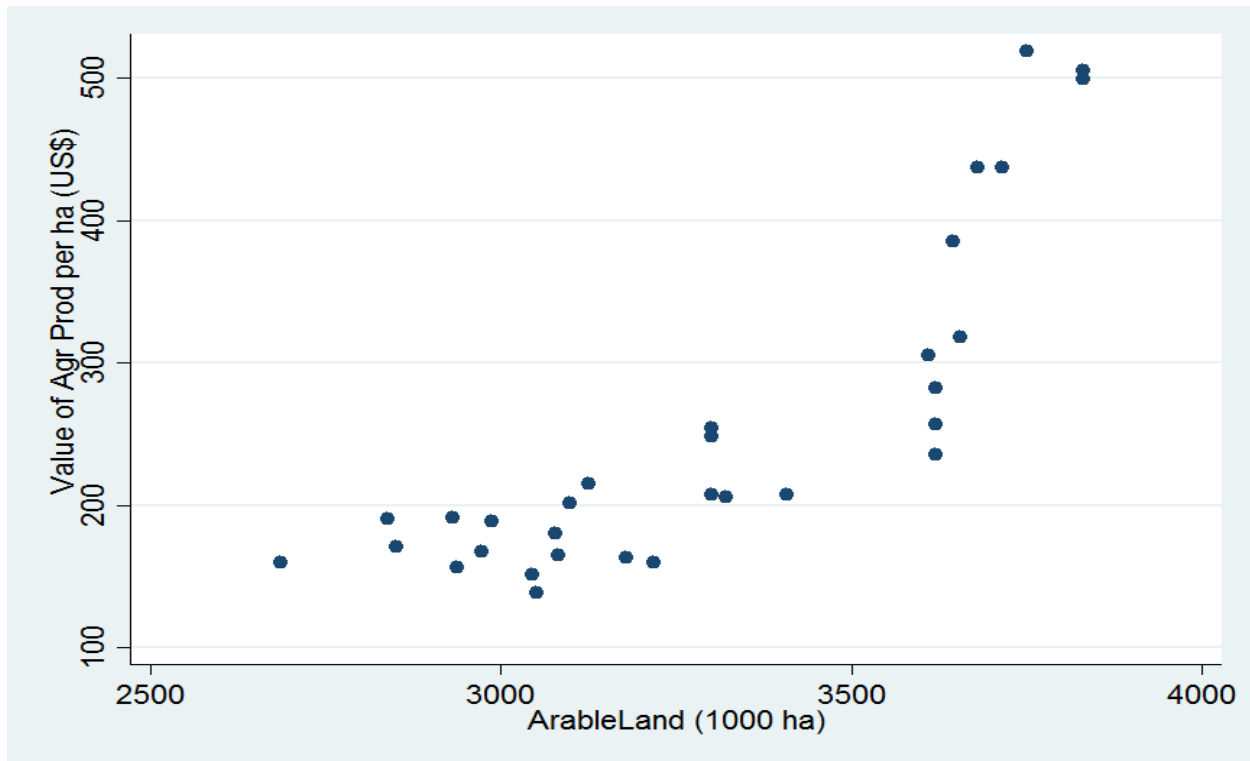
Figure 5: Value of Agr. Prod. per ha and Capital Formation in Agriculture in Senegal



Source: FAOStatistics (2025)

In figure 6 below, the relationship between the value of agricultural per hectare and size of the arable land is depicted. There seems to be some positive association between the two up to 3,500 (1000 ha), the positive correlation is more apparent beyond 3,500 (1000 ha). As the land over which increases, the value of agricultural production generated per hectare increases. This could be related to the fact that as farm sizes grow, farmers have easier access to technology and assets, due to economies of scale. The casual relationship between the value of agricultural production per hectare and size of the arable land will be further analyzed through regression analysis.

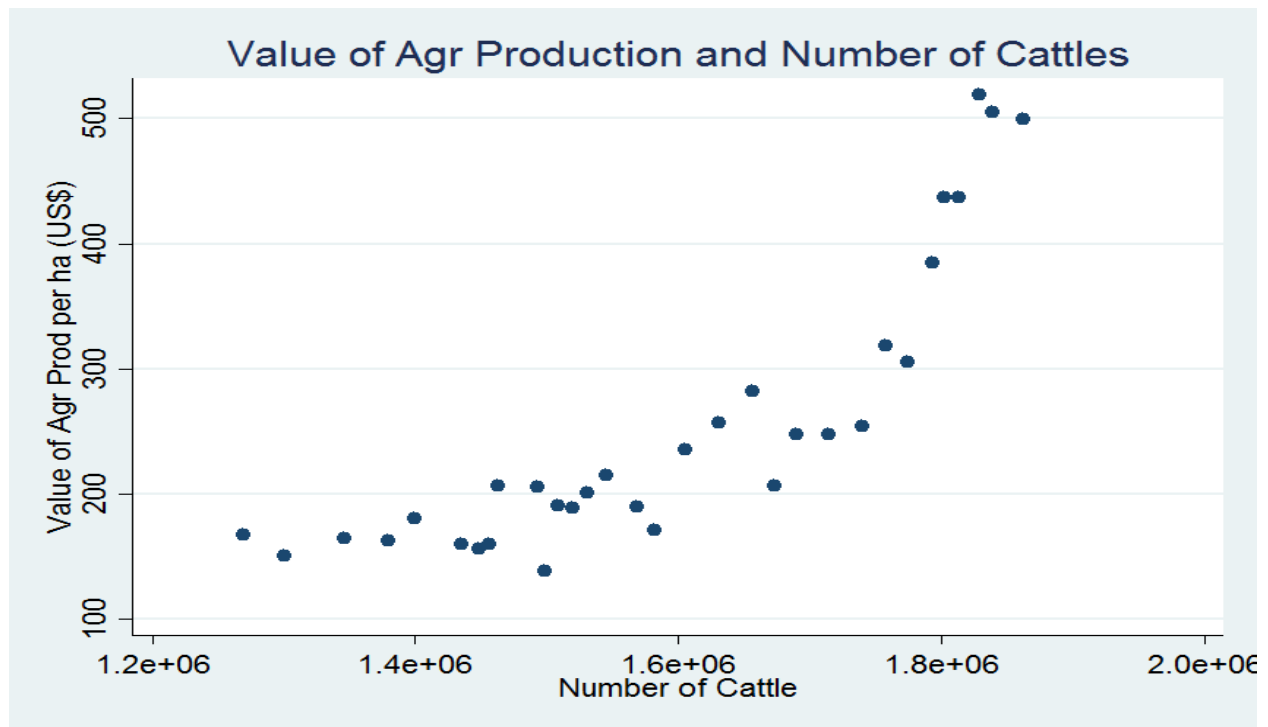
Figure 6: Value of Agr. Prod. per ha and the Size of the Arable Land in Senegal



Source: FAOStatistics (2025)

In figure 7 below, the relationship between the value of agricultural production per hectare and number of cattle is depicted. We see a positive association between the two, especially at the higher number of cattles. Livestock production provides additional income to farmers and cattle meat (i.e. beef) generates higher income for the farmers. Hence, number of cattles can be influential on resilience of farmers, which will be further analyzed through regression analysis below.

Figure 7: Value of Agr. Prod. per ha and the Number of Cattles in Senegal



Source: FAOStatistics (2025)

Regression Analysis of Determinant of Resilience

In this section of the report, we conduct regression analysis to determine the factors influencing resilience of the family farmers and the small-scale producers. In the current analysis we use the following econometric model;

$$Resilience = \beta_1 + \beta_2 Credit + \beta_3 Capital + \beta_4 Cattle + \beta_5 ArableLand + \varepsilon$$

where *resilience* is the dependent variable and measured as the percentage change in total value of agricultural production in Senegal. For the independent variables, *credit* is credit to agriculture measured in million US\$, *capital* is the gross fixed capital formation in agriculture measure in million US\$, *cattle* is the number of cattle measured in livestock units (e.g. dairy cow is equal to one), and *arable land* is the amount of arable land measured in 1000 ha. β_k 's are the coefficients to be estimated and ε is the error term. The results of the regression is represented in table 1

below. The regression is overall statistically significant at 1 percent significance level and the adjusted R-squared is 0.745, which reflects that 74.5% of the variation in resilience is explained by the independent variables in the regression. For the independent variables, capital is statistically significant at 1 percent significance level (i.e. p-value of 0.000) and has a positive coefficient. As the fixed capital formation in agriculture increases, the resilience of farmers increase. Hence, as farmers have higher access to capital, such farm infrastructure, machines and

Table 1. Regression Analysis Results for the Resilience in Senegal

Dept. Variable: % Change in Value of Total Agricultural Production for Senegal				
Variable	Coeff.	Std. Err.	t-Stat	p-Value
Δ Credit	- 0.090	0.137	-0.66	0.522
Δ Capital	1.424	0.296	8.17	0.000
Δ Cattle	0.050	0.002	0.22	0.832
Δ ArableLand	0.067	0.514	3.99	0.012
Constant	-0.045	0.057	0.44	0.442
<i>N</i>	19			
<i>Adjusted R²</i>	0.745			
F(4,14)	36.87			
p-Value	0.000			

equipment, farmers can generate higher agricultural production value, which strengthens their resilience to external shocks. The arable land variable is also statistically significant at 5 percent

significance level (e.g. p-value of 0.012) and has a positive coefficient. Hence, as the farmers access to arable land increases, farmers' resilience to external shocks increase.

The results of the second regression model, where the resilience is measure as the percentage change in value of agricultural production per hectare is represented below in table. The regression is overall statistically significant at 1 percent significance level (e.g. p-value of 0.006). The adjusted R-squared value is 0.508. Hence, 50.8 percent of the variation the dependent variable resilience is explained by the variation in the independent variables in the model. For the independent variables, capital variable has positive and statistically significant effect on the

Table 2. Regression Analysis Results for the Resilience in Senegal Based per Hectare

Dept. Variable: % Change in Value of Agricultural Production per Hectare for Senegal				
Variable	Coeff.	Std. Err.	t-Stat	p-Value
Δ Credit	- 0.003	0.002	-1.15	0.271
Δ Capital	0.004	0.002	2.11	0.053
Δ Cattle	0.0001	0.0000	1.92	0.076
Δ ArableLand	0.001	0.0002	1.98	0.068
Constant	-0.049	0.049	-1.00	0.337
<i>N</i>	19			
Adjusted R ²	0.508			
F(4,14)	5.66			
p-Value	0.006			

resilience of farmers, with a p-value of 0.053. Similar to the previous regression, arable land variable also has a positive and statistically significant effect on the resilience. Hence, as the

farmers access to capital and arable land increases, their resilience also increases measured as the percentage change in value of agricultural production per hectare. Higher access to arable land could reflect economics of scale, which could make farmers gain advantage in use of new technologies and make investment that require higher fixed costs. In the current regression, number of cattles variable is also statistically significant and has a positive coefficient. Hence, as the number of cattles farmers have increases, farmers' resilience also increases. Raising cattle provides additional and higher income to farmers, which is like an income diversification and a safety net against external shocks.

Policy Recommendations Based on the Regression Results

Based on the regression results, we recommend the following policies to strengthening the resilience of family farmers and small-scale producers in Senegal;

- Financial support programs, such as cost share programs, can be established for farmers to accumulate farm capital (e.g. building, equipment, machinery).
- Farmers access to arable land can be increased through government support programs, such as rent cost sharing, and long term rental contracts through leasing. Care should be taken for deforestation.
- Educational and financial support programs for livestock operators can be established to increase the number of cattle holdings.

Principal Component Analysis

Principle component analysis can be used to further analyze the structure of the independent variables used in a regression, especially when they are correlated with each other.

In the current study we use principle component analysis to see if the independent variables can be grouped in different categories, reflecting different components. In addition to the *FertilizerN*,

which is the amount of nitrogen fertilizer used in Senegal, as it is the main fertilizer used by the farmers. The results of the principal component analysis is reflected in table 3 below.

Table 3. Results of the Principal Component Analysis

Variable	Comp1	Comp2
Credit	0.470	-0.254
Capital	0.471	-0.355
Cattle	0.478	-0.119
ArableLand	0.439	0.042
FertilizerN	0.366	0.890
Component	Eigenvalue	Proportion
Comp1	4.11	0.82
Comp2	0.54	0.11
N	20	

All the variables have positive and similar effect on the first component, which could reflect the positive effect of productive assets and inputs on value of agricultural production created. On the other hand, *FertilizerN* variable has the largest and positive on component 2, differentiating itself from variables such as capital. Hence, the second component could reflect of the influence of variables input on value of agricultural product produced. To measure the influence of component one and two on the resilience of the farmers, we now use these components as independent variables in the regression analysis did in the previous section. The results of the regression analysis for resilience measured as the percentage change in the value of total

agricultural production is represented in the table 4 below. The regression is overall statistically significant at 1 percent significance level (i.e. p-value is 0.002) and the adjusted R-squared is 0.496. The first principal component PC1 (i.e. productive assets and inputs) has positive and statistically significant effect on the resilience of the farmers. However, the second principal component PC2 (i.e. variable inputs) has negative and statistically significant effect on the resilience of farmers. In Senegal, nitrogen fertilizer is not domestically produced and it is imported from other countries. Hence, heavily reliance on import dependent inputs could make farmers more susceptible to external shocks. Farmers reliance on import dependent nitrogen

Table 4. Regression Analysis Results for Resilience with Principal Components

<i>Dept. Variable: % Change in Value of Total Agricultural Production</i>				
<i>Variable</i>	<i>Coeff.</i>	<i>Std. Err.</i>	<i>t-Stat</i>	<i>p-Value</i>
<i>Δ PC1: Productive Assets</i>	0.573	0.139	4.10	0.001
<i>Δ PC2: Variable Inputs</i>	-0.279	0.086	-3.24	0.005
<i>Constant</i>	-0.023	0.079	-0.30	0.768
<i>N</i>	19			
<i>Adjusted R²</i>	0.496			
<i>F(2,16)</i>	9.87			
<i>p-Value</i>	0.002			

fertilizer can be decreased through promoting organic farming and use of animal manure as a fertilizer. To check the robustness of our results, we also do a regression with resilience

measured as the percentage change in value of agricultural production per hectare. The results from that regression are presented in table 5 below. The regression is overall statistically significant and the value of adjusted R-squared is 0.322. The results from this regression is confirmative of the results from the previous regression. The principal component one (i.e. productive assets and inputs) have positive and principal component two (i.e. variable input) has negative influence on the resilience of farmers. To further analyze the use of import dependent variable input nitrogen fertilizer, in figure 8 below total use of nitrogen fertilizer in Senegal is represented. We see that overall there is an increase in total use of nitrogen fertilizer over time

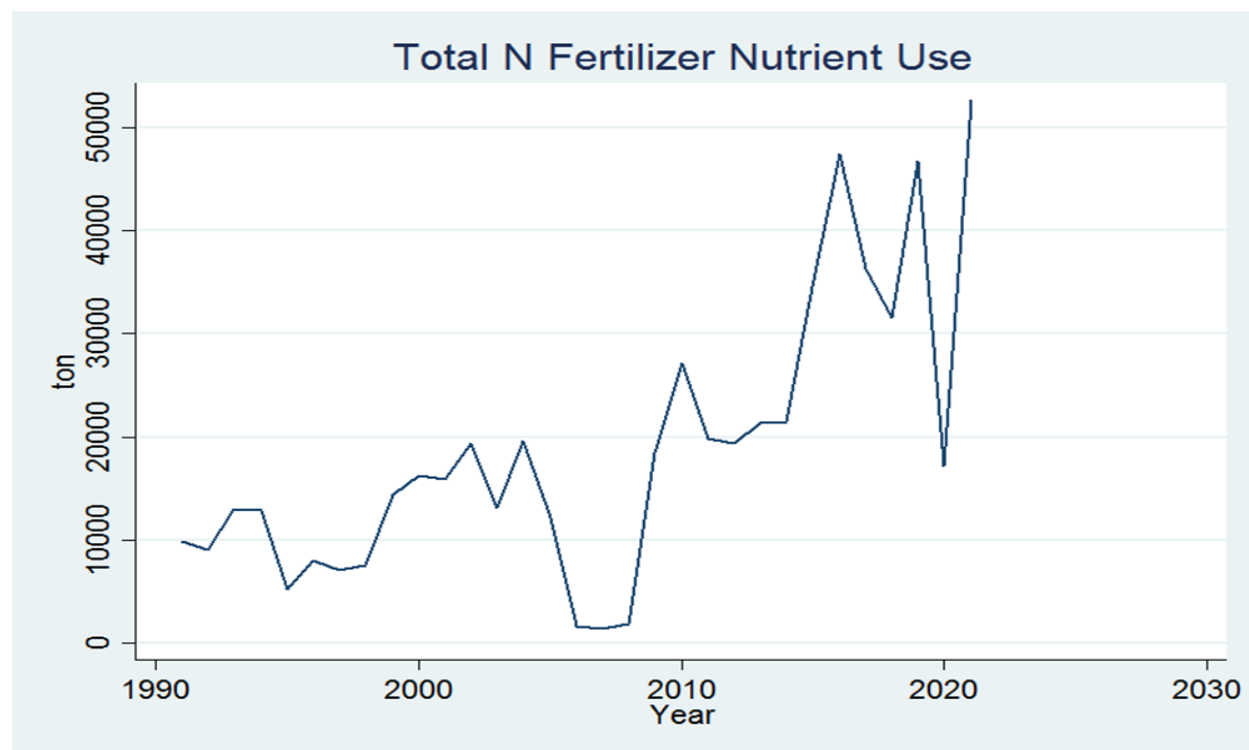
Table 4. Regression Analysis Results for Resilience per Hectare with Principal Components

Dept. Variable: % Change in Value of Agricultural Production per Hectare				
Variable	Coeff.	Std. Err.	t-Stat	p-Value
Δ PC1: Productive Assets	0.241	0.077	3.11	0.007
Δ PC2: Variable Inputs	-0.101	0.047	-2.12	0.050
Constant	-0.014	0.044	-0.32	0.750
<i>N</i>	19			
<i>Adjusted R²</i>	0.322			
<i>F(2,16)</i>	5.27			
<i>p-Value</i>	0.017			

in Senegal, especially after 2010, but there are significant yearly fluctuations. For example in 2020, during the COVID-19 there is a significant decrease in nitrogen fertilizer use. The Ukraine

and Russian War could also negatively influence the supply of nitrogen fertilizer for Senegal. Since, nitrogen fertilizer is one of the major inputs in plant production, significant decreases in its use can cause significant yield losses. This again signifies the promotion of organic farming and manure as a crop nutrient.

Figure 8: Total Use of Nitrogen Fertilizer in Senegal



Policy Implications

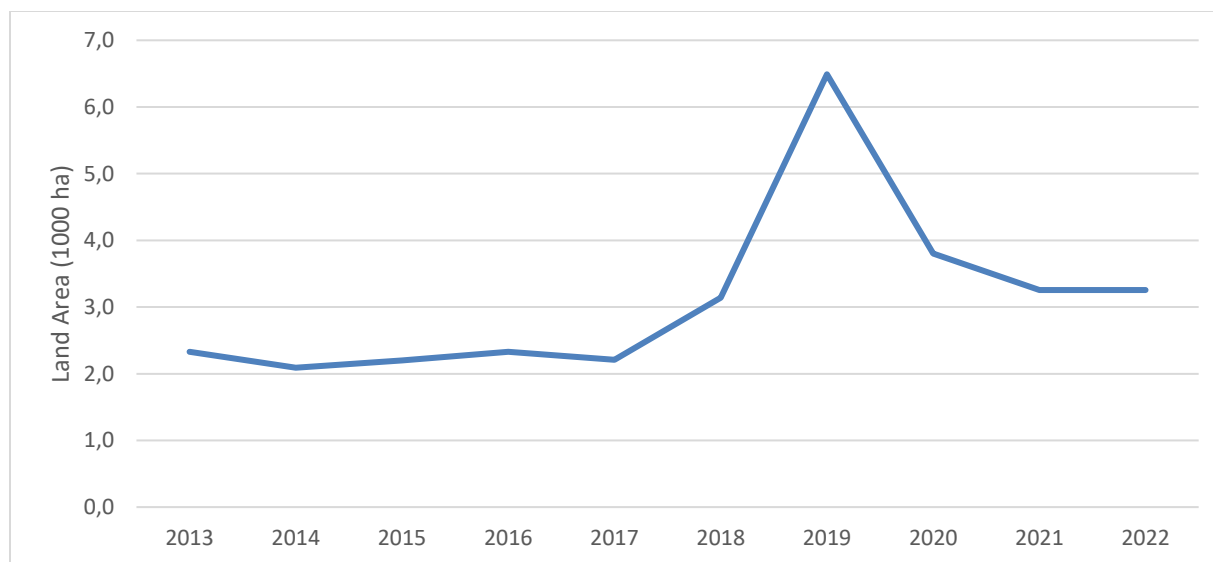
- Farmers' reliance on especially import dependent variable input can be decreased through alternative production systems, such as organic farming and use of manure.
- Multi-year cost share programs can be developed to help farmers with the cost of organic production and yield decreases due to use of manure.

Land area over which organic production is done in Senegal further analyzed in figure 2 below.

Based on the available data, the certified organic production is done over 2,300 ha in 20213 and

increased to 6,500 ha in 2019. Then, with the start of COVID-19 pandemic, starts to decline in reaches to 3,300 ha in 2022. Organic production is crucial for sustainable agriculture and provides a niche marker premium for the farmers, which enhances revenues generated. Organic production is not input intensive, but relies heavily on market premium to become profitable.

Figure 9: Land Area under Certified Organic Production in Senegal



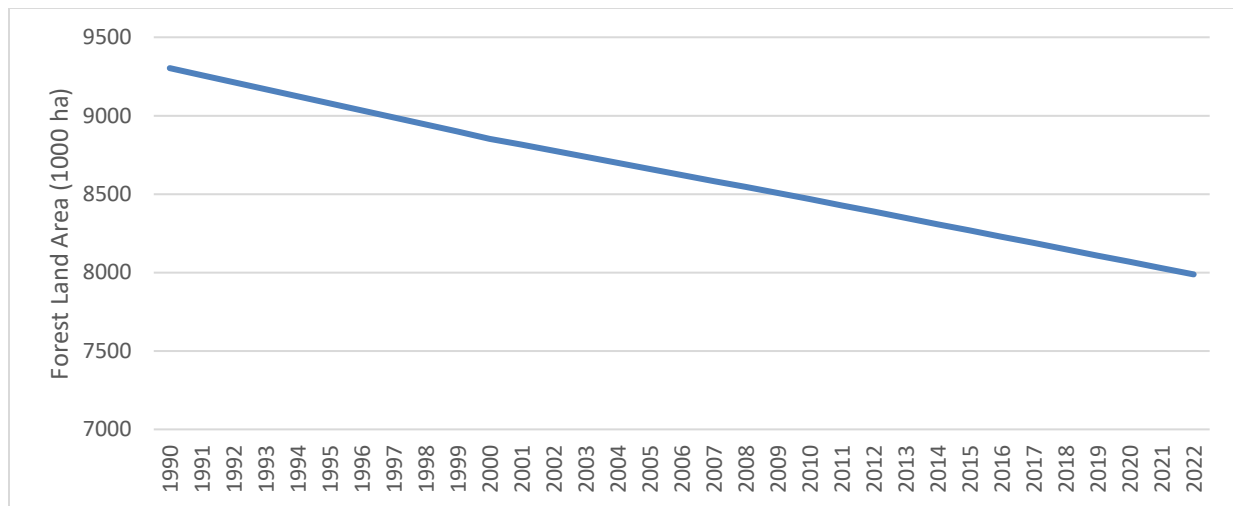
Source: FAOStatistics (2025)

With the start of COVID-19, it is high likely that the producers could not obtain price premium in the market due to income losses caused by the COVID-19. Organic production enhances resilience of farmers both to climate related shocks and price shocks to fertilizers and other chemical input. Hence, it is important to increase organic production to enhance resilience of farmers. Government educational programs can be made to educate public about the benefits of organic products, cost share programs can be made to cover part of the costs of converting from conventional agriculture to organic agriculture. Also marketing support programs can be developed to connect farmers to different market outlets, such as those in big cities and even to international markets.

Implications for Sustainability

In the regression analysis in the previous sections, it was found that as farmers' access to arable land increases, the resilience of farmers increases. However, care should be given as this land does not come from deforestation. Forest land is critical both sustainable agriculture and income generated for the farmers as a productive asset. Hence, increasing the forest land enhances farmers' resilience to economic and climate shocks. Forest land area in Senegal is represented in figure 10 below. We see that forest land area steadily decreased from 9.3 million ha in 1990 to 8 million ha in 2022. Hence, there is a significant deforestation occurring in Senegal. This land conversion is likely to be done to generate land for agriculture. However, this deforestation

Figure 10: Forest Land Area in Senegal



Source: FAOStatistics (2025)

makes farmers more prone to soil erosion, draught, lost habitat, and more CO₂ emissions. Strict regulations should be applied to prevent deforestation. A market based approach could be to educate public to generate market premium for crops produced without deforestation, which is currently in the European Union. Farmers could be trained to export to European Union market. Another approach could be to generate market for forestry products produced by the farmers.

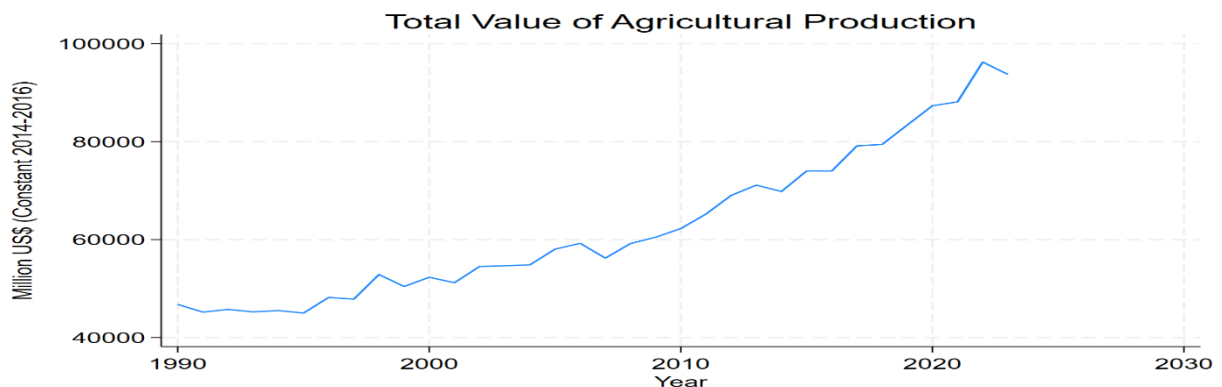
V. Desk-Based Case Study: Türkiye

In this part of the report, we study the resilience of family farmers and small-scale producers in Türkiye. We will first analyze the resilience and then identify the factors those influence the resilience of farmers in Türkiye. Based on the identified factors, policy recommendations will be provided to strengthening the resilience of the family farmers and small-scale producers in Türkiye.

A. Measurement of Resilience

Total value of agricultural production measured in 2014-2016 million US\$ is given in figure 1 below. Total value of agricultural production is around the same level between 1990 and 1995 with some fluctuations. However, the total value agricultural production starts to increase after 1995. Especially after 2008, the increase in total value of agricultural production is more significant. We see some stability during the COVID-19 era, but then the total value of agricultural production increases again 2022, yet there is a decrease in 2023. Climate change related factors can be influential. Overall, there has been a positive trend in the value of agricultural production in Türkiye, since 1995.

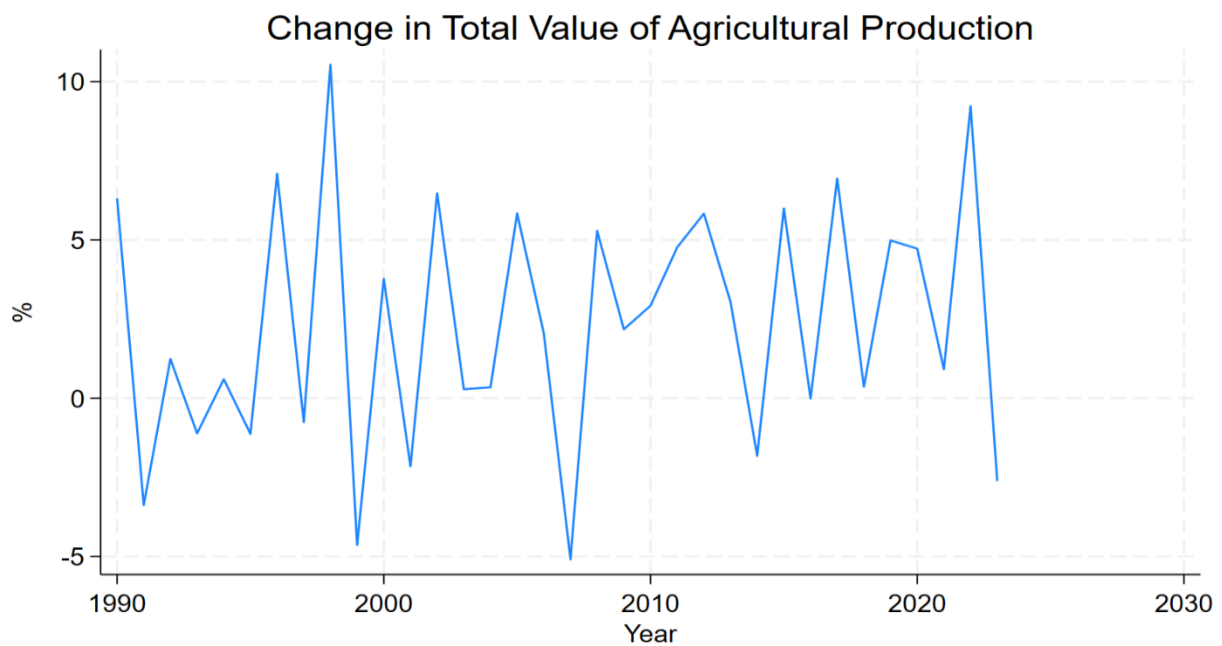
Figure 1: Total Value of Agricultural Production in Türkiye



Source: FAOStatistics (2025)

Percentage change in total value of agricultural production in Türkiye, which is used a measure of resilience of farmers, is given in figure 2 below. We see both positive and negative values, especially between 1990 and 2008. We see only two negative changes after 2008. Hence, farmers in Türkiye become more resilient after 2008. However, there is a negative change in 2023. Farmers access to markets, finance, and technology should monitored to prevent further negative changes. In the following parts, we will further investigate the reasons using regression analysis.

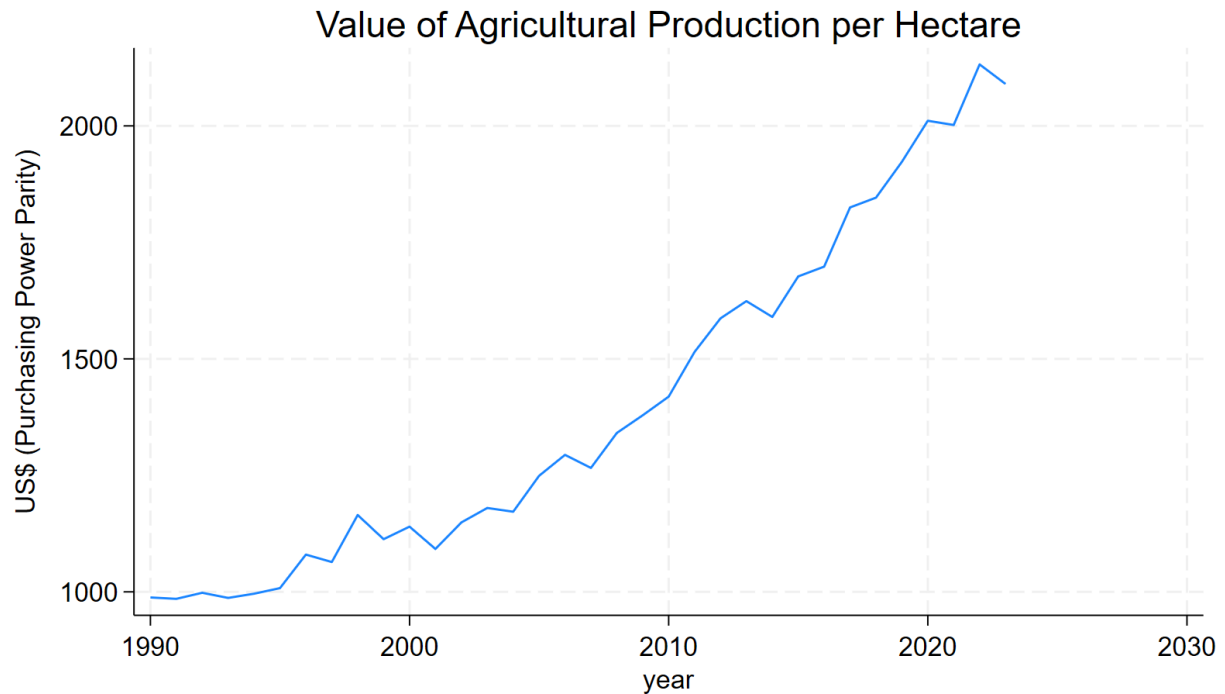
Figure 2: Change in Total Value of Agricultural Production in Türkiye



Total value of agricultural production per hectare is shown in figure 3 below. Overall, we see a significant increase, especially starting 2010. Turkish Government's support to agriculture, especially for better technology (i.e. use of certified seed varieties) use and infrastructure (i.e. use of pressurized irrigation systems) can be the potential reasons behind this increase. Yet, we also

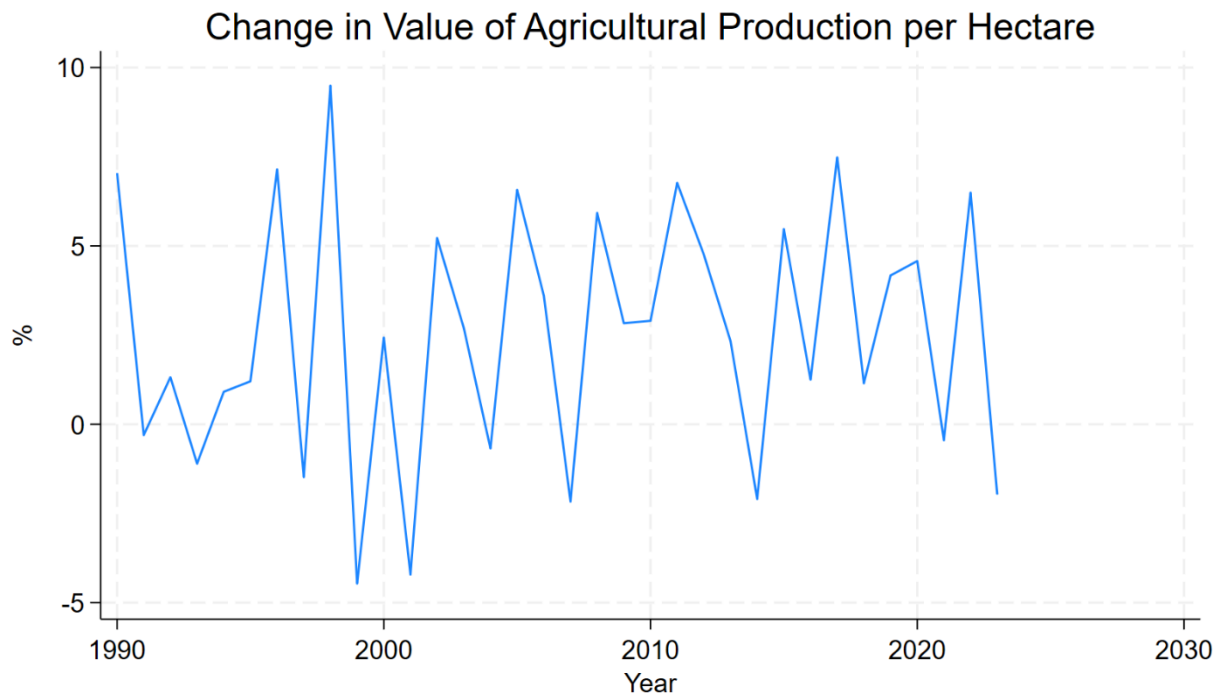
observe yearly fluctuations besides the positive trend. Promoting use of agricultural insurance can help farmers, especially during those years when there is a negative shock to production.

Figure 3: Total Value of Agricultural Production per Hectare in Türkiye



The percentage change in the total value of agricultural production per hectare, which is also used as measure of resilience of farmers, is shown in figure 4. We see both positive and negative values between 1990 and 2008. There are seems to be more negative values before 2008, but there are also negative values in the recent years. Hence, based on the percentage change in total value of agricultural production per hectare, farmers face challenges in their resilience in the recent years. This could again be due to the import dependent inputs, such as nitrogen based fertilizer use in Türkiye, for which both the increases in exchange rates and Ukraine-Russian can be influential. The decrease in resilience could also be due to climate related factors, which has been significantly influencing agriculture in Türkiye.

Figure 4: Change in Total Value of Agricultural Production per Hectare in Türkiye

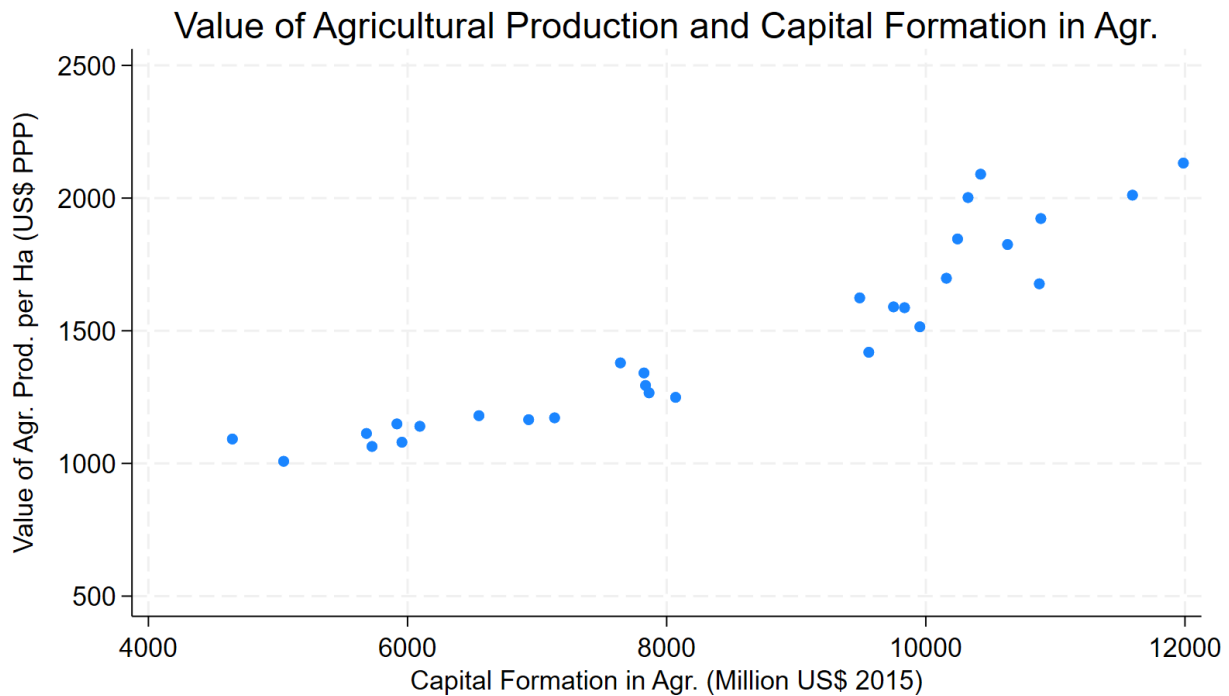


Source: FAOStatistics (2025)

B. Determinants of Resilience in Türkiye

In this section of the report we analyze the factors that influence resilience of family farmers and small-scale producers in Türkiye. With the identified factors policy recommendations will be developed to strengthening the resilience of farmers. In figure 5 below, the relationship between the value of agricultural production per hectare and capital formation in agriculture is presented. A positive association is seen between the two. As the value of capital formation in agricultural increases, we see an increase in the value of agricultural production per hectare. Farmers' access to higher agricultural capital, such as equipment and farm structure, can be influential on the value generated per hectare. To analyze the casual relationship between the two, regression analysis will be used in the next sub-section.

Figure 5: Value of Agr. Prod. per ha and Capital Formation in Agriculture in Türkiye

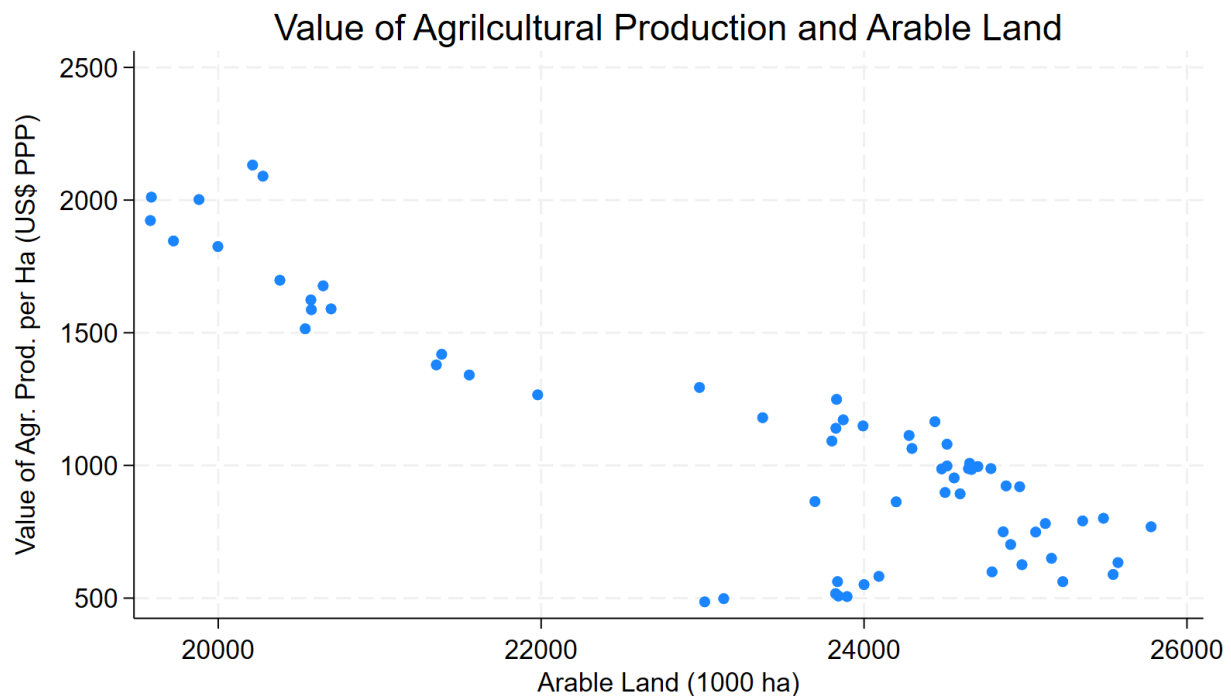


Source: FAOStatistics (2025)

In figure 6 below, the relationship between the value of agricultural per hectare and size of the arable land is depicted. There seems to be negative association between the two. As the amount of arable land increases, the value of agricultural production generated per hectare decreases.

This is a concern, as Turkish Government emphasize the use of idle land to agricultural production, which can further cause a decrease in the value of agricultural production per hectare in Türkiye, based on the figure 6. This could be related to the fact that instead of farm sizes grow and benefit from economies of scale, farmland could be split into more pieces and owners in Türkiye, which can decrease the efficiency. The causal relationship between the value of agricultural production per hectare and size of the arable land will be further analyzed through regression analysis.

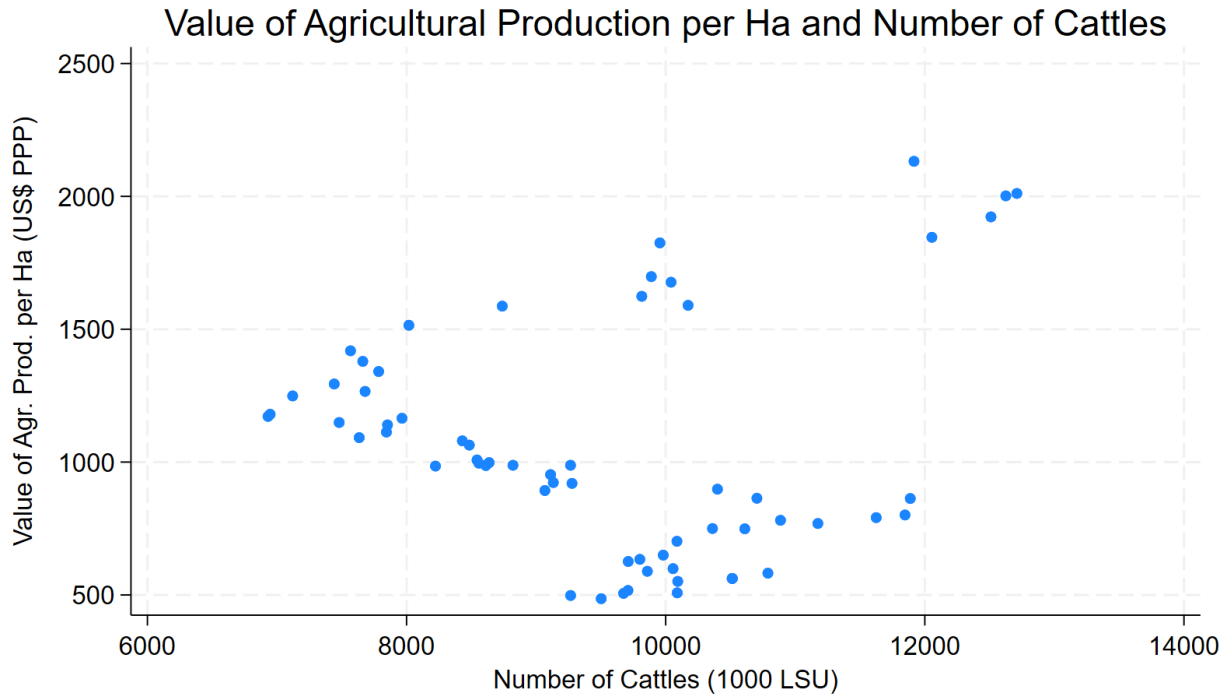
Figure 6: Value of Agr. Prod. per ha and the Size of the Arable Land in Türkiye



Source: FAOStatistics (2025)

In figure 7 below, the relationship between the value of agricultural production per hectare and number of cattle is depicted. We see a positive association between the two up to 8 million LSU and above 12 million LSU. However, there is no clear positive or negative trend in between 8 million and 12 million LSU. This could be due to having smaller herd sizes, even if the total number of cattle increases and also separate farmers owning cattle and growing feed crops. Supporting cattle growers to own land and grow especially feed crops can increase the value of agricultural production per hectare. Livestock production provides additional income to farmers and can be influential on resilience of farmers, which will be further analyzed through regression analysis below.

Figure 7: Value of Agr. Prod. per ha and the Number of Cattles in Türkiye



Source: FAOStatistics (2025)

Regression Analysis of Determinant of Resilience

In this section of the report, we conduct regression analysis to determine the factors influencing resilience of the family farmers and the small-scale producers. In the current analysis we use the following econometric model;

$$Resilience = \beta_1 + \beta_2 Credit + \beta_3 Capital + \beta_4 Cattle + \beta_5 ArableLand + \varepsilon$$

where *resilience* is the dependent variable and measured as the percentage change in total value of agricultural production in Senegal. For the independent variables, *credit* is credit to agriculture measured in million US\$, *capital* is the gross fixed capital formation in agriculture measure in million US\$, *cattle* is the number of cattle measured in livestock units (e.g. dairy cow is equal to one), and *arable land* is the amount of arable land measured in 1000 ha. β_k 's are the coefficients to be estimated and ε is the error term. The results of the regression is represented in table 1

below. The regression is overall statistically significant at 10 percent significance level and the adjusted R-squared is 0.234, which reflects that 23.4% of the variation in resilience is explained by the independent variables in the regression. For the independent variables, the coefficient for credit variable is statistically significant at a 5 percent significance level (i.e. p-value of 0.047) and has a positive coefficient. Hence, as credit to agriculture increases, the resilience of farmers increases. Farmers in general purchase their input with an arrangement to pay at the harvest date. Hence, when there is a negative production shock to their agricultural production, farmers will face difficulties paying their debt and obtain production inputs the following year. For that reason, it is very curial for farmers to access credit to continue agricultural production and enhance their resilience towards negative economic shocks. Alternative arrangement can be

Table 1. Regression Analysis Results for the Resilience in Türkiye

Dept. Variable: % Change in Value of Total Agricultural Production for Türkiye				
Variable	Coeff.	Std. Err.	t-Stat	p-Value
Δ Credit	0.0000188	8.78e-06	2.14	0.047
Δ Capital	0.0000127	0.000012	1.00	0.329
Δ Cattle	1.05e-09	1.20e-08	0.09	0.931
Δ ArableLand	0.0000195	0.000017	1.13	0.275
Constant	0.0293235	0.008806	3.33	0.004
<i>N</i>	23			
<i>Adjusted R²</i>	0.234			
F(4,18)	2.68			
p-Value	0.065			

made to create easier access to credit for farmers. Farmers' access to credit with deferred repayments with low interest rate is important for increasing the resilience of farmers and continuation of agricultural production especially for family farmers and small-scale producers. Also, promoting agricultural insurance through cost share for insurance premiums is an important policy option to promote farmers' access to alternative sources of funds in case negative production shocks occur. Promoting the enhancement of social capital is also important for farmers to help each other to promote the continuation of agricultural production. In some cases, farmers rely on other farmers or family members to finance their agricultural production. Enhancement of social capital is especially important in those situations. Farmers can be given financial support to work together and solve the problems together, which will eventually support their resilience towards negative economic events.

The results of the second regression model, where the resilience is measured as the percentage change in value of agricultural production per hectare is represented below in table. The regression is overall statistically significant at a 5 percent significance level (e.g. p-value of 0.047). The adjusted R-squared value is 0.265. Hence, 26.5 percent of the variation the dependent variable resilience is explained by the variation in the independent variables in the model. For independent variables, credit variable has positive and statistically significant effect on the resilience of farmers, with a p-value of 0.020. The capital variable has positive, but statistically insignificant coefficient. On the other hand, the arable land variable has negative coefficient, but it is also not statistically significant. These results are similar to the results of the previous regression. Based on the data analysis, farmers' access to credit signifies itself for the resilience of farmer during negative economic, environmental, or social shocks to the agricultural production system. Based on the results, we provide policy recommendations next.

Table 2. Regression Analysis Results for the Resilience in Türkiye Based per Hectare

Dept. Variable: % Change in Value of Agricultural Production per Hectare for Türkiye				
Variable	Coeff.	Std. Err.	t-Stat	p-Value
Δ Credit	0.0000204	8.00e-06	2.55	0.020
Δ Capital	0.0000122	0.0000116	1.06	0.303
Δ Cattle	3.15e-09	1.09e-08	0.29	0.776
Δ ArableLand	-0.000010	0.0002	-0.66	0.516
Constant	-0.049	0.049	2.90	0.010
<i>N</i>	23			
Adjusted R ²	0.265			
F(4,19)	2.99			
p-Value	0.047			

C. Policy Recommendations Based on Regression Results

Based on the regression analysis we recommend the following policies to strengthening the resilience of family farmers and small-scale producers in Türkiye;

- Farmers' access to credit with deferred repayments with low interest rate is important for increasing the resilience of farmers and continuation of agricultural production especially for family farmers and small-scale producers.
- Promoting agricultural insurance through cost share for insurance premiums is an important policy option to promote farmers' access to alternative sources of funds in case negative production shocks occur.

- Promoting the enhancement of social capital is also important for farmers to help each other to promote the continuation of agricultural production. Farmers can be given financial support to work together and solve the problems together, which will eventually support their resilience towards negative economic events.
- As the use of idle land to agricultural production, instead of causing farmers to have farmland in difference locations, separated farmland locations should be gathered as much as possible.
- Alternative institutional arrangements can also be made, such as land rental by the neighbors or share cropping to make sure farmers have access to farmland adjacent to each other.

Principal Component Analysis

Principle component analysis can be used to further analyze the structure of the independent variables used in a regression, especially when they are correlated with each other. In the current study we use principal component analysis to see if the independent variables can be grouped in different categories, reflecting different components. In addition, we add *FertilizerN* as an additional variable, which is the amount of nitrogen fertilizer used in Türkiye, as it is the main fertilizer used by the farmers. The results of the principal component analysis are reflected in table 3 below. Credit to agriculture, number of cattle, and nitrogen fertilizer used have positive and similar effect on component 1. On the other hand, capital and arable land have negative effect on component 1. Hence, component 1 can be access to variable inputs. On the other hand, *FertilizerN* variable has the largest and positive on component 2, differentiating itself from capital variable. Capital, number of cattle, and arable land variables also have positive effect on component 2. Hence, this component could be to general component with total inputs used.

Table 3. Results of the Principal Component Analysis

Variable	Comp1	Comp2
Credit	0.476	-0.187
Capital	-0.435	0.545
Cattle	0.443	0.361
ArableLand	-0.477	0.232
FertilizerN	0.399	0.695

Component	Eigenvalue	Proportion
<i>Comp1</i>	3.99	0.79
<i>Comp2</i>	0.57	0.11
<i>N</i>	24	

To measure the influence of component one and two on the resilience of the farmers, we now use these components as independent variables in the regression analysis did in the previous section. The results of the regression analysis for resilience measured as the percentage change in the value of total agricultural production is represented in the table 4 below. The regression is overall statistically significant at 10 percent significance level (i.e. p-value is 0.095) and the adjusted R-squared is 0.124. The first principal component PC1 has positive and statistically significant effect on the resilience of the farmers. However, the second principal component PC2 does not have Statistically significant effect on the resilience of farmers. Hence, in Türkiye, farmers' access to credit and production inputs, such as nitrogen fertilizer, significantly influence the

resilience of farmers. Turkish Government has support programs for livestock production to increase the herd size of the farmers and fertilizer use. Livestock support program should be continued and herd sizes should be motivated to increase, while efficient use of fertilizer use (i.e. not to overuse) should be promoted by doing soil testing and matching the crop needs with the amount of nutrients available in the soil.

Table 4. Regression Analysis Results for Resilience with Principal Components

<i>Dept. Variable: Change in Value of Total Agricultural Production</i>				
<i>Variable</i>	<i>Coeff.</i>	<i>Std. Err.</i>	<i>t-Stat</i>	<i>p-Value</i>
<i>PC1</i>	540163	248354	2.17	0.041
<i>PC2</i>	-479056	657046	-0.73	0.474
<i>Constant</i>	1806840	486138	3.72	0.001
<i>N</i>	24			
<i>Adjusted R²</i>	0.124			
<i>F(2,21)</i>	2.63			
<i>p-Value</i>	0.095			

To check the robustness of our results, we also do a regression with resilience measured as the percentage change in value of agricultural production per hectare. The results from that regression are presented in table 5 below. The regression is overall statistically significant at a 5 percent significance level and the value of adjusted R-squared is 0.177. The results from this regression is confirmative of the results from the previous regression. The principal component one has positive and statistically significant influence on the resilience of farmers. However,

principal component two does not have statistically significant effect. To further analyze the use of import dependent variable input nitrogen fertilizer, in figure 8 below total use of nitrogen fertilizer in Türkiye is represented. We see that overall there is an increase in total use of nitrogen fertilizer over time in Senegal, especially after 2010, but there are significant yearly

Table 5. Regression Analysis Results for Resilience per Hectare with Principal Components

Dept. Variable: Change in Value of Agricultural Production per Hectare				
Variable	Coeff.	Std. Err.	t-Stat	p-Value
PC1	10.967	4.854	2.26	0.035
PC2	-17.554	12.84	-1.37	0.186
Constant	40.291	9.501	4.24	0.000
<i>N</i>	24			
<i>Adjusted R²</i>	0.177			
F(2,16)	3.49			
p-Value	0.049			

fluctuations. For example, COVID-19 related disruptions and the exchange rate fluctuations could be the potential reasons for the decrease in 2021. Since nitrogen fertilizer is one of the major inputs in plant production, significant decreases in its use can cause significant yield losses. This again signifies the promotion of organic farming and manure as a crop nutrient. In figure 9, we look at the relationship between nitrogen fertilizer use and value of agricultural production per hectare. It is seen that there was an increase in the value of agricultural production per hectare up to a point (i.e. 1.6 million tons), but then started to decrease. Hence, there can be

Figure 8: Total Use of Nitrogen Fertilizer in Türkiye

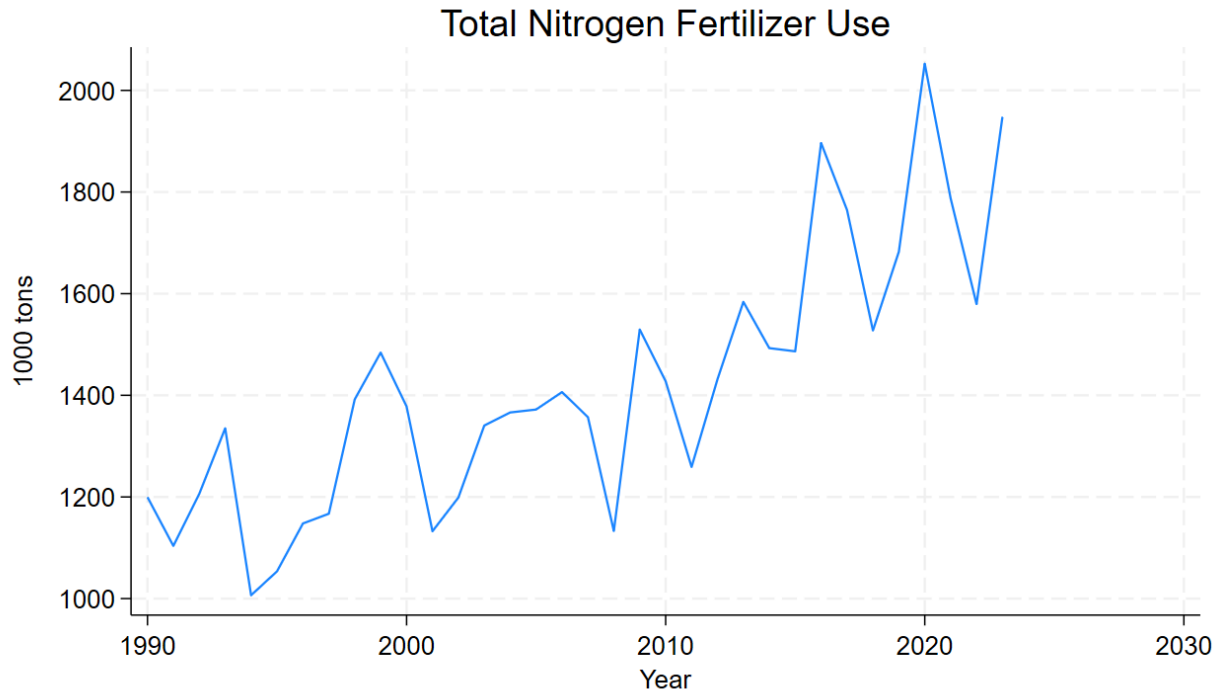
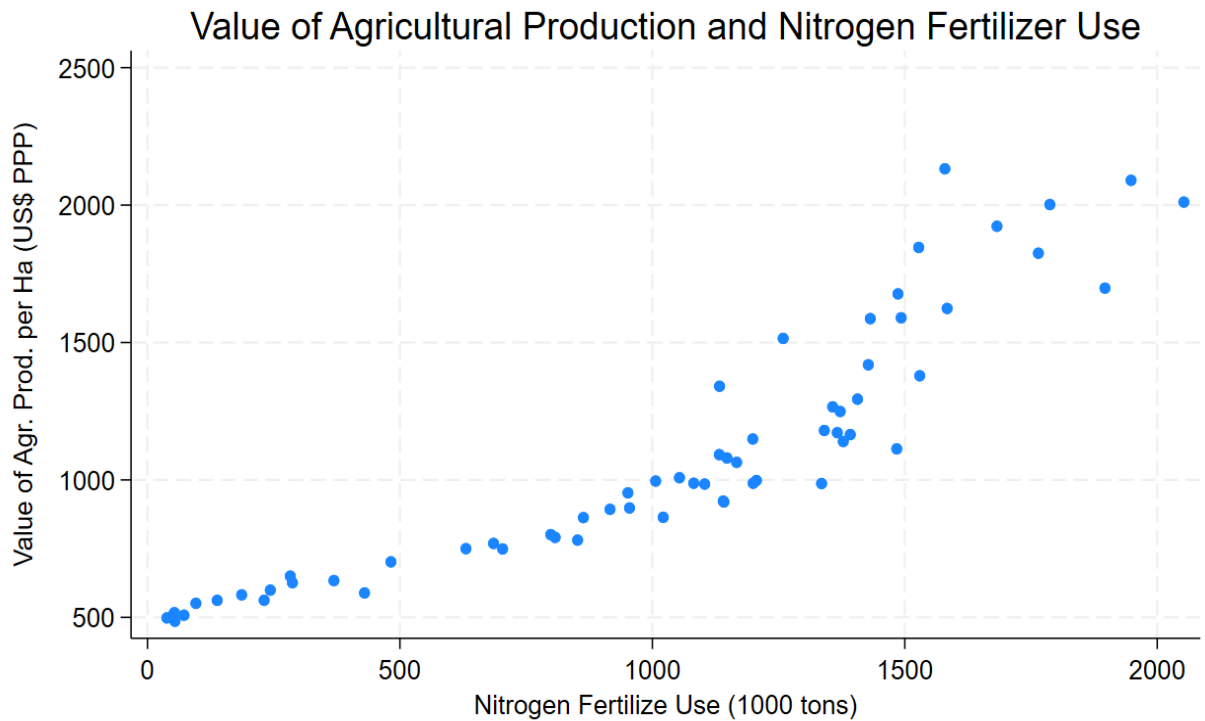


Figure 9: Total Use of Nitrogen Fertilizer in Türkiye



an overuse of nitrogen fertilizer per hectare in Türkiye. This can lead to economic losses and environmental pollution. To avoid this, precision agricultural (i.e. using fertilizer based on crop needs) technologies should be promoted and use of soil test to better match the amount of fertilizer used with crop needs.

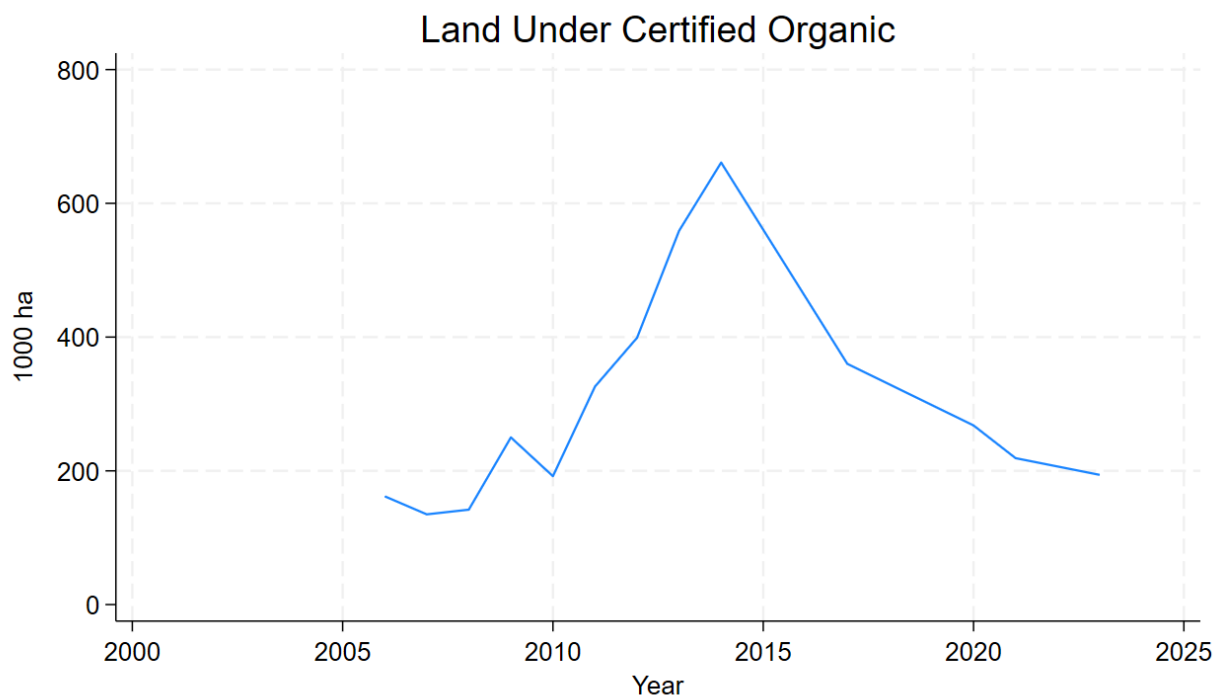
Policy Implications

- Farmers' reliance on especially import dependent variable input can be decreased through alternative production systems, such as organic farming and use of manure.
- Multi-year cost share programs can be developed to help farmers with the cost of organic production and yield decreases due to use of manure.
- Precision agriculture (i.e. using fertilizer based on crop needs) technologies should be promoted and use of soil tests to better match the amount of fertilizer used with crop needs.

Land area over which organic production is done in Türkiye further analyzed in figure 2 below. Based on the available data, the certified organic production is done over 190 thousand ha in 2006 and increased to around 650 thousand ha in 2014. However, there has been a steady decline and going back to 200 thousand ha in 2022. Organic production enhances resilience of farmers both to climate related shocks and price shocks to fertilizers and other chemical input. Hence, it is important to increase organic production to enhance the resilience of farmers. Organic production is crucial for sustainable agriculture and provides a niche market premium for the farmers, which enhances revenues generated. Organic production is not input intensive but relies heavily on market premium to become profitable. Farmers can face marketing problems for their organic products. Farmers need to collect the market premium for organic production to be profitable. With economic slowdowns and lack of trust to certification processes can be potential

reasons from consumers' side for a decline in demand. On the other hand, since organic yields are lower than conventionally grown crops, farmers might find organic production not profitable over time. Turkish government has financial support programs to promote organic production. These programs should be multi-year programs to promote continuous organic production. Support programs in terms of direct marketing and establishing a marketing cooperative and creating a brand could be potential policies to support farmers to grow crops organically.

Figure 10: Land Area under Certified Organic Production in Türkiye



Source: FAOStatistics (2025)

Implications for Sustainability

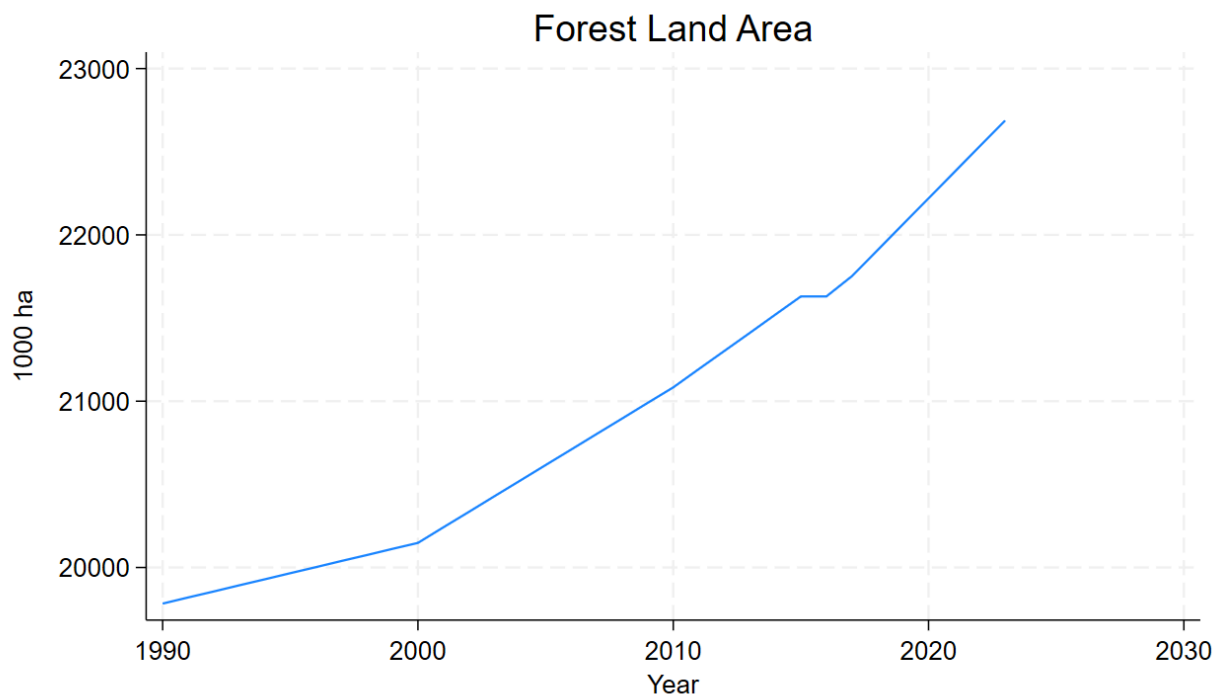
Adding more land to agricultural production is always a topic of discussion in Türkiye.

Especially, recently the Turkish Government is emphasizing on bringing idle agricultural land into the production. However, care should be taken about the forest land is not taken into

agricultural production. Forest land is critical both sustainable agriculture and income generated

for the farmers as a productive asset. Hence, increasing the forest land enhances farmers' resilience to economic and climate shocks. Forest land area in Türkiye is represented in figure 11 below. We see that forest land area steadily increase, especially since 2000, reaching to around 22.5 million ha in 2022. Hence, government efforts should continue to increase the amount of forest land area, as Türkiye is prone to soil erosion. A market-based approach could be to educate the public to generate market premium for crops produced without deforestation, which is currently in the European Union. Farmers could be trained to export to the European Union market. Another approach could be to generate market for forestry products produced by the farmers.

Figure 11: Forest Land Area in Türkiye



Source: FAOStatistics (2025)

VI. Desk-Based Case Study: United States

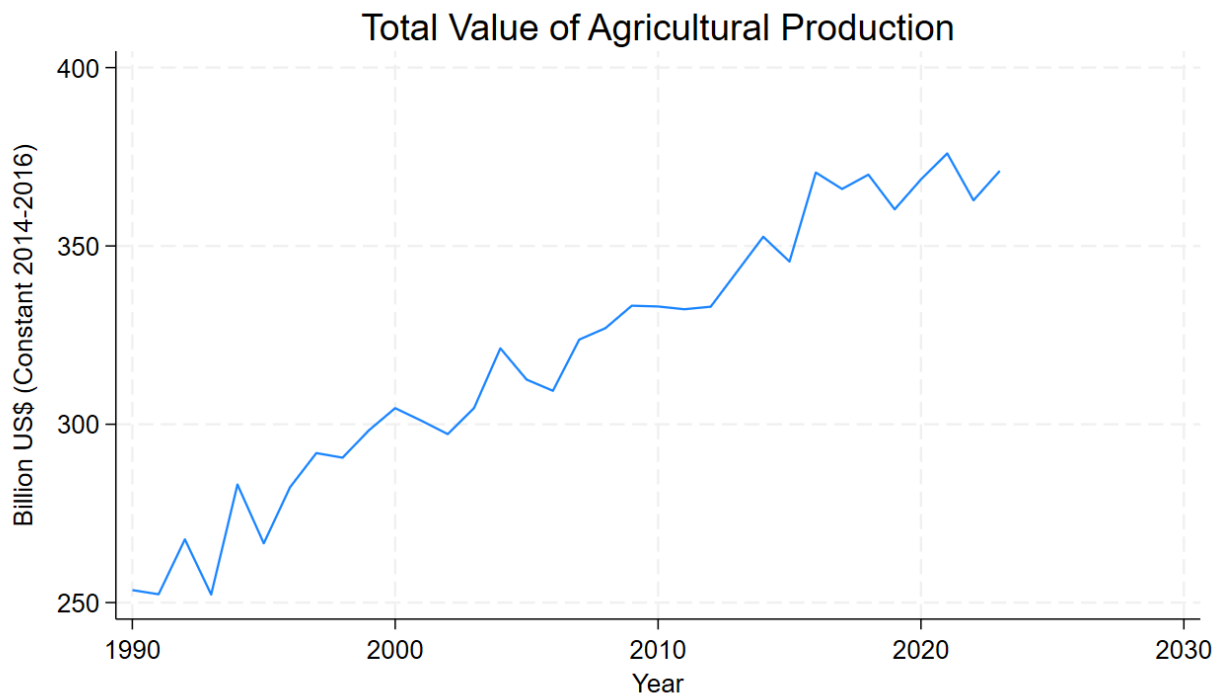
In this part of the report, we study the resilience of family farmers and small-scale producers in the United States. We will first analyze the resilience and then identify the factors those influence the resilience of farmers in the United States. Based on the identified factors, policy recommendations will be provided to strengthening the resilience of the family farmers and small-scale producers in the United States.

C. Measurement of Resilience

Total value of agricultural production measured in 2014-2016 million US\$ is given in figure1 below. Total value of agricultural production in the United States has been increasing since 1990's with general yearly fluctuations to around 2015. Then yearly fluctuations seem to keep the value of agricultural production at the similar level as 2023. United States has been significant amount of fund on new technology development in agriculture and promote use of these new technologies by the farmers. The United States also has a unique very effective extension system. The universities are given duties to extend the technology to the farmers. All these could be the potential reasoning behind the increase in total value of agricultural production in the United States. On the other hand, draught and other climate related events, increasing input costs, and reliance on import can be the potential reasons why the total value of agricultural production in the United States is not increasing.

Percentage change in total value of agricultural production in the United States, which is used a measure of resilience of farmers, is given in figure 2 below. The positive and zero values during the external shocks indicate that the agricultural production system is resilient, as the value generated from agricultural production continued without a decrease. On the other hand, the

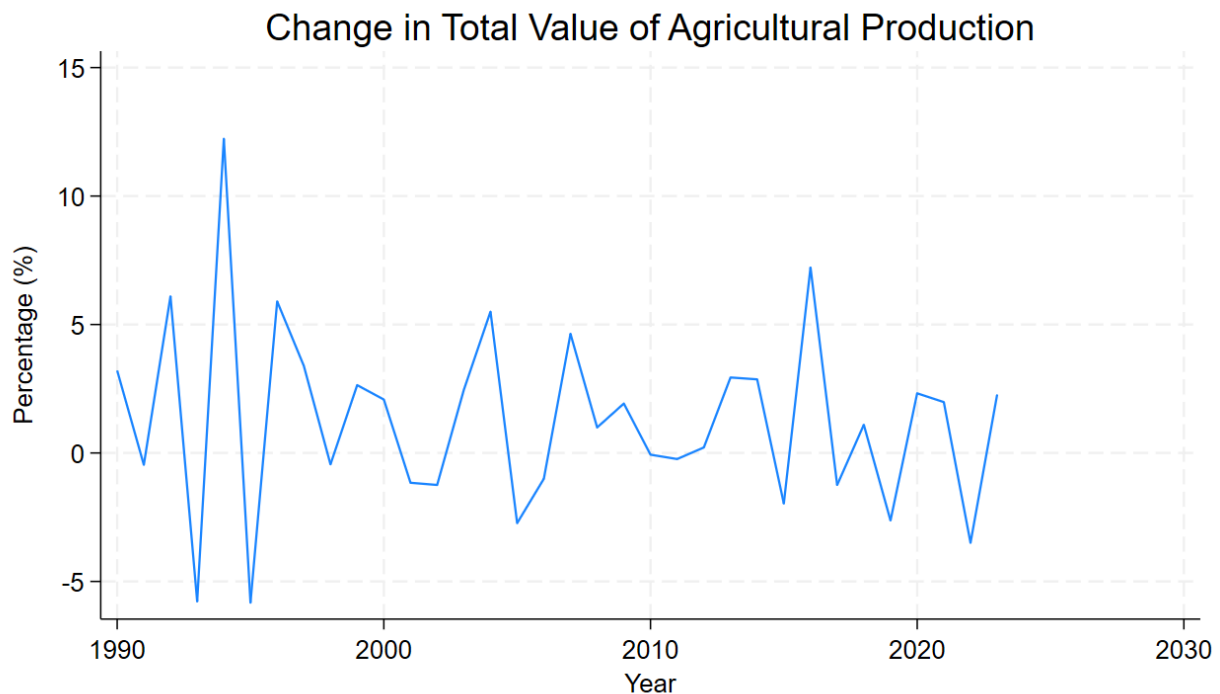
Figure 1: Total Value of Agricultural Production in United States



Source: FAOStatistics (2025)

negative values during the external shocks indicate the non-resilience of the system, as the value generated from agricultural production decreased. We see both positive and negative large values, between 1990 and 2000. Then mostly positive values until 2015. However, we see mostly negative values since 2015. Hence, the resilience of farmers in the United States show variation from one year to another and from one period to another. Similar to the other countries reviewed, farmers in the United States are resilient to external shocks in one year and non-resilient in the following year. Hence, even in the United States, the resilience of the farmers to external shocks should be checked regularly. The resilience of farmers shows less fluctuations between 1995 and 2015 in the United States. Farmers look more resilient during that period. However, farmers show less resilience since 2015.

Figure 2: Change in Total Value of Agricultural Production in the United States

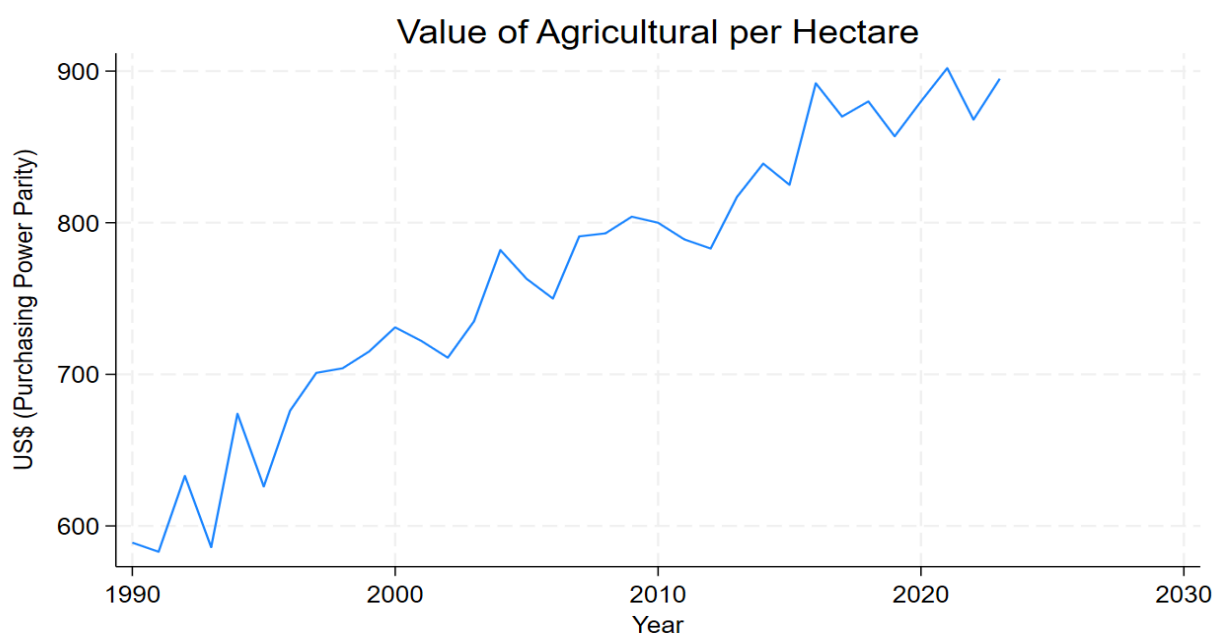


Total value of agricultural production per hectare is shown in figure 3 below. Overall, we see a steady increase with yearly fluctuations until 2015. Having larger farms, easier access to credit and new technology makes production more productive. However, there seems to be a slowdown since 2015. This could be due to increasing input costs and not being able to access new or better technology.

The percentage change in the total value of agricultural production per hectare, which is also used as measure of resilience of farmers in the current study, is shown in figure 4. We see both positive and negative values between 1990 and 2000. However, the values are mostly positive and with very large in magnitude. For example a 15 percent increase occurred in year 1994. Such increase are possibly through adoption of news technologies related to production, which was the focus of agricultural policy in the United States back then. Between 2000 and 2010 we still see both positive and negative values, but the magnitude of negative values are relatively smaller,

reflecting increase in resilience of farmers during that period. The large in magnitude of positive value again show the continuation of access to new and better technologies and inputs. With the start of 2010 we see more negative values, but again positive values are larger in magnitude. With the heavy influence of climate change, especially occurrence of draught is a potential reason for these

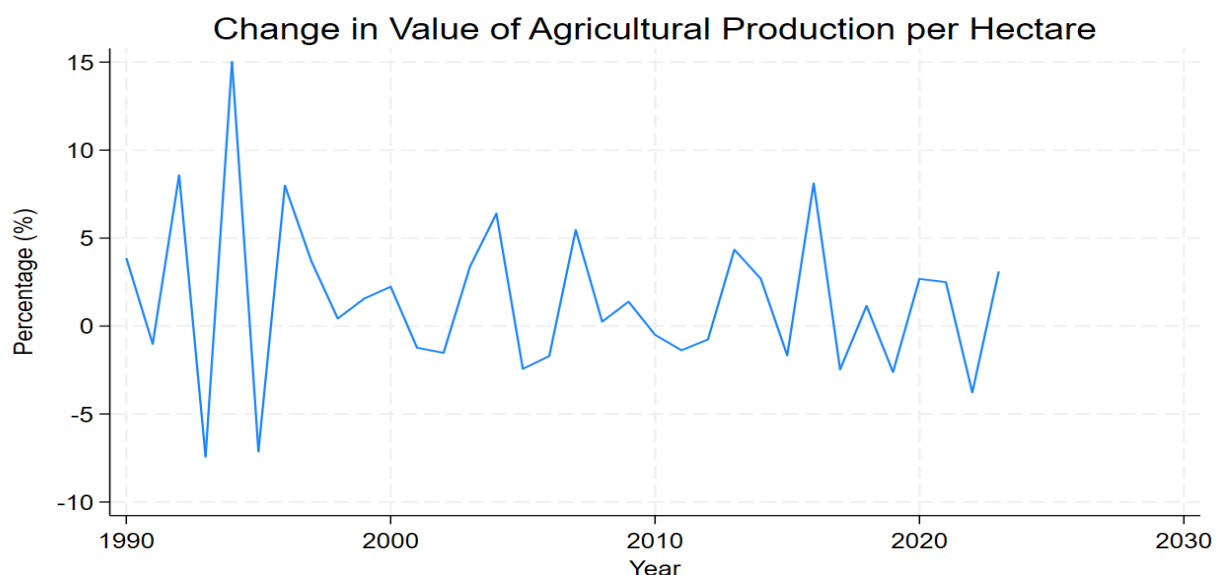
Figure 3: Total Value of Agricultural Production per Hectare in the United States



negative values. Since 2020, we see one negative value, which reflects that farmers became more resilient in the recent few years. The negative value occurred in 2022 could be related to Ukraine-Russian war, climate change, and also reliance on imports, especially in fruits and vegetables. The United States Department of Agriculture has both at the Federal and State level programs to promote economic, environmental and social sustainability. With an effective extension system, where universities are formally responsible for teaching farmers the new technologies and solving their problems, there can be an increase in the resilience of farmers, especially family farmers and small-scale producers. The United States also heavily invest in

farmers markets and other direct marketing strategies for farmers to increase resilience of farmers. These can easily be applied to OIC member countries to increase the resilience of family farmers and small-scale producers.

Figure 4: Change in Total Value of Agricultural Production per Hectare in the United States



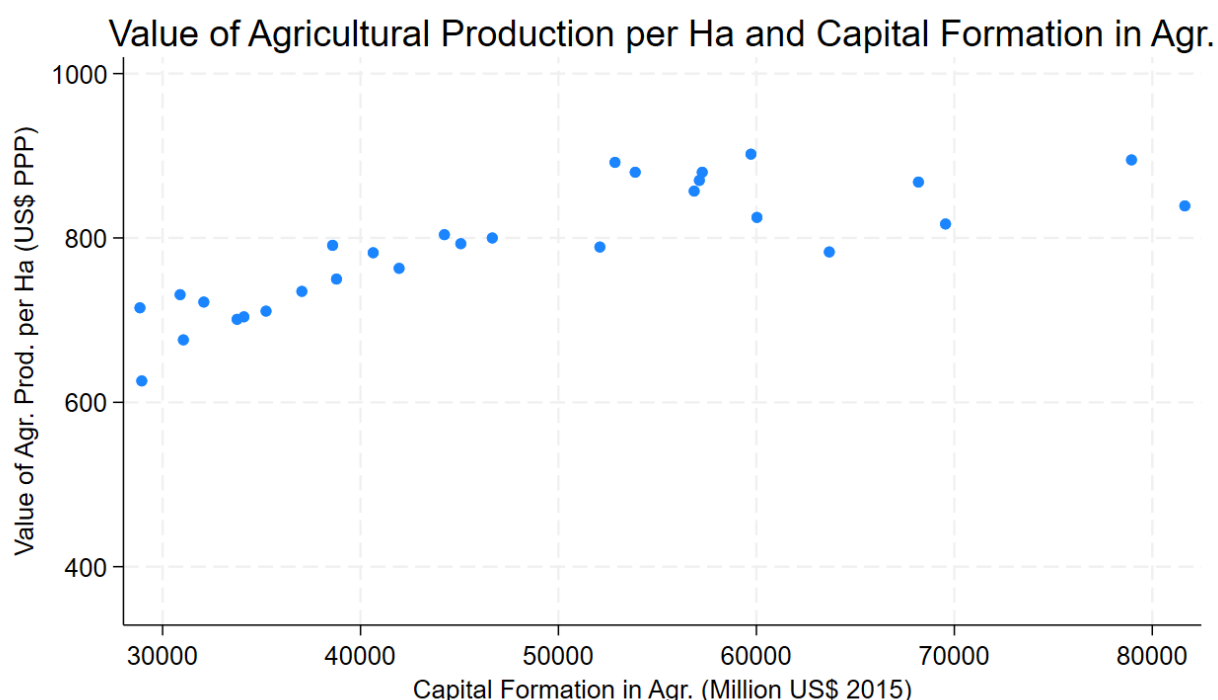
Source: FAOStatistics (2025)

D. Determinants of Resilience in the United States

In this section of the report we analyze the factors that influence resilience of family farmers and small-scale producers in the United States. With the identified factors policy recommendations will be developed to strengthening the resilience of farmers. In figure 5 below, the relationship between the value of agricultural production per hectare and capital formation in agriculture is presented. A positive association is seen between the two. As the value of capital formation in agricultural increases, we see an increase in the value of agricultural production per hectare. Farmers' access to higher agricultural capital, such as equipment and farm structure, can be

influential on the value generated per hectare. To analyze the casual relationship between the two, regression analysis will be used in the next sub-section.

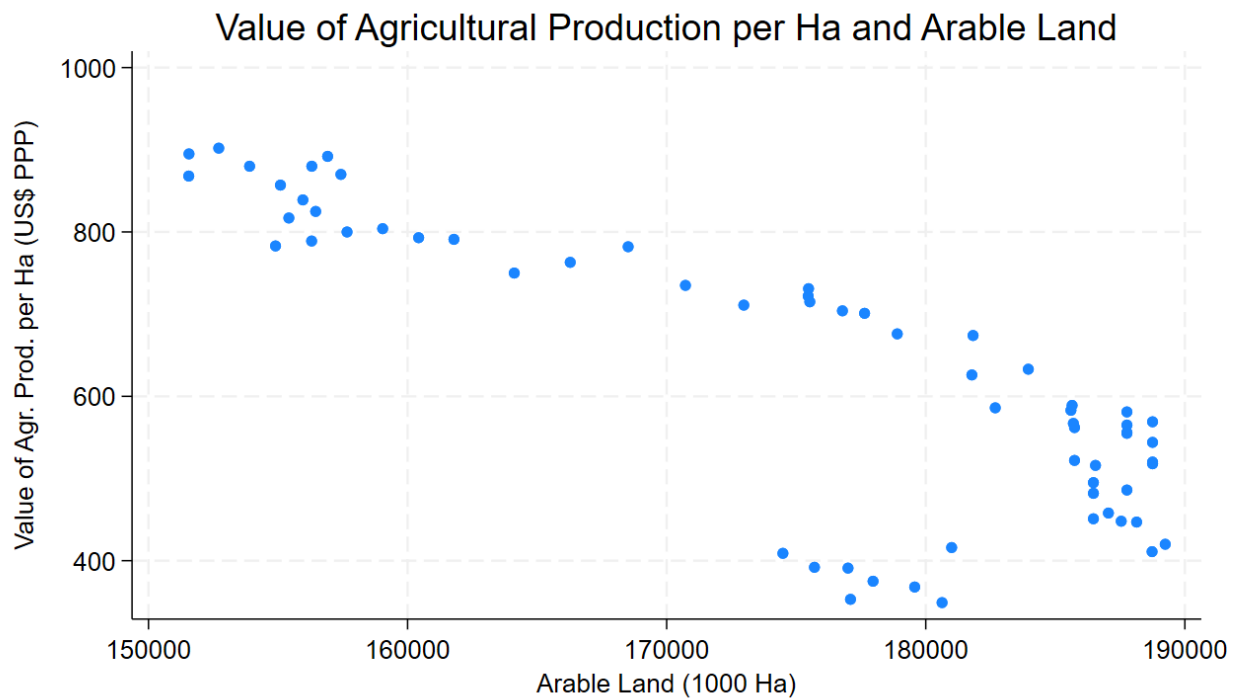
Figure 5: Value of Agr. Prod. per ha and Capital Formation in Agriculture in the United States



Source: FAOStatistics (2025)

In figure 6 below, the relationship between the value of agricultural per hectare and size of the arable land is depicted. There seems to be some positive association between the two up to 3,500 (1000 ha), the positive correlation is more apparent beyond 3,500 (1000 ha). As the land over which increases, the value of agricultural production generated per hectare increases. This could be related to the fact that as farm sizes grow, farmers have easier access to technology and assets, due to economies of scale. The casual relationship between the value of agricultural production per hectare and size of the arable land will be further analyzed through regression analysis.

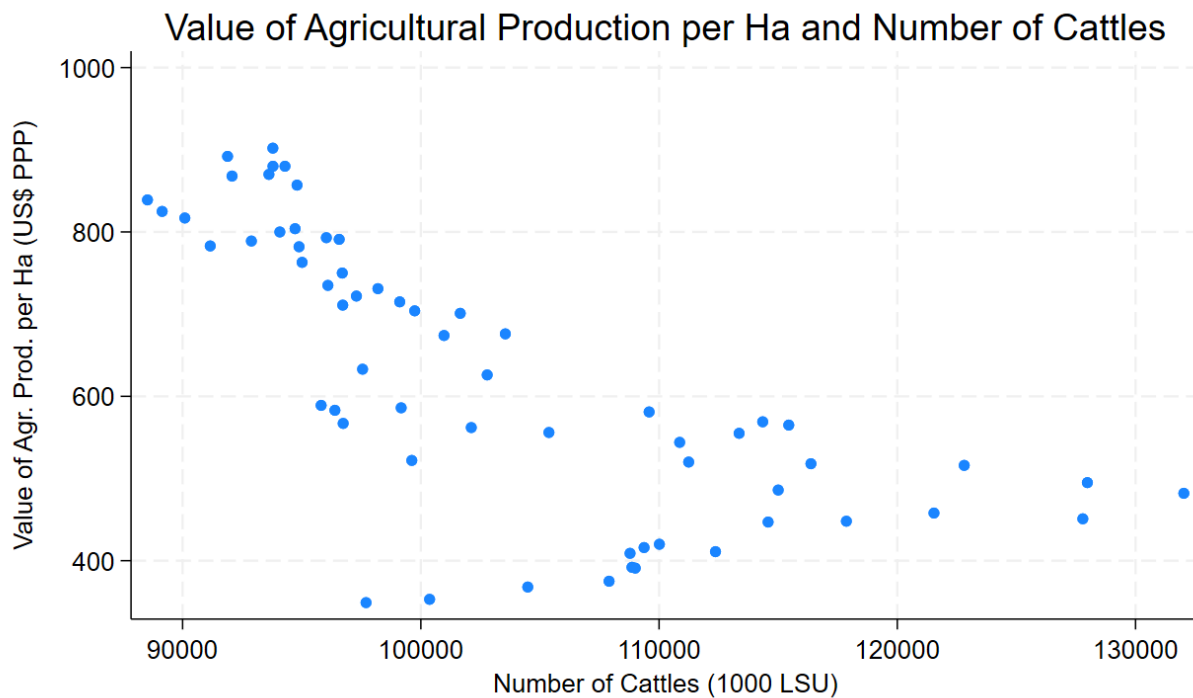
Figure 6: Value of Agr. Prod. per ha and the Size of the Arable Land in the United States



Source: FAOStatistics (2025)

In figure 7 below, the relationship between the value of agricultural production per hectare and number of cattle is depicted. We see a positive association between the two, especially at the higher number of cattles. Livestock production provides additional income to farmers and cattle meat (i.e. beef) generates higher income for the farmers. Hence, number of cattles can be influential on resilience of farmers, which will be further analyzed through regression analysis below.

Figure 7: Value of Agr. Prod. per ha and the Number of Cattles in the United States



Source: FAOStatistics (2025)

Regression Analysis of Determinant of Resilience

In this section of the report, we conduct regression analysis to determine the factors influencing resilience of the family farmers and the small-scale producers. In the current analysis we use the following econometric model;

$$Resilience = \beta_1 + \beta_2 Credit + \beta_3 Capital + \beta_4 Cattle + \beta_5 ArableLand + \varepsilon$$

where *resilience* is the dependent variable and measured as the percentage change in total value of agricultural production in United States. For the independent variables, *credit* is credit to agriculture measured in million US\$, *capital* is the gross fixed capital formation in agriculture measure in million US\$, *cattle* is the number of cattle measured in livestock units (e.g. dairy cow is equal to one), and *arable land* is the amount of arable land measured in 1000 ha. β_k 's are the coefficients to be estimated and ε is the error term.

The results of the regression is represented in table 1 below. The regression is overall statistically significant at 1 percent significance level and the adjusted R-squared is 0.745, which reflects that 74.5% of the variation in resilience is explained by the independent variables in the regression. For the independent variables, capital is statistically significant at 1 percent significance level (i.e. p-value of 0.000) and has a positive coefficient. As the fixed capital formation in agriculture increases, the resilience of farmers increase. Hence, as farmers have higher access to capital, such farm infrastructure, machines and

Table 1. Regression Analysis Results for the Resilience in the United States

Dept. Variable: Change in Value of Total Agr. Production for the United States				
Variable	Coeff.	Std. Err.	t-Stat	p-Value
Δ Credit	0.1124	0.3343	0.34	0.740
Δ Capital	0.1464	0.7167	0.20	0.840
Δ Cattle	0.0005	0.0018	0.30	0.766
Δ ArableLand	-0.0001	0.0018	-0.08	0.939
Constant	4.0777	2.7319	1.49	0.150
<i>N</i>	26			
<i>R</i> ²	0.008			
F(4,21)	0.05			
p-Value	0.995			

equipment, farmers can generate higher agricultural production value, which strengthens their resilience to external shocks. The arable land variable is also statistically significant at 5 percent

significance level (e.g. p-value of 0.012) and has a positive coefficient. Hence, as the farmers access to arable land increases, farmers' resilience to external shocks increase.

The results of the second regression model, where the resilience is measure as the percentage change in value of agricultural production per hectare is represented below in table. The regression is overall statistically significant at 1 percent significance level (e.g. p-value of 0.006). The adjusted R-squared value is 0.508. Hence, 50.8 percent of the variation the dependent variable resilience is explained by the variation in the independent variables in the model. For the independent variables, capital variable has positive and statistically significant effect on the

Table 2. Regression Results for the Resilience in the United States Based on per Hectare

Dept. Variable: Change in Value of Agr. Production per Hectare for the United States				
Variable	Coeff.	Std. Err.	t-Stat	p-Value
Δ Credit	0.047	0.951	0.05	0.960
Δ Capital	0.474	2.039	0.23	0.818
Δ Cattle	0.001	0.005	0.22	0.830
Δ ArableLand	-0.001	0.005	-0.22	0.827
Constant	9.578	7.771	1.23	0.231
<i>N</i>	26			
R^2	0.05			
F(4,21)	0.03			
p-Value	0.998			

resilience of farmers, with a p-value of 0.053. Similar to the previous regression, arable land variable also has a positive and statistically significant effect on the resilience. Hence, as the

farmers access to capital and arable land increases, their resilience also increases measured as the percentage change in value of agricultural production per hectare. Higher access to arable land could reflect economics of scale, which could make farmers gain advantage in use of new technologies and make investment that require higher fixed costs. In the current regression, number of cattles variable is also statistically significant and has a positive coefficient. Hence, as the number of cattles farmers have increases, farmers' resilience also increases. Raising cattle provides additional and higher income to farmers, which is like an income diversification and a safety net against external shocks.

E. Policy Recommendations Based on the Regression Results

Based on the regression results, we recommend the following policies to strengthening the resilience of family farmers and small-scale producers in United States;

- Financial support programs, such as cost share programs, can be established for farmers to accumulate farm capital (e.g. building, equipment, machinery).
- Farmers access to arable land can be increased through government support programs, such as rent cost sharing, and long term rental contracts through leasing. Care should be taken for deforestation.
- Educational and financial support programs for livestock operators can be established to increase the number of cattle holdings.

Principal Component Analysis

Principle component analysis can be used to further analyze the structure of the independent variables used in a regression, especially when they are correlated with each other.

In the current study we use principle component analysis to see if the independent variables can be grouped in different categories, reflecting different components. In addition to the *FertilizerN*,

which is the amount of nitrogen fertilizer used in United States, as it is the main fertilizer used by the farmers. The results of the principal component analysis is reflected in table 3 below.

Table 3. Results of the Principal Component Analysis

Variable	Comp1	Comp2	Comp3	Comp4
Capital	0.486	-0.045	-0.126	0.389
Credit	0.408	-0.597	0.663	-0.165
Cattle	-0.476	0.123	0.377	-0.486
ArableLand	-0.473	-0.047	0.435	0.764
FertilizerN	0.382	0.790	0.461	0.019
Component	Eigenvalue	Proportion		
<i>Comp1</i>	3.82	0.76		
<i>Comp2</i>	0.59	0.11		
<i>Comp3</i>	0.33	0.06		
<i>Comp4</i>	0.13	0.03		
<i>N</i>	27			

All the variables have positive and similar effect on the first component, which could reflect the positive effect of productive assets and inputs on value of agricultural production created. On the other hand, *FertilizerN* variable has the largest and positive on component 2, differentiating itself from variables such as capital. Hence, the second component could reflect of the influence of variables input on value of agricultural product produced. To measure the influence of component one and two on the resilience of the farmers, we now use these components as

independent variables in the regression analysis did in the previous section. The results of the regression analysis for resilience measured as the percentage change in the value of total agricultural production is represented in the table 4 below. The regression is overall statistically significant at 1 percent significance level (i.e. p-value is 0.002) and the adjusted R-squared is 0.496. The first principal component PC1 (i.e. productive assets and inputs) has positive and statistically significant effect on the resilience of the farmers. However, the second principal component PC2 (i.e. variable inputs) has negative and statistically significant effect on the resilience of farmers. In United States, nitrogen fertilizer is not domestically produced and it is imported from other countries. Hence, heavily reliance on import dependent inputs could make farmers more susceptible to external shocks. Farmers reliance on import dependent nitrogen

Table 4. Regression Analysis Results for Resilience with Principal Components

<i>Dept. Variable: Change in Value of Total Agricultural Production</i>				
<i>Variable</i>	<i>Coeff.</i>	<i>Std. Err.</i>	<i>t-Stat</i>	<i>p-Value</i>
$\Delta PC1:$	1.520	8.276	0.18	0.856
$\Delta PC2: \text{Variable Inputs}$	-1.475	2.497	-0.59	0.561
$\Delta PC3: \text{Variable Inputs}$	-3.654	7.897	-0.46	0.652
$\Delta PC4: \text{Variable Inputs}$	-4.553	14.123	-0.32	0.750
<i>Constant</i>	3.705	2.662	1.39	0.179
<i>N</i>	26			
<i>R²</i>	0.264			
<i>F(4,21)</i>	0.35			
<i>p-Value</i>	0.840			

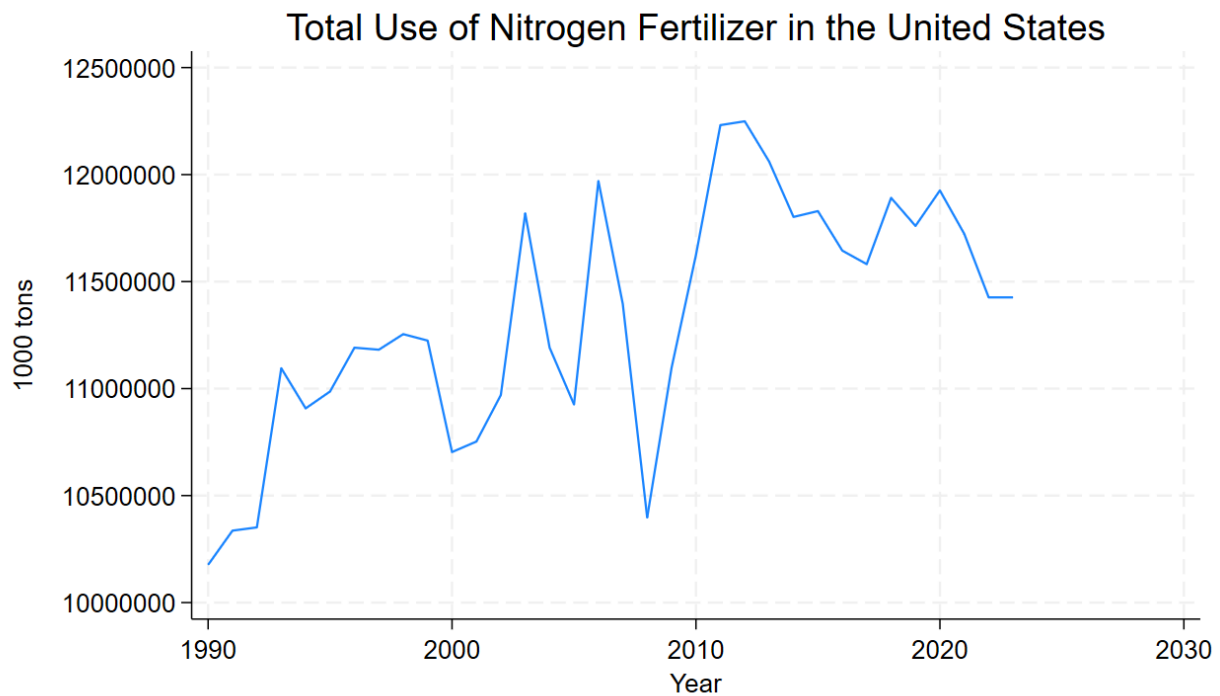
fertilizer can be decreased through promoting organic farming and use of animal manure as a fertilizer. To check the robustness of our results, we also do a regression with resilience measured as the percentage change in value of agricultural production per hectare. The results from that regression are presented in table 5 below. The regression is overall statistically significant and the value of adjusted R-squared is 0.322. The results from this regression is confirmative of the results from the previous regression. The principal component one (i.e. productive assets and inputs) have positive and principal component two (i.e. variable input) has negative influence on the resilience of farmers. To further analyze the use of import dependent variable input nitrogen fertilizer, in figure 8 below total use of nitrogen fertilizer in United States is represented. We see that overall there is an increase in total use of nitrogen fertilizer over time

Table 4. Regression Analysis Results for Resilience per Hectare with Principal Components

Dept. Variable: Change in Value of Agricultural Production per Hectare				
Variable	Coeff.	Std. Err.	t-Stat	p-Value
$\Delta PC1$:	6.440	23.289	0.28	0.785
$\Delta PC2$: Variable Inputs	-4.178	7.027	-0.59	0.558
$\Delta PC3$: Variable Inputs	-13.534	22.474	-0.60	0.553
$\Delta PC4$: Variable Inputs	-21.224	39.742	-0.53	0.599
Constant	8.529	7.493	1.14	0.268
<i>N</i>	26			
R^2	0.080			
F(4,21)	0.45			
p-Value	0.769			

in United States, especially after 2010, but there are significant yearly fluctuations. For example in 2020, during the COVID-19 there is a significant decrease in nitrogen fertilizer use. The Ukraine and Russian War could also negatively influence the supply of nitrogen fertilizer for United States. Since, nitrogen fertilizer is one of the major inputs in plant production, significant decreases in its use can cause significant yield losses. This again signifies the promotion of organic farming and manure as a crop nutrient.

Figure 8: Total Use of Nitrogen Fertilizer in the United States

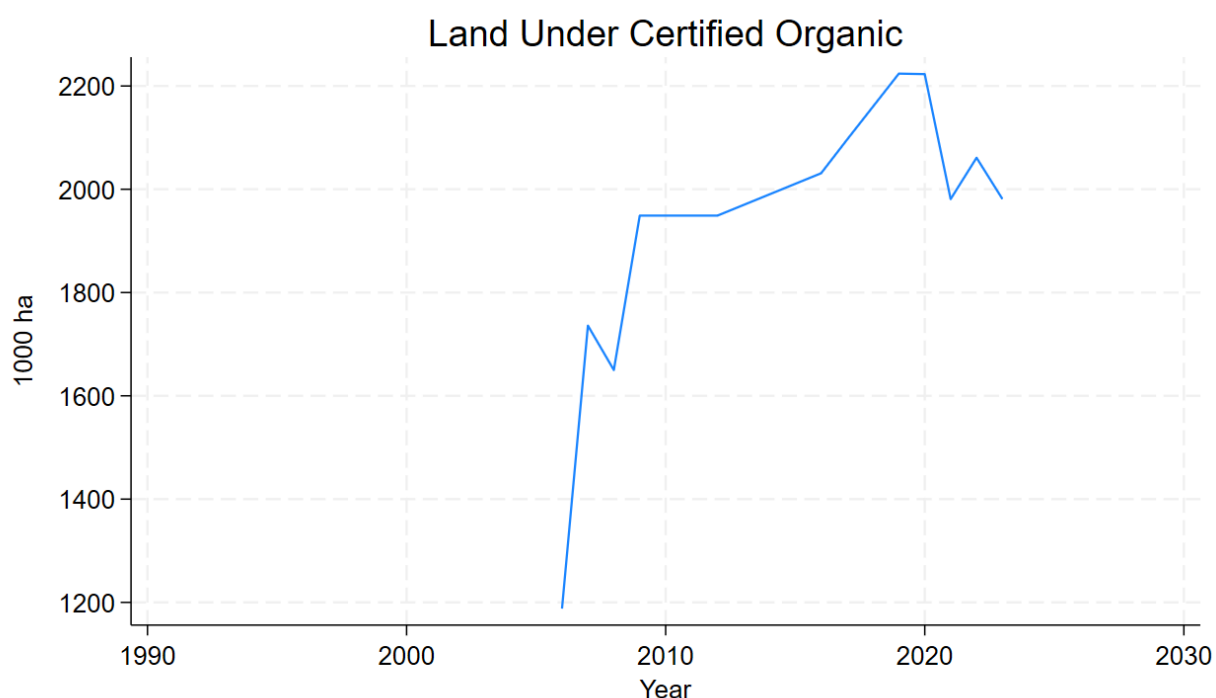


Policy Implications

- Farmers' reliance on especially import dependent variable input can be decreased through alternative production systems, such as organic farming and use of manure.
- Multi-year cost share programs can be developed to help farmers with the cost of organic production and yield decreases due to use of manure.

Land area over which organic production is done in United States further analyzed in figure 2 below. Based on the available data, the certified organic production is done over 2,300 ha in 2013 and increased to 6,500 ha in 2019. Then, with the start of COVID-19 pandemic, starts to decline in reaches to 3,300 ha in 2022. Organic production is crucial for sustainable agriculture and provides a niche market premium for the farmers, which enhances revenues generated. Organic production is not input intensive, but relies heavily on market premium to become profitable.

Figure 9: Land Area under Certified Organic Production in the United States



Source: FAOStatistics (2025)

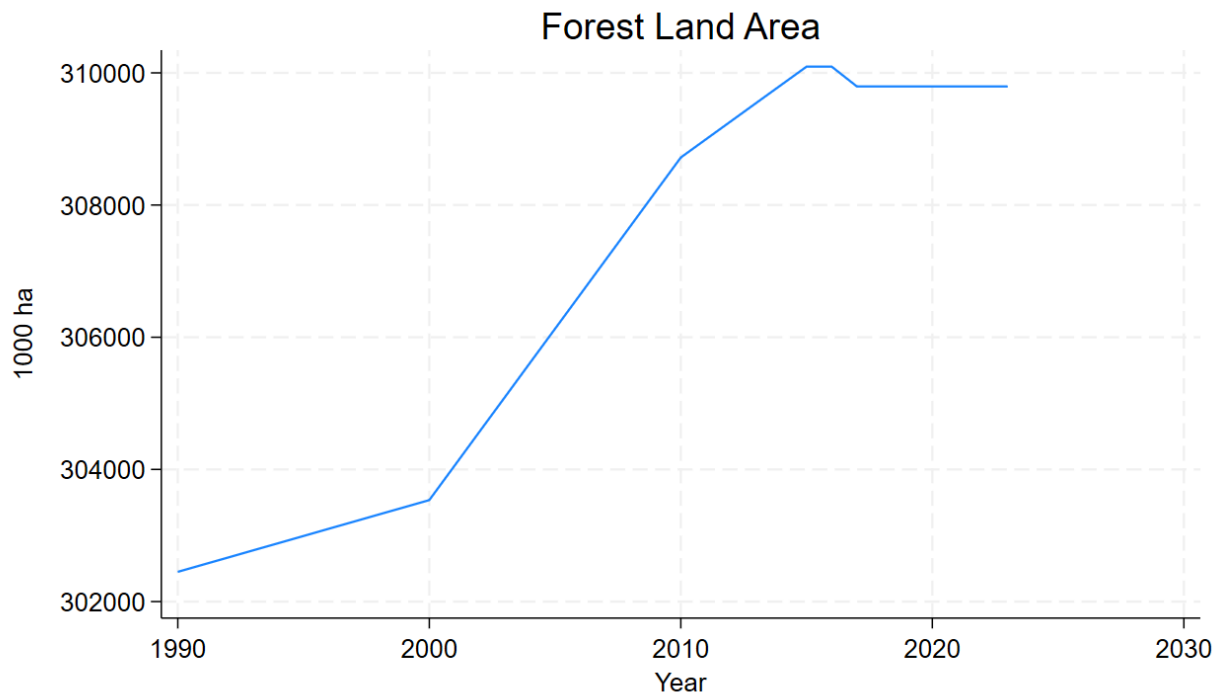
With the start of COVID-19, it is high likely that the producers could not obtain price premium in the market due to income losses caused by the COVID-19. Organic production enhances resilience of farmers both to climate related shocks and price shocks to fertilizers and other chemical input. Hence, it is important to increase organic production to enhance resilience of

farmers. Government educational programs can be made to educate public about the benefits of organic products, cost share programs can be made to cover part of the costs of converting from conventional agriculture to organic agriculture. Also marketing support programs can be developed to connect farmers to different market outlets, such as those in big cities and even to international markets.

Implications for Sustainability

In the regression analysis in the previous sections, it was found that as farmers' access to arable land increases, the resilience of farmers increases. However, care should be given as this land does not come from deforestation. Forest land is critical both sustainable agriculture and income generated for the farmers as a productive asset. Hence, increasing the forest land enhances farmers' resilience to economic and climate shocks. Forest land area in United States is represented in figure 10 below. We see that forest land area steadily decreased from 9.3 million ha in 1990 to 8 million ha in 2022. Hence, there is a significant deforestation occurring in United States. This land conversion is likely to be done to generate land for agriculture. However, this deforestation

Figure 10: Forest Land Area in the United States



Source: FAOStatistics (2025)

makes farmers more prone to soil erosion, draught, lost habitat, and more CO₂ emissions. Strict regulations should be applied to prevent deforestation. A market based approach could be to educate public to generate market premium for crops produced without deforestation, which is currently in the European Union. Farmers could be trained to export to European Union market. Another approach could be to generate market for forestry products produced by the farmers.

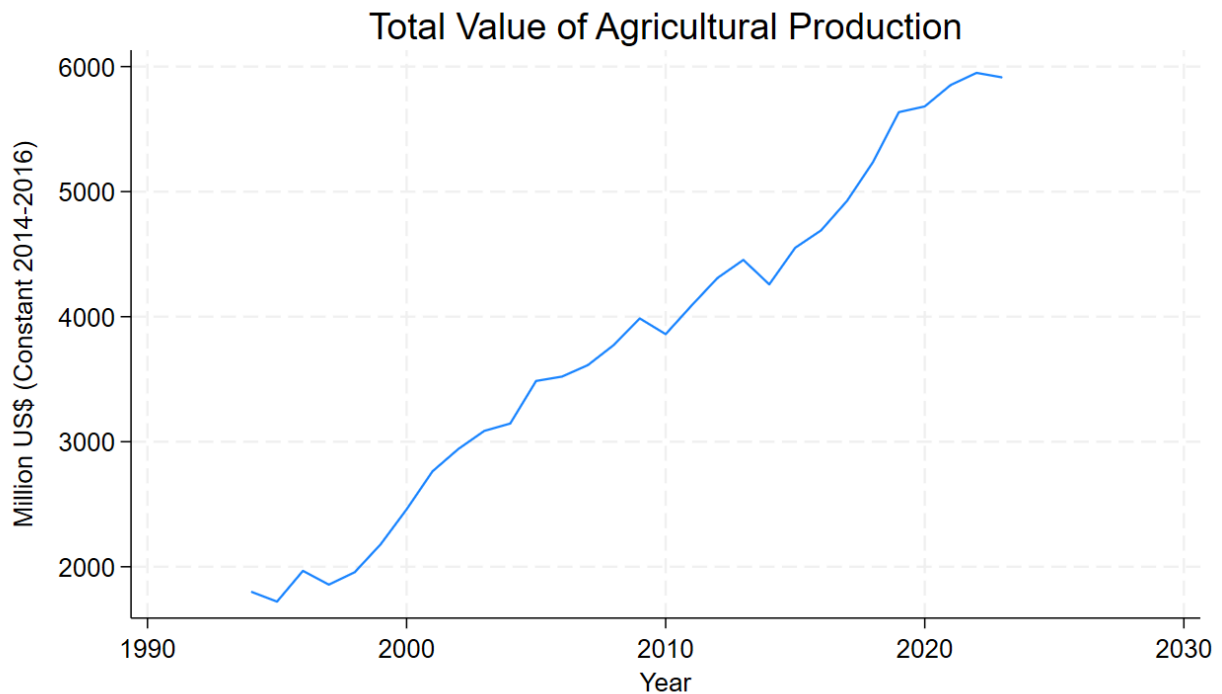
VII. Field Study: Azerbaijan

In this part of the report, we study the resilience of family farmers and small-scale producers in Azerbaijan. We will first analyze the resilience and then identify the factors those influence the resilience of farmers in Azerbaijan. Based on the identified factors, policy recommendations will be provided to strengthening the resilience of the family farmers and small-scale producers in Azerbaijan.

D. Measurement of Resilience

Total value of agricultural production measured in 2014-2016 million US\$ is given in figure 4 below. Total value of agricultural production is around the same level between 1990 and 2005 with some fluctuations. We see some decrease around year 2000. However, the total value agricultural production starts to increase especially after 2010. Azerbaijan has seen increases in infrastructure though out the country, especially after 2010 (FAO, 2024). This could also influence the value created from agricultural production. We see some stability during the COVID-19 era, but then the total value of agricultural production increases to around 4,5 billion US\$ in 2023.

Figure 1: Total Value of Agricultural Production in Azerbaijan

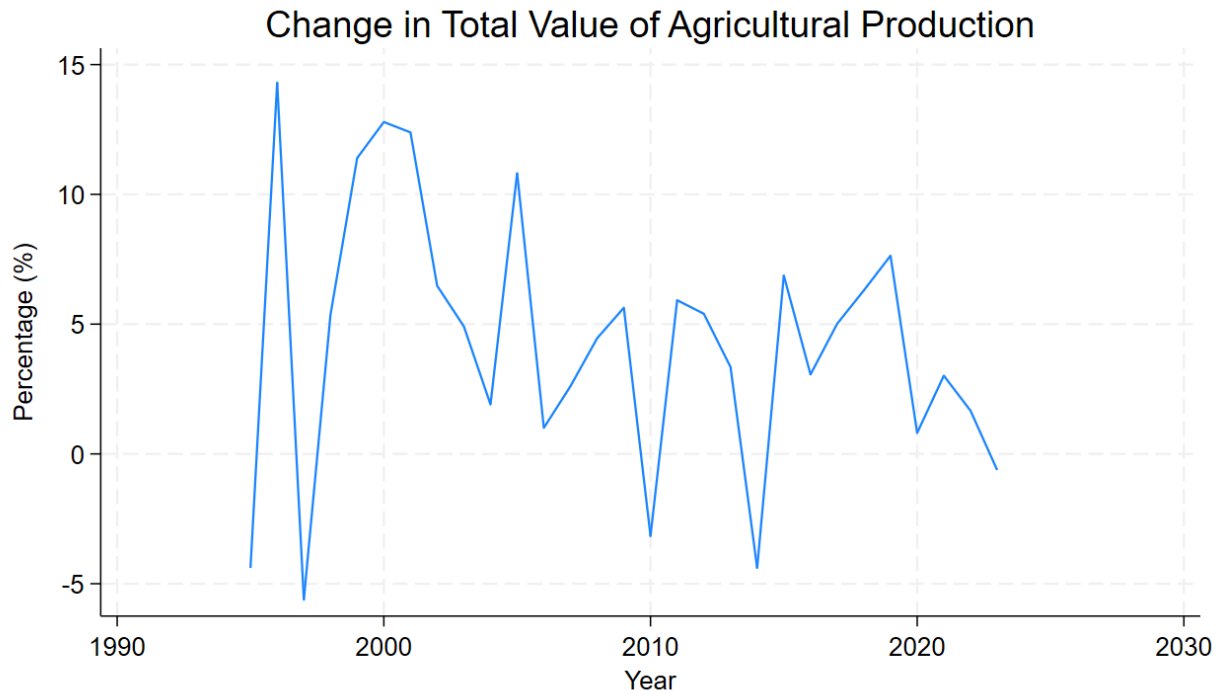


Source: FAOStatistics (2025)

Percentage change in total value of agricultural production in Azerbaijan, which is used as a measure of resilience of farmers, is given in figure 2 below. The positive and zero values during the external shocks indicate that the agricultural production system is resilient, as the value generated from agricultural production continued without a decrease. On the other hand, the negative values during the external shocks indicate the non-resilience of the system, as the value generated from agricultural production decreased. We see both positive and negative values, especially between 1990 and 2010. Hence, resilience of farmers can show variation from one year to another. Farmers can be resilient to external shocks in one year and non-resilient in the following year. Hence, the resilience of the farmers to external shocks should be checked

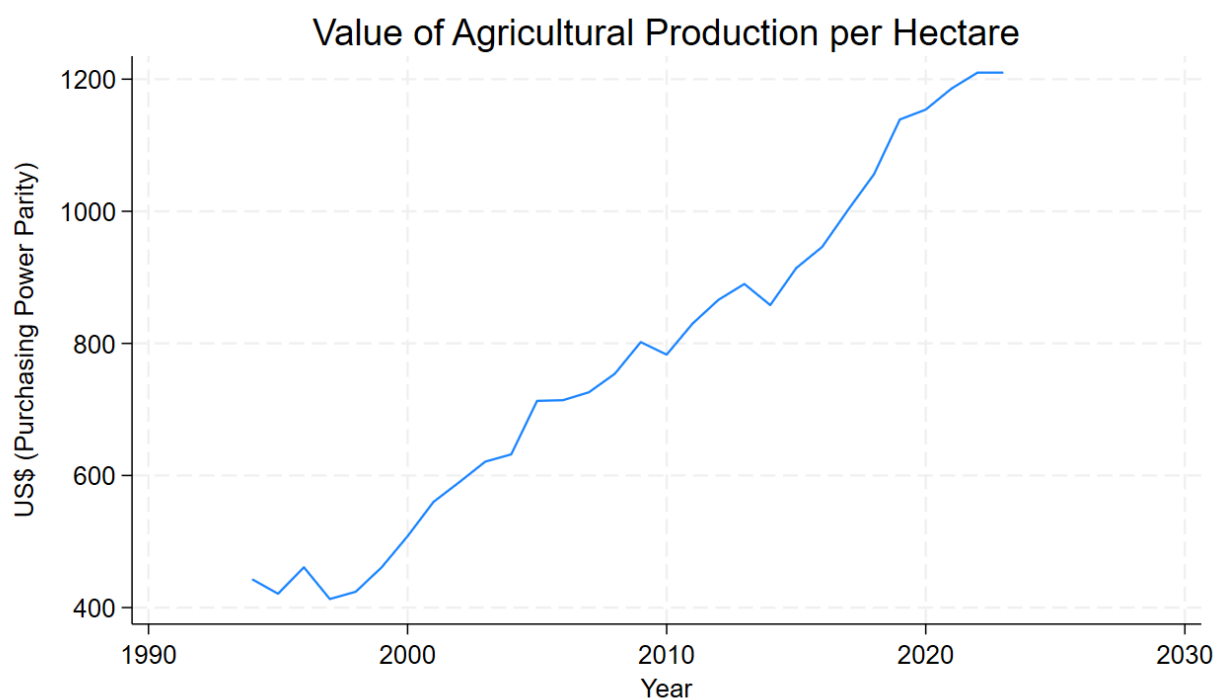
regularly. In Azerbaijan, resilience of farmers shows less fluctuations after 2010 and farmers look more resilient post 2010 period.

Figure 2: Change in Total Value of Agricultural Production in Azerbaijan



Total value of agricultural production per hectare is shown in figure 3 below. Overall, we see yearly fluctuations, especially between 1990 and 2010. This could be due to hostile economic

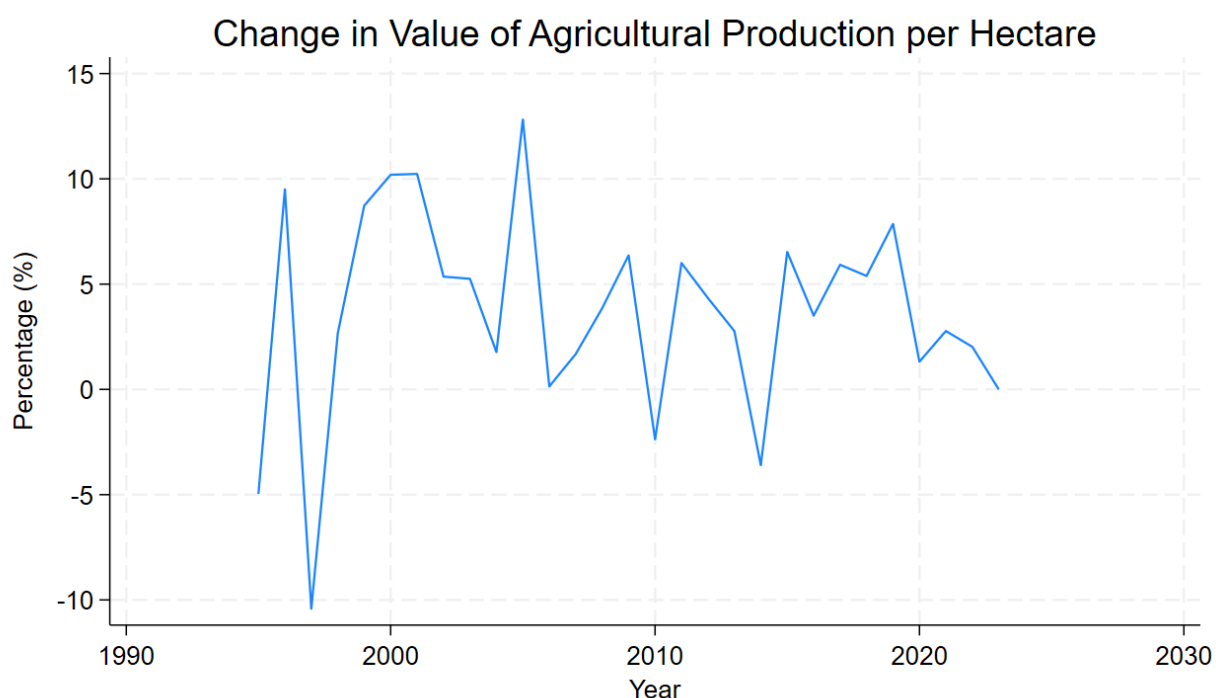
Figure 3: Total Value of Agricultural Production per Hectare in Azerbaijan



conditions during this period. After 2010, there is a positive trend and the value reaches to 510 US\$ per ha in 2020. We then see a decrease in the total value of agricultural production per hectare in the recent years. The percentage change in the total value of agricultural production per hectare, which is also used as measure of resilience of farmers, is shown in figure 4. We see both positive and negative values between 1990 and 2023. There are seems to be more negative values before 2010, but there are also negative values in the recent years. Hence, based on the percentage change in total value of agricultural production per hectare, farmers lost their resilience in the recent years. This could be due to the import depend inputs, such as fertilizer use in Azerbaijan, for which Ukraine and Russian was has been highly influential. The decrease in

resilience could also be due to the draught occurred in Azerbaijan, as the country is highly vulnerable to the effects of climate change (<https://www.copernicus.eu/et/node/10014>).

Figure 4: Change in Total Value of Agricultural Production per Hectare in Azerbaijan



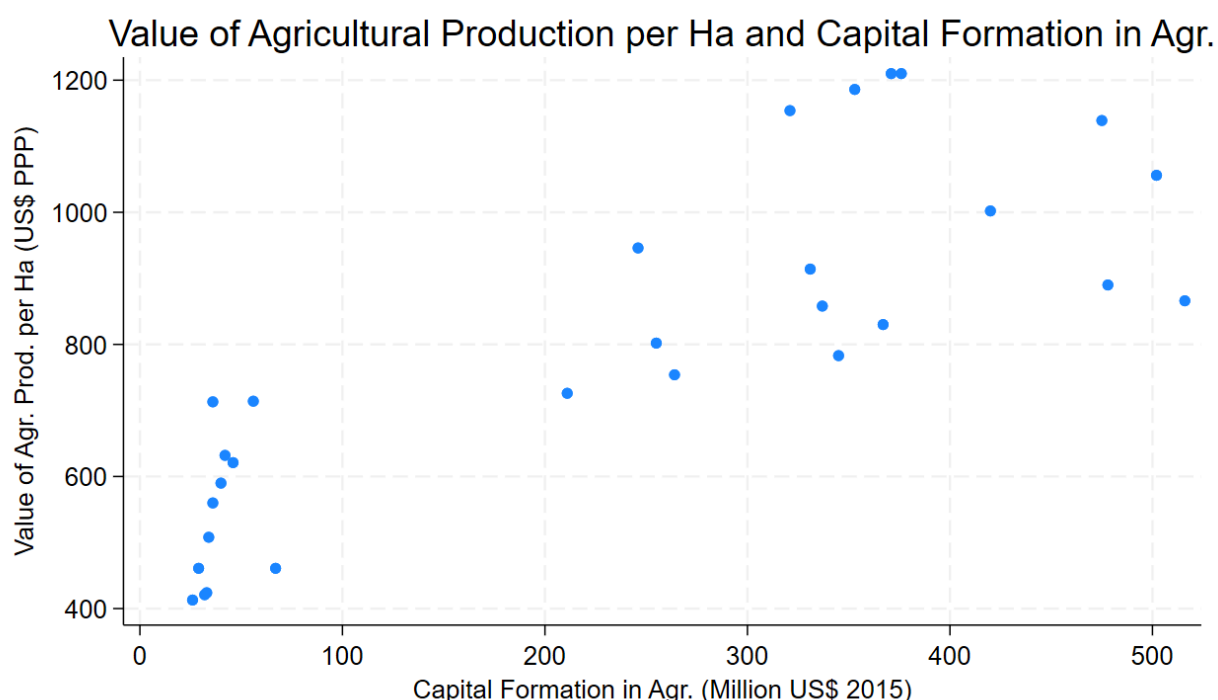
Source: FAOStatistics (2025)

E. Determinants of Resilience in Azerbaijan

In this section of the report we analyze the factors that influence resilience of family farmers and small-scale producers in Azerbaijan. With the identified factors policy recommendations will be developed to strengthening the resilience of farmers. In figure 5 below, the relationship between the value of agricultural production per hectare and capital formation in agriculture is presented. A positive association is seen between the two. As the value of capital formation in agricultural increases, we see an increase in the value of agricultural production per hectare. Farmers' access

to higher agricultural capital, such as equipment and farm structure, can be influential on the value generated per hectare. To analyze the casual relationship between the two, regression analysis will be used in the next sub-section.

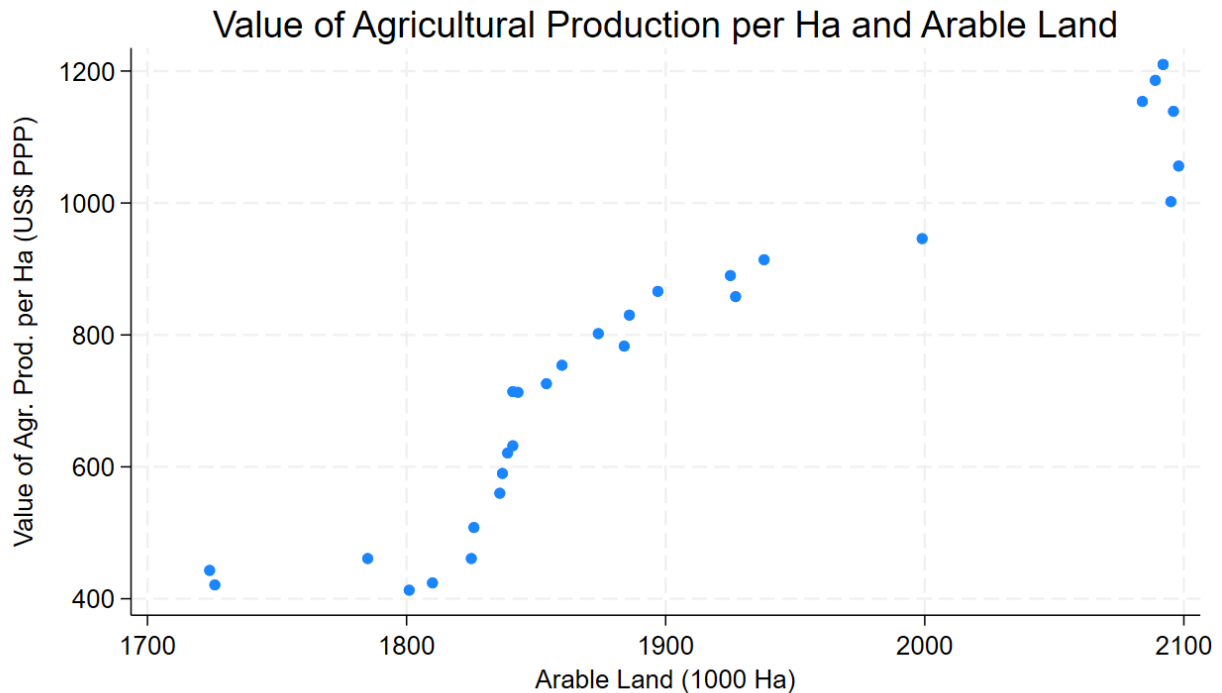
Figure 5: Value of Agr. Prod. per ha and Capital Formation in Agriculture in Azerbaijan



Source: FAOStatistics (2025)

In figure 6 below, the relationship between the value of agricultural per hectare and size of the arable land is depicted. There seems to be some positive association between the two up to 3,500 (1000 ha), the positive correlation is more apparent beyond 3,500 (1000 ha). As the land over which increases, the value of agricultural production generated per hectare increases. This could be related to the fact that as farm sizes grow, farmers have easier access to technology and assets, due to economies of scale. The casual relationship between the value of agricultural production per hectare and size of the arable land will be further analyzed through regression analysis.

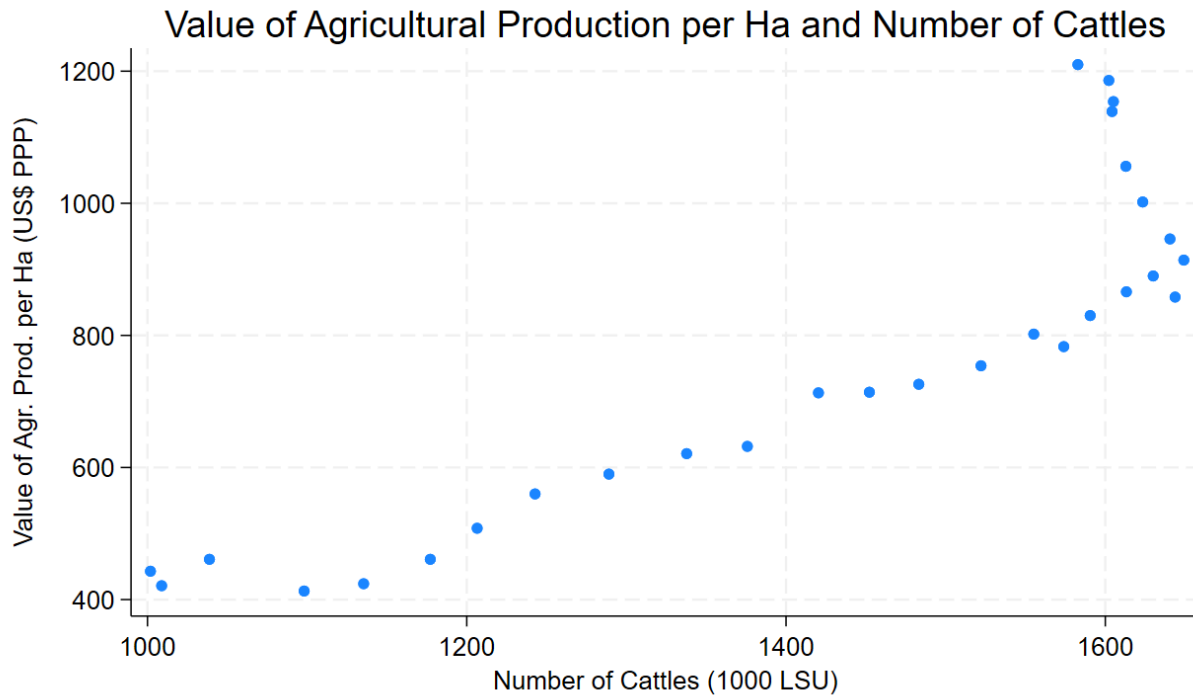
Figure 6: Value of Agr. Prod. per ha and the Size of the Arable Land in Azerbaijan



Source: FAOStatistics (2025)

In figure 7 below, the relationship between the value of agricultural production per hectare and number of cattle is depicted. We see a positive association between the two, especially at the higher number of cattles. Livestock production provides additional income to farmers and cattle meat (i.e. beef) generates higher income for the farmers. Hence, number of cattles can be influential on resilience of farmers, which will be further analyzed through regression analysis below.

Figure 7: Value of Agr. Prod. per ha and the Number of Cattles in Azerbaijan



Source: FAOStatistics (2025)

Regression Analysis of Determinant of Resilience

In this section of the report, we conduct regression analysis to determine the factors influencing resilience of the family farmers and the small-scale producers. In the current analysis we use the following econometric model;

$$Resilience = \beta_1 + \beta_2 Credit + \beta_3 Capital + \beta_4 Cattle + \beta_5 ArableLand + \varepsilon$$

where *resilience* is the dependent variable and measured as the percentage change in total value of agricultural production in Azerbaijan. For the independent variables, *credit* is credit to agriculture measured in million US\$, *capital* is the gross fixed capital formation in agriculture measure in million US\$, *cattle* is the number of cattle measured in livestock units (e.g. dairy cow is equal to one), and *arable land* is the amount of arable land measured in 1000 ha. β_k 's are the

coefficients to be estimated and ε is the error term. The results of the regression is represented in table 1 below. The regression is overall statistically significant at 1 percent significance level and the adjusted R-squared is 0.745, which reflects that 74.5% of the variation in resilience is explained by the independent variables in the regression. For the independent variables, capital is statistically significant at 1 percent significance level (i.e. p-value of 0.000) and has a positive coefficient. As the fixed capital formation in agriculture increases, the resilience of farmers increase. Hence, as farmers have higher access to capital, such farm infrastructure, machines and

Table 1. Regression Analysis Results for the Resilience in Azerbaijan

Dept. Variable: Change in Value of Total Agricultural Production for Azerbaijan				
Variable	Coeff.	Std. Err.	t-Stat	p-Value
Credit	477	403	1.18	0.256
Capital	-648	294	-2.20	0.045
Cattle	0.085	0.96	0.09	0.931
Constant	119597	1362424	0.09	0.931
<i>N</i>	18			
<i>Adjusted R²</i>	0.197			
F(3,14)	2.39			
p-Value	0.113			

equipment, farmers can generate higher agricultural production value, which strengthens their resilience to external shocks. The arable land variable is also statistically significant at 5 percent

significance level (e.g. p-value of 0.012) and has a positive coefficient. Hence, as the farmers access to arable land increases, farmers' resilience to external shocks increase.

The results of the second regression model, where the resilience is measure as the percentage change in value of agricultural production per hectare is represented below in table. The regression is overall statistically significant at 1 percent significance level (e.g. p-value of 0.006). The adjusted R-squared value is 0.508. Hence, 50.8 percent of the variation the dependent variable resilience is explained by the variation in the independent variables in the model. For the independent variables, capital variable has positive and statistically significant effect on the

Table 2. Regression Analysis Results for the Resilience in Azerbaijan Based on per Hectare

Dept. Variable: Change in Value of Agricultural Production per Hectare for Azerbaijan				
Variable	Coeff.	Std. Err.	t-Stat	p-Value
Credit	0.065	0.083	0.78	0.447
Capital	-0.129	0.061	-2.11	0.053
Cattle	0.00006	0.00019	0.30	0.765
Constant	-34	281	-0.12	0.905
<i>N</i>	18			
Adjusted R ²	0.137			
F(3,14)	1.90			
p-Value	0.176			

resilience of farmers, with a p-value of 0.053. Similar to the previous regression, arable land variable also has a positive and statistically significant effect on the resilience. Hence, as the farmers access to capital and arable land increases, their resilience also increases measured as the

percentage change in value of agricultural production per hectare. Higher access to arable land could reflect economics of scale, which could make farmers gain advantage in use of new technologies and make investment that require higher fixed costs. In the current regression, number of cattles variable is also statistically significant and has a positive coefficient. Hence, as the number of cattles farmers have increases, farmers' resilience also increases. Raising cattle provides additional and higher income to farmers, which is like an income diversification and a safety net against external shocks.

F. Policy Recommendations Based on the Regression Results

Based on the regression results, we recommend the following policies to strengthening the resilience of family farmers and small-scale producers in Azerbaijan;

- Financial support programs, such as cost share programs, can be established for farmers to accumulate farm capital (e.g. building, equipment, machinery).
- Farmers access to arable land can be increased through government support programs, such as rent cost sharing, and long term rental contracts through leasing. Care should be taken for deforestation.
- Educational and financial support programs for livestock operators can be established to increase the number of cattle holdings.

Principal Component Analysis

Principle component analysis can be used to further analyze the structure of the independent variables used in a regression, especially when they are correlated with each other.

In the current study we use principle component analysis to see if the independent variables can be grouped in different categories, reflecting different components. In addition to the *FertilizerN*,

which is the amount of nitrogen fertilizer used in Azerbaijan, as it is the main fertilizer used by the farmers. The results of the principal component analysis is reflected in table 3 below.

Table 3. Results of the Principal Component Analysis

Variable	Comp1	Comp2	Comp3	Comp4
Capital	0.505	0.148	-0.550	-0.620
Credit	0.290	0.711	0.301	0.285
Cattle	0.557	0.194	0.105	0.170
ArableLand	0.435	-0.478	-0.335	0.623
FertilizerN	0.400	-0.452	0.694	-0.340
Component	Eigenvalue	Proportion		
<i>Comp1</i>	2.89	0.58		
<i>Comp2</i>	1.34	0.27		
<i>Comp3</i>	0.48	0.10		
<i>Comp4</i>	0.21	0.04		
<i>N</i>	18			

All the variables have positive and similar effect on the first component, which could reflect the positive effect of productive assets and inputs on value of agricultural production created. On the other hand, *FertilizerN* variable has the largest and positive on component 2, differentiating itself from variables such as capital. Hence, the second component could reflect of the influence of variables input on value of agricultural product produced. To measure the influence of

component one and two on the resilience of the farmers, we now use these components as independent variables in the regression analysis did in the previous section. The results of the regression analysis for resilience measured as the percentage change in the value of total agricultural production is represented in the table 4 below. The regression is overall statistically significant at 1 percent significance level (i.e. p-value is 0.002) and the adjusted R-squared is 0.496. The first principal component PC1 (i.e. productive assets and inputs) has positive and statistically significant effect on the resilience of the farmers. However, the second principal component PC2 (i.e. variable inputs) has negative and statistically significant effect on the resilience of farmers. In Azerbaijan, nitrogen fertilizer is not domestically produced and it is imported from other countries. Hence, heavily reliance on import dependent inputs could make farmers more susceptible to external shocks. Farmers reliance on import dependent nitrogen

Table 4. Regression Analysis Results for Resilience with Principal Components

<i>Dept. Variable: Change in Value of Total Agricultural Production</i>				
<i>Variable</i>	<i>Coeff.</i>	<i>Std. Err.</i>	<i>t-Stat</i>	<i>p-Value</i>
<i>PC1: Productive Assets</i>	8972	18606	0.48	0.638
<i>PC2: Variable Inputs</i>	-61952	27329	-2.27	0.041
<i>PC3: Variable Inputs</i>	-19729	45280	-0.44	0.670
<i>PC4: Variable Inputs</i>	-145836	68372	-2.13	0.053
<i>Constant</i>	155808	30745	5.07	0.000
<i>N</i>	18			
<i>Adjusted R²</i>	0.264			
<i>F(4,13)</i>	2.53			

p-Value 0.091

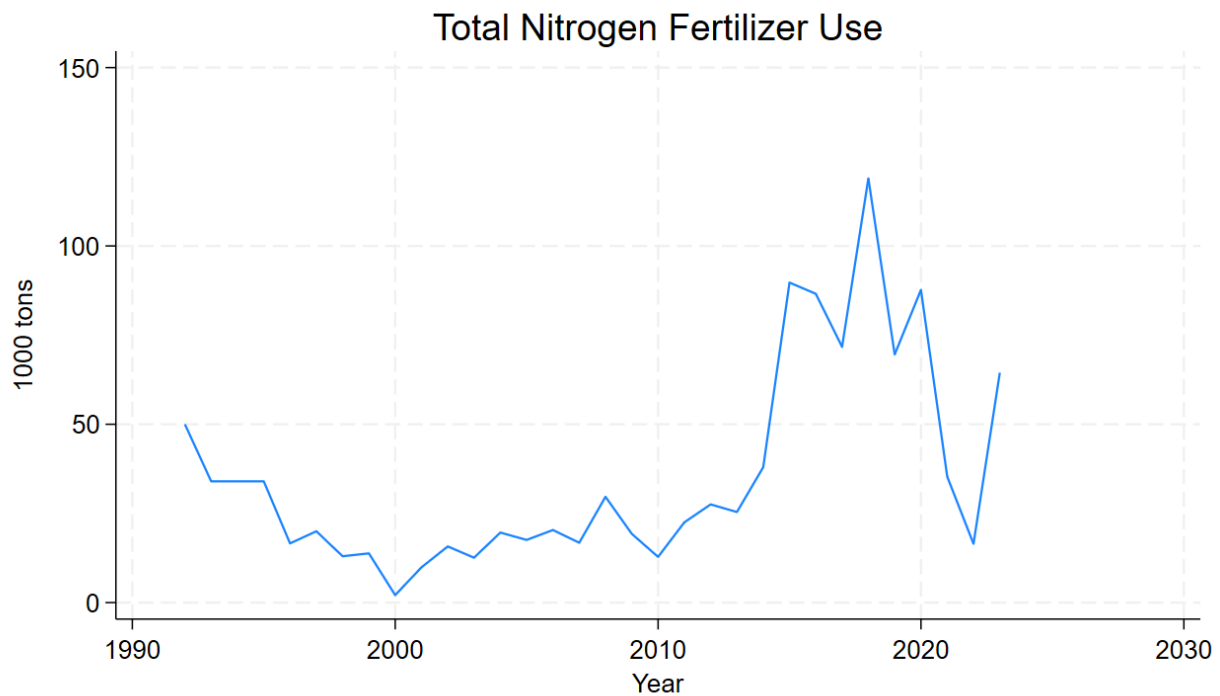
fertilizer can be decreased through promoting organic farming and use of animal manure as a fertilizer. To check the robustness of our results, we also do a regression with resilience measured as the percentage change in value of agricultural production per hectare. The results from that regression are presented in table 5 below. The regression is overall statistically significant and the value of adjusted R-squared is 0.322. The results from this regression is confirmative of the results from the previous regression. The principal component one (i.e. productive assets and inputs) have positive and principal component two (i.e. variable input) has negative influence on the resilience of farmers. To further analyze the use of import dependent variable input nitrogen fertilizer, in figure 8 below total use of nitrogen fertilizer in Azerbaijan is represented. We see that overall there is an increase in total use of nitrogen fertilizer over time

Table 4. Regression Analysis Results for Resilience per Hectare with Principal Components

Dept. Variable: Change in Value of Agricultural Production per Hectare				
Variable	Coeff.	Std. Err.	t-Stat	p-Value
PC1: Productive Assets	1.548	4.010	0.39	0.705
PC2: Variable Inputs	-12.655	5.891	-2.15	0.048
Constant	32.111	6.627	4.85	0.000
<i>N</i>	18			
<i>Adjusted R²</i>	0.139			
<i>F(2,15)</i>	2.38			
<i>p-Value</i>	0.126			

in Azerbaijan, especially after 2010, but there are significant yearly fluctuations. For example in 2020, during the COVID-19 there is a significant decrease in nitrogen fertilizer use. The Ukraine and Russian War could also negatively influence the supply of nitrogen fertilizer for Azerbaijan. Since, nitrogen fertilizer is one of the major inputs in plant production, significant decreases in its use can cause significant yield losses. This again signifies the promotion of organic farming and manure as a crop nutrient.

Figure 8: Total Use of Nitrogen Fertilizer in Azerbaijan

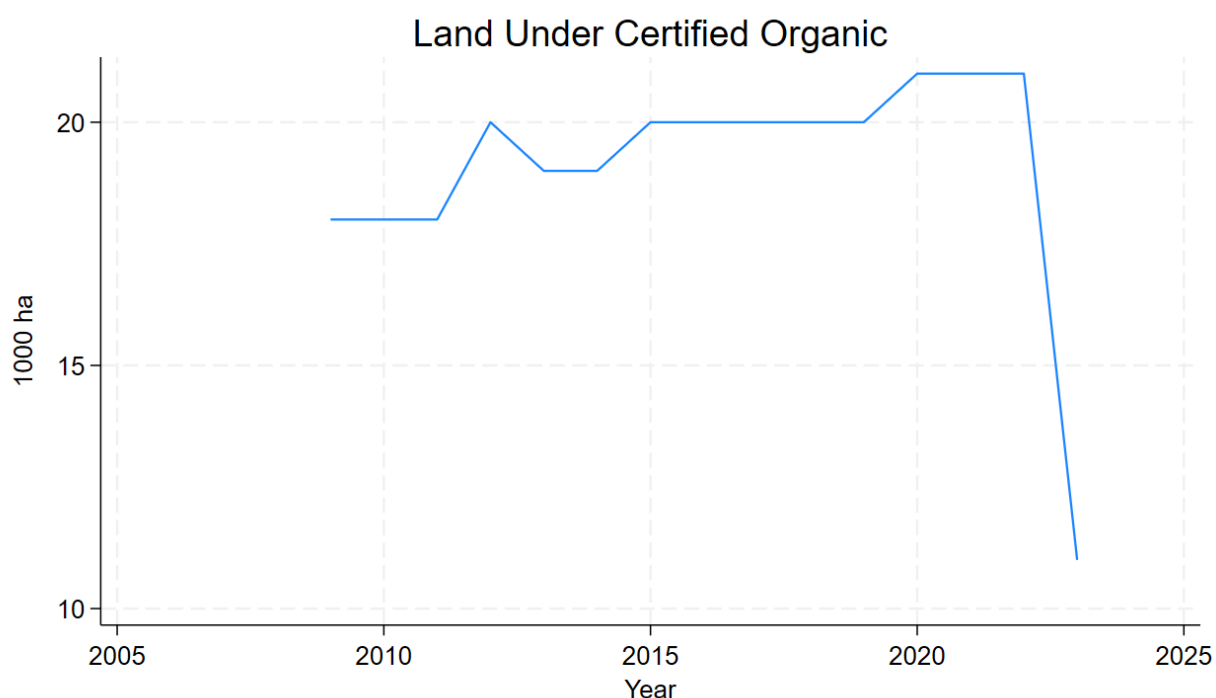


Policy Implications

- Farmers' reliance on especially import dependent variable input can be decreased through alternative production systems, such as organic farming and use of manure.
- Multi-year cost share programs can be developed to help farmers with the cost of organic production and yield decreases due to use of manure.

Land area over which organic production is done in Azerbaijan further analyzed in figure 2 below. Based on the available data, the certified organic production is done over 2,300 ha in 2013 and increased to 6,500 ha in 2019. Then, with the start of COVID-19 pandemic, starts to decline in reaches to 3,300 ha in 2022. Organic production is crucial for sustainable agriculture and provides a niche market premium for the farmers, which enhances revenues generated. Organic production is not input intensive, but relies heavily on market premium to become profitable.

Figure 9: Land Area under Certified Organic Production in Azerbaijan



Source: FAOStatistics (2025)

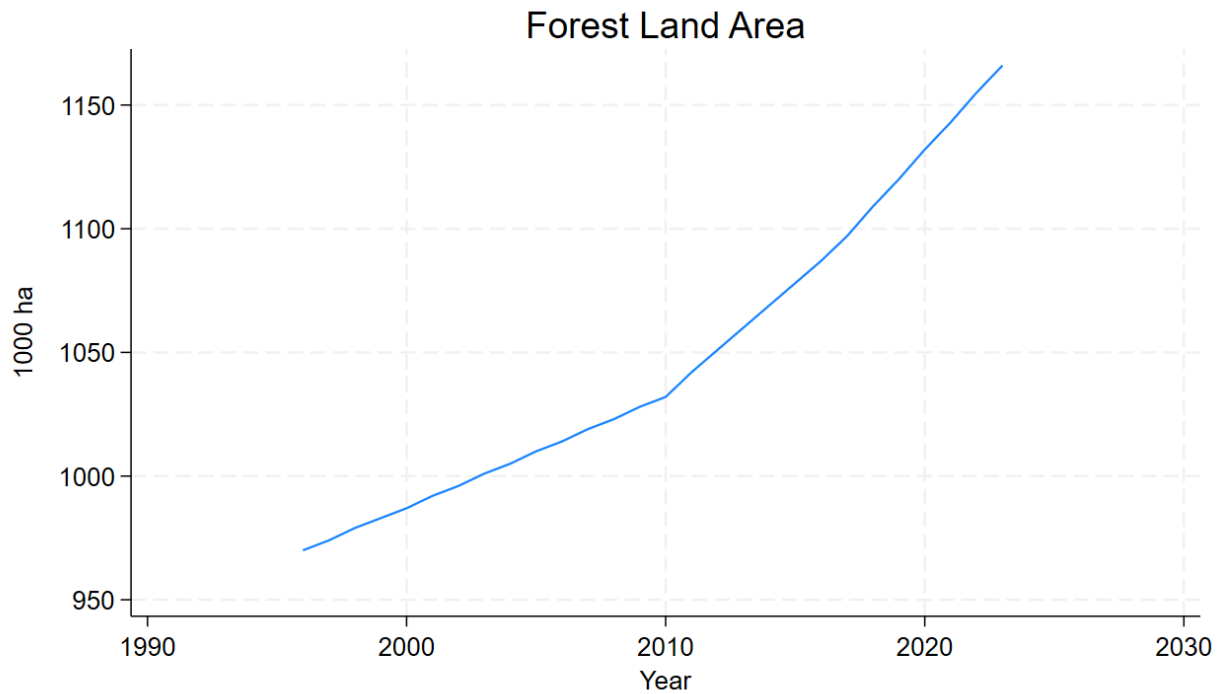
With the start of COVID-19, it is high likely that the producers could not obtain price premium in the market due to income losses caused by the COVID-19. Organic production enhances resilience of farmers both to climate related shocks and price shocks to fertilizers and other chemical input. Hence, it is important to increase organic production to enhance resilience of

farmers. Government educational programs can be made to educate public about the benefits of organic products, cost share programs can be made to cover part of the costs of converting from conventional agriculture to organic agriculture. Also marketing support programs can be developed to connect farmers to different market outlets, such as those in big cities and even to international markets.

Implications for Sustainability

In the regression analysis in the previous sections, it was found that as farmers' access to arable land increases, the resilience of farmers increases. However, care should be given as this land does not come from deforestation. Forest land is critical both sustainable agriculture and income generated for the farmers as a productive asset. Hence, increasing the forest land enhances farmers' resilience to economic and climate shocks. Forest land area in Azerbaijan is represented in figure 10 below. We see that forest land area steadily decreased from 9.3 million ha in 1990 to 8 million ha in 2022. Hence, there is a significant deforestation occurring in Azerbaijan. This land conversion is likely to be done to generate land for agriculture. However, this deforestation

Figure 10: Forest Land Area in Azerbaijan



Source: FAOStatistics (2025)

makes farmers more prone to soil erosion, draught, lost habitat, and more CO₂ emissions. Strict regulations should be applied to prevent deforestation. A market based approach could be to educate public to generate market premium for crops produced without deforestation, which is currently in the European Union. Farmers could be trained to export to European Union market. Another approach could be to generate market for forestry products produced by the farmers.

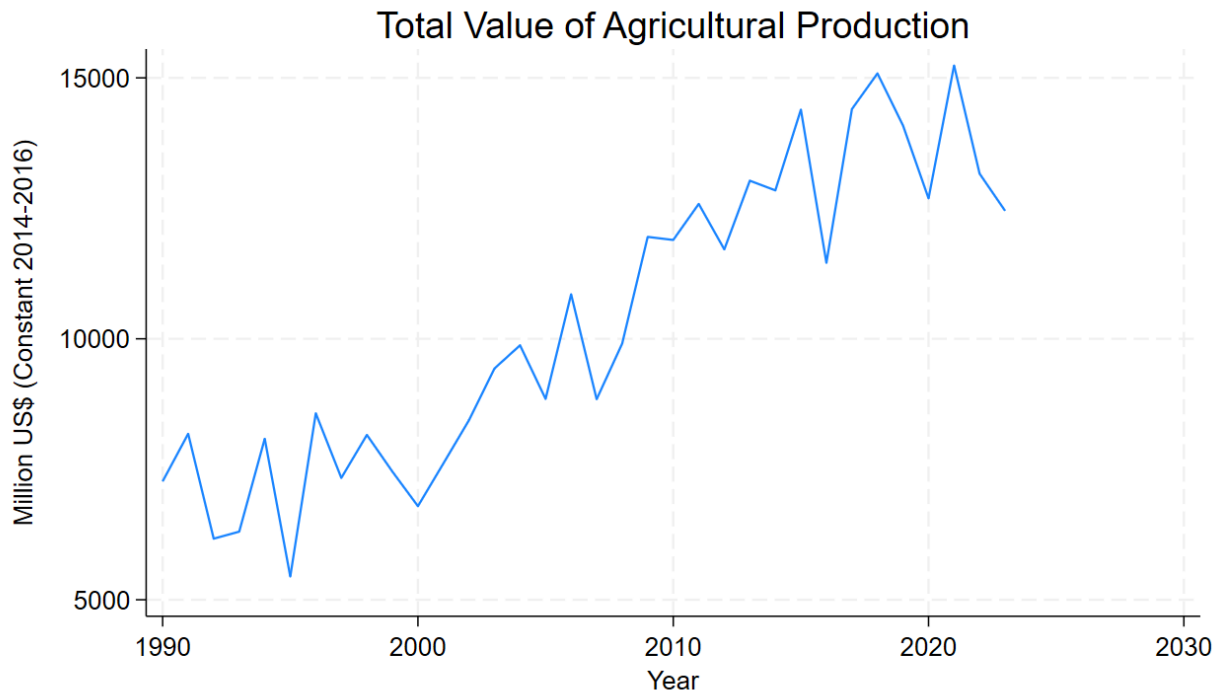
VIII. Field Study: Morocco

In this part of the report, we study the resilience of family farmers and small-scale producers in Morocco. We will first analyze the resilience and then identify the factors those influence the resilience of farmers in Morocco. Based on the identified factors, policy recommendations will be provided to strengthening the resilience of the family farmers and small-scale producers in Morocco.

G. Measurement of Resilience

Total value of agricultural production measured in 2014-2016 million US\$ is given in figure 4 below. Total value of agricultural production is around the same level between 1990 and 2005 with some fluctuations. We see some decrease around year 2000. However, the total value agricultural production starts to increase especially after 2010. Morocco has seen increases in infrastructure though out the country, especially after 2010 (FAO, 2024). This could also influence the value created from agricultural production. We see some stability during the COVID-19 era, but then the total value of agricultural production increases to around 4,5 billion US\$ in 2023.

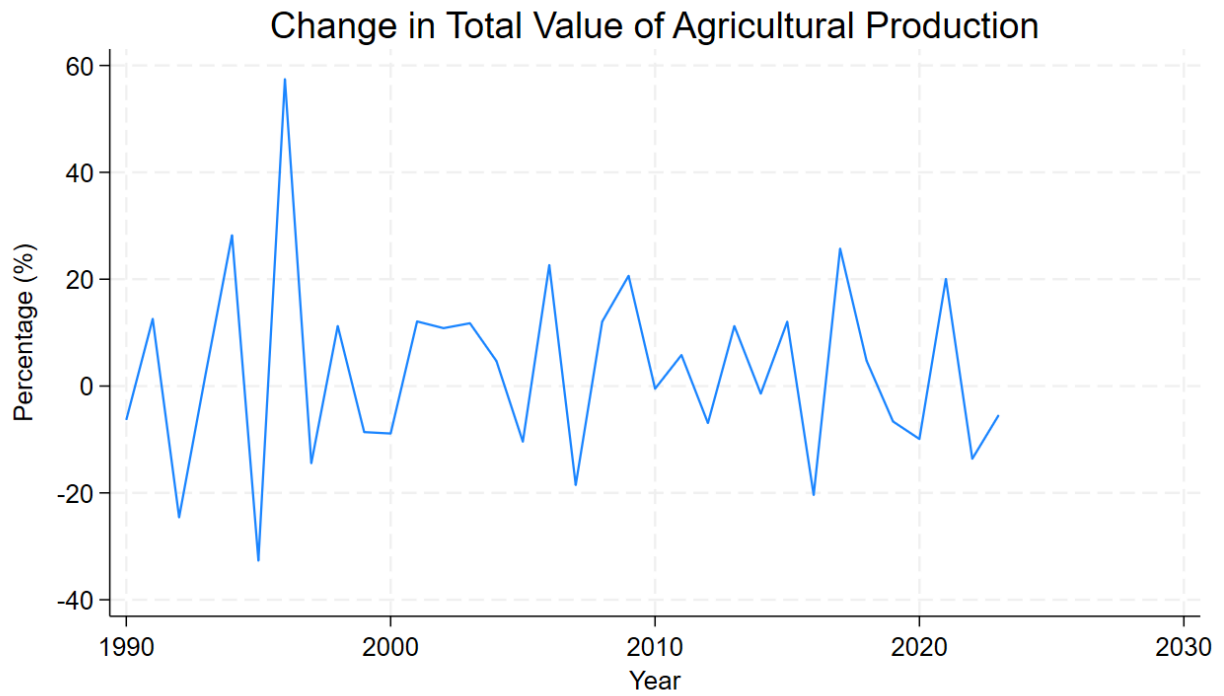
Figure 1: Total Value of Agricultural Production in Morocco



Source: FAOStatistics (2025)

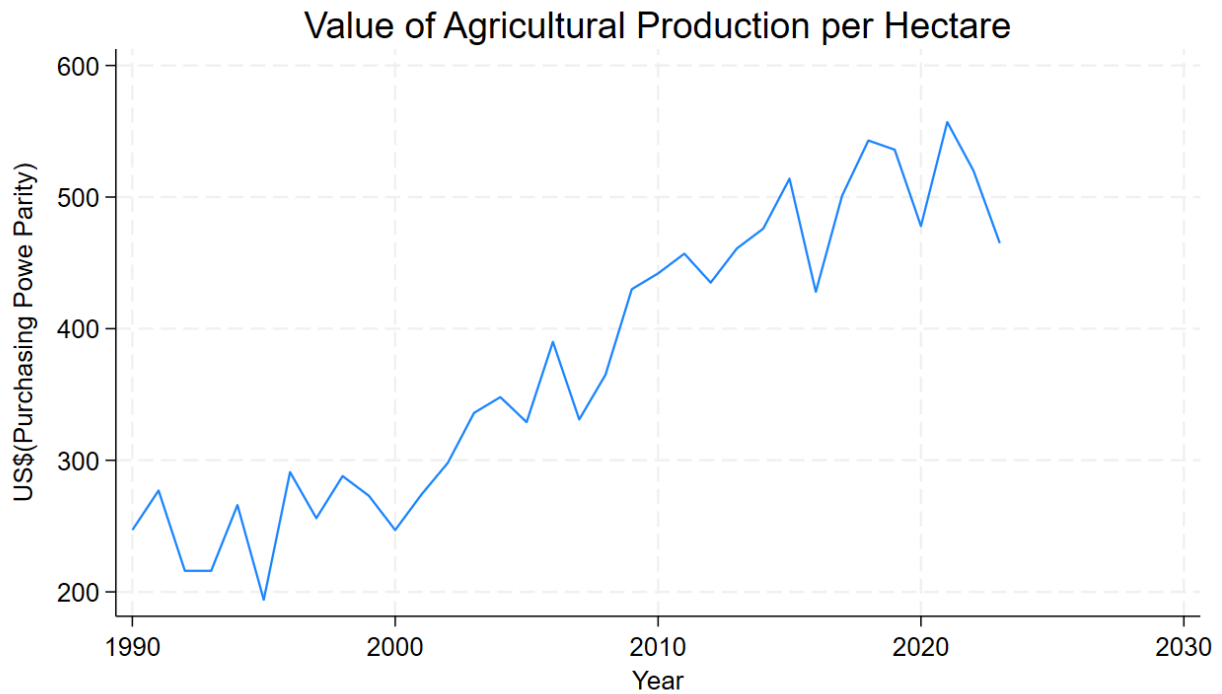
Percentage change in total value of agricultural production in Morocco, which is used as a measure of resilience of farmers, is given in figure 2 below. The positive and zero values during the external shocks indicate that the agricultural production system is resilient, as the value generated from agricultural production continued without a decrease. On the other hand, the negative values during the external shocks indicate the non-resilience of the system, as the value generated from agricultural production decreased. We see both positive and negative values, especially between 1990 and 2010. Hence, resilience of farmers can show variation from one year to another. Farmers can be resilient to external shocks in one year and non-resilient in the following year. Hence, the resilience of the farmers to external shocks should be checked regularly. In Morocco, resilience of farmers shows less fluctuations after 2010 and farmers look more resilient post 2010 period.

Figure 2: Change in Total Value of Agricultural Production in Morocco



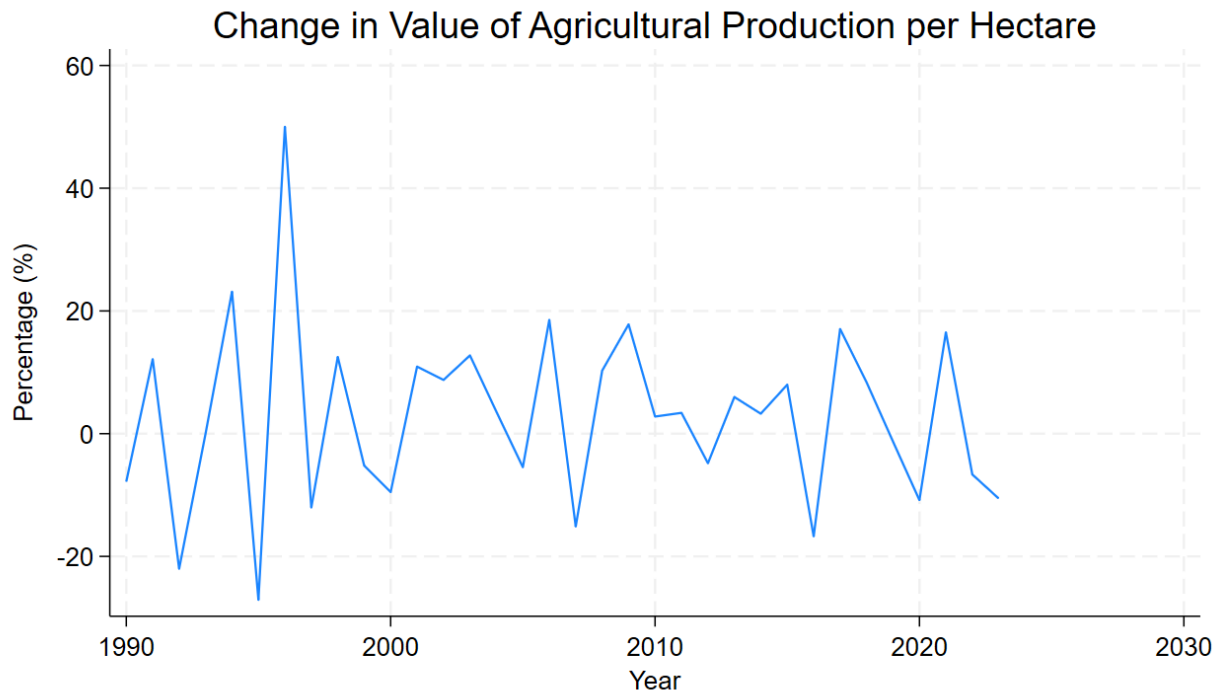
Total value of agricultural production per hectare is shown in figure 3 below. Overall, we see yearly fluctuations, especially between 1990 and 2010. This could be due to hostile economic

Figure 3: Total Value of Agricultural Production per Hectare in Morocco



conditions during this period. After 2010, there is a positive trend and the value reaches to 510 US\$ per ha in 2020. We then see a decrease in the total value of agricultural production per hectare in the recent years. The percentage change in the total value of agricultural production per hectare, which is also used as measure of resilience of farmers, is shown in figure 4. We see both positive and negative values between 1990 and 2023. There are seems to be more negative values before 2010, but there are also negative values in the recent years. Hence, based on the percentage change in total value of agricultural production per hectare, farmers lost their resilience in the recent years. This could be due to the import depend inputs, such as fertilizer use in Morocco, for which Ukraine and Russian was has been highly influential. The decrease in resilience could also be due to the draught occurred in Morocco, as the country is highly vulnerable to the effects of climate change (<https://www.copernicus.eu/et/node/10014>).

Figure 4: Change in Total Value of Agricultural Production per Hectare in Morocco

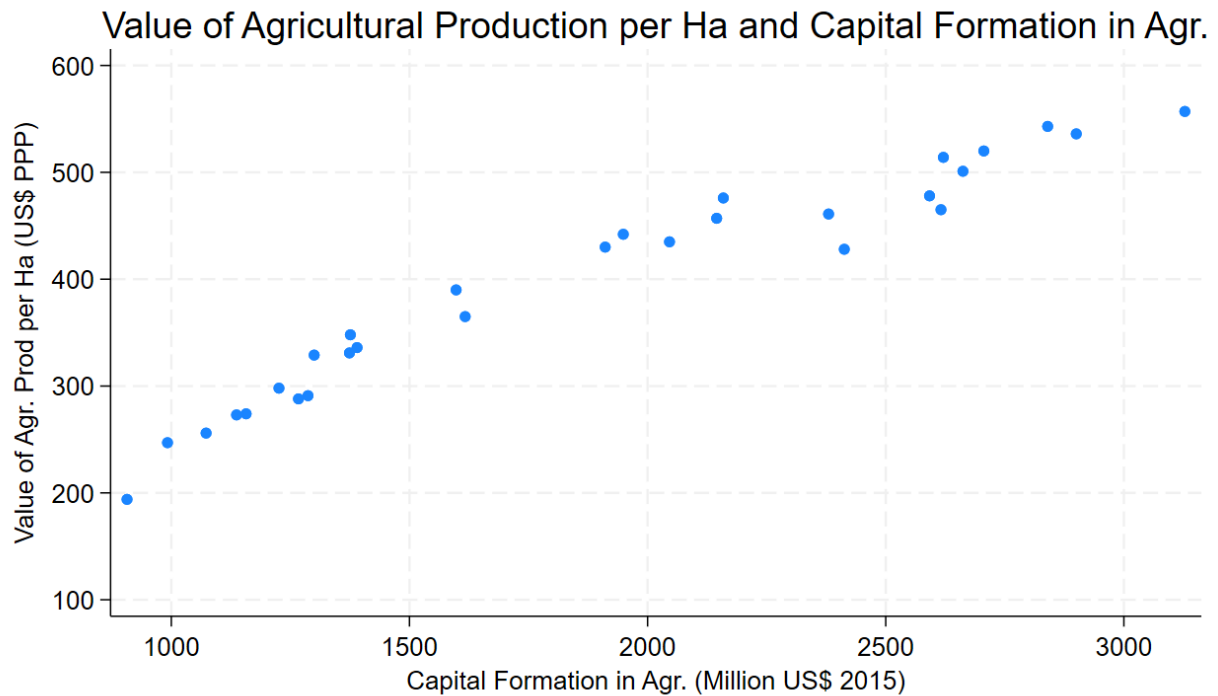


Source: FAOStatistics (2025)

H. Determinants of Resilience in Morocco

In this section of the report we analyze the factors that influence resilience of family farmers and small-scale producers in Morocco. With the identified factors policy recommendations will be developed to strengthen the resilience of farmers. In figure 5 below, the relationship between the value of agricultural production per hectare and capital formation in agriculture is presented. A positive association is seen between the two. As the value of capital formation in agriculture increases, we see an increase in the value of agricultural production per hectare. Farmers' access to higher agricultural capital, such as equipment and farm structure, can be influential on the value generated per hectare. To analyze the casual relationship between the two, regression analysis will be used in the next sub-section.

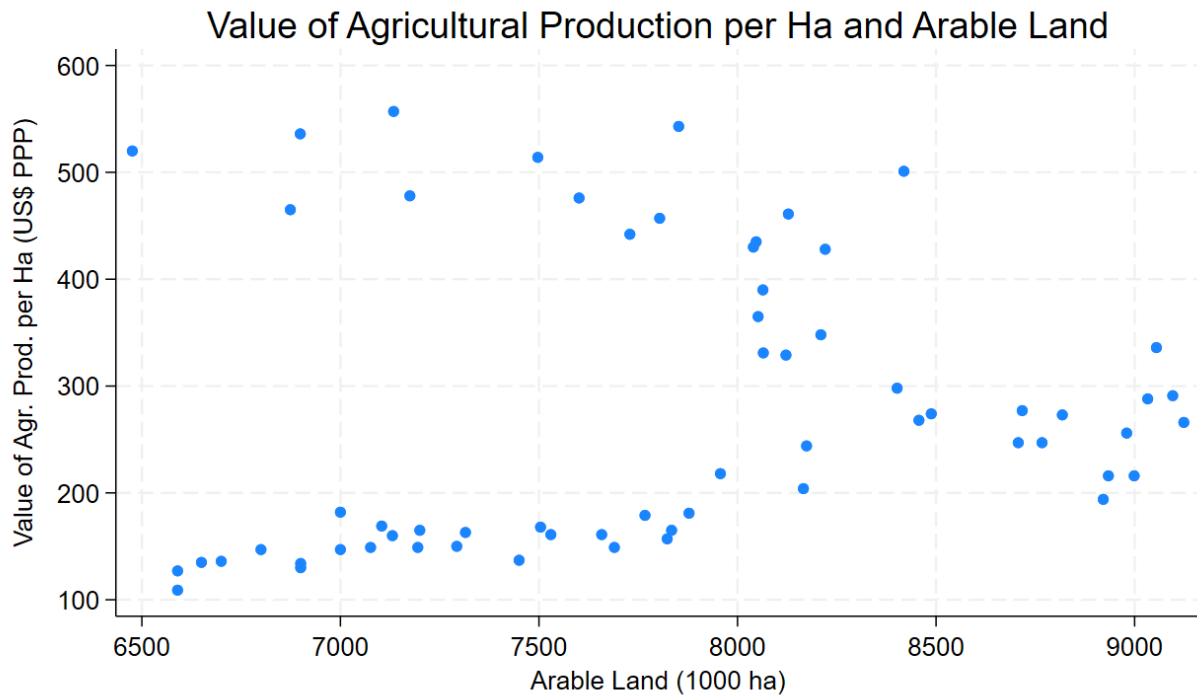
Figure 5: Value of Agr. Prod. per ha and Capital Formation in Agriculture in Morocco



Source: FAOStatistics (2025)

In figure 6 below, the relationship between the value of agricultural per hectare and size of the arable land is depicted. There seems to be some positive association between the two up to 3,500 (1000 ha), the positive correlation is more apparent beyond 3,500 (1000 ha). As the land over which increases, the value of agricultural production generated per hectare increases. This could be related to the fact that as farm sizes grow, farmers have easier access to technology and assets, due to economies of scale. The casual relationship between the value of agricultural production per hectare and size of the arable land will be further analyzed through regression analysis.

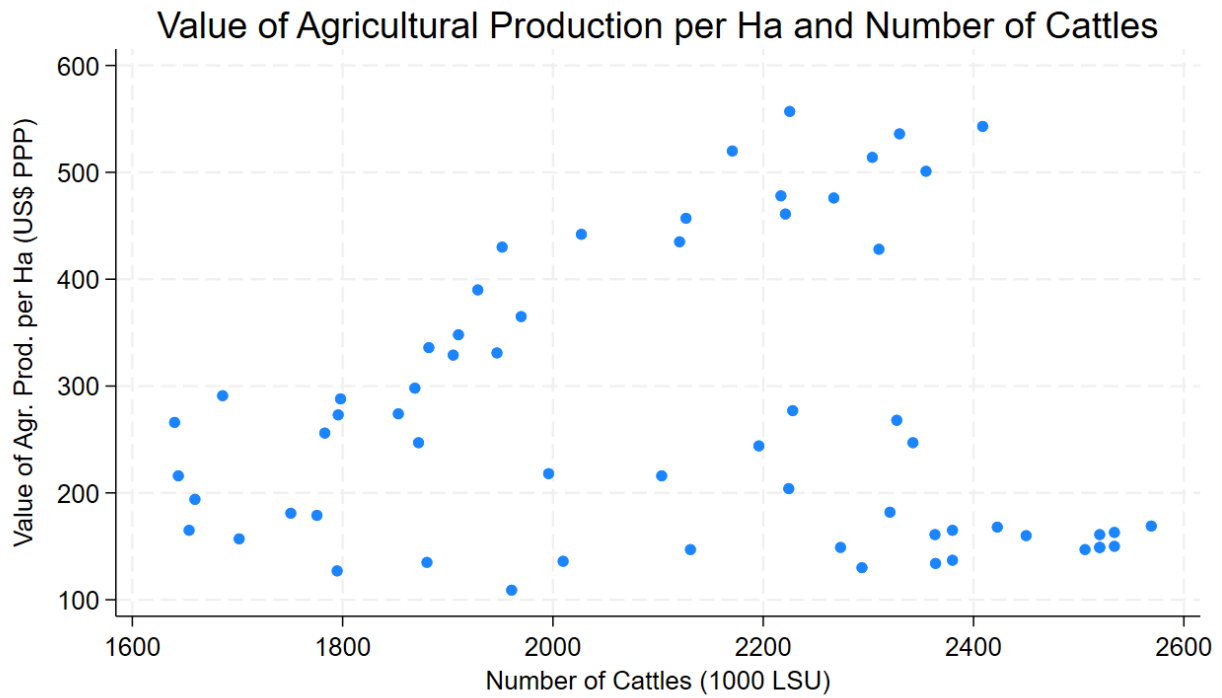
Figure 6: Value of Agr. Prod. per ha and the Size of the Arable Land in Morocco



Source: FAOStatistics (2025)

In figure 7 below, the relationship between the value of agricultural production per hectare and number of cattle is depicted. We see a positive association between the two, especially at the higher number of cattles. Livestock production provides additional income to farmers and cattle meat (i.e. beef) generates higher income for the farmers. Hence, number of cattles can be influential on resilience of farmers, which will be further analyzed through regression analysis below.

Figure 7: Value of Agr. Prod. per ha and the Number of Cattles in Morocco



Source: FAOStatistics (2025)

Regression Analysis of Determinant of Resilience

In this section of the report, we conduct regression analysis to determine the factors influencing resilience of the family farmers and the small-scale producers. In the current analysis we use the following econometric model;

$$Resilience = \beta_1 + \beta_2 Credit + \beta_3 Capital + \beta_4 Cattle + \beta_5 ArableLand + \varepsilon$$

where *resilience* is the dependent variable and measured as the percentage change in total value of agricultural production in Morocco. For the independent variables, *credit* is credit to agriculture measured in million US\$, *capital* is the gross fixed capital formation in agriculture measure in million US\$, *cattle* is the number of cattle measured in livestock units (e.g. dairy cow is equal to one), and *arable land* is the amount of arable land measured in 1000 ha. β_k 's are the coefficients to be estimated and ε is the error term. The results of the regression is represented in table 1 below. The regression is overall statistically significant at 1 percent significance level and

the adjusted R-squared is 0.745, which reflects that 74.5% of the variation in resilience is explained by the independent variables in the regression. For the independent variables, capital is statistically significant at 1 percent significance level (i.e. p-value of 0.000) and has a positive coefficient. As the fixed capital formation in agriculture increases, the resilience of farmers increase. Hence, as farmers have higher access to capital, such farm infrastructure, machines and

Table 1. Regression Analysis Results for the Resilience in Morocco

Dept. Variable: % Change in Value of Total Agricultural Production for Morocco				
Variable	Coeff.	Std. Err.	t-Stat	p-Value
Δ Credit	0.0004197	0.000074	5.64	0.000
Δ Capital	-0.000138	0.000150	-0.92	0.377
Δ Cattle	1.53e-07	4.60e-07	0.33	0.745
Δ ArableLand	-0.000059	0.000079	-0.75	0.472
Δ FertilizerN	7.16e-07	3.35e-07	2.14	0.058
Constant	0.007687	0.022151	0.35	0.058
<i>N</i>	16			
<i>Adjusted R²</i>	0.740			
F(4,10)	9.55			
p-Value	0.014			

equipment, farmers can generate higher agricultural production value, which strengthens their resilience to external shocks. The arable land variable is also statistically significant at 5 percent

significance level (e.g. p-value of 0.012) and has a positive coefficient. Hence, as the farmers' access to arable land increases, farmers' resilience to external shocks increase.

The results of the second regression model, where the resilience is measure as the percentage change in value of agricultural production per hectare is represented below in table. The regression is overall statistically significant at 1 percent significance level (e.g. p-value of 0.006). The adjusted R-squared value is 0.508. Hence, 50.8 percent of the variation the dependent variable resilience is explained by the variation in the independent variables in the model. For the independent variables, capital variable has positive and statistically significant effect on the

Table 2. Regression Analysis Results for the Resilience in Morocco Based per Hectare

Dept. Variable: % Change in Value of Agricultural Production per Hectare for Morocco				
Variable	Coeff.	Std. Err.	t-Stat	p-Value
Δ Credit	0.0003123	0.0000673	4.64	0.001
Δ Capital	-0.000094	0.0001358	-0.69	0.504
Δ Cattle	1.65e-07	4.16e-07	0.40	0.700
Δ ArableLand	-0.000094	0.0000719	-1.33	0.220
Δ FertilizerN	3.41e-07	3.03e-07	1.13	0.287
Constant	0.0053767	0.0200455	0.27	0.794
<i>N</i>	16			
Adjusted R ²	0.640			
F(5,10)	6.35			
p-Value	0.007			

resilience of farmers, with a p-value of 0.053. Similar to the previous regression, arable land variable also has a positive and statistically significant effect on resilience. Hence, as the farmers' access to capital and arable land increases, their resilience also increases measured as the percentage change in value of agricultural production per hectare. Higher access to arable land could reflect economics of scale, which could make farmers gain advantage in use of new technologies and make investment that require higher fixed costs. In the current regression, number of cattles variable is also statistically significant and has a positive coefficient. Hence, as the number of cattles farmers have increases, farmers' resilience also increases. Raising cattle provides additional and higher income to farmers, which is like an income diversification and a safety net against external shocks.

Ī. Policy Recommendations Based on the Regression Results

Based on the regression results, we recommend the following policies to strengthening the resilience of family farmers and small-scale producers in Morocco;

- Financial support programs, such as cost share programs, can be established for farmers to accumulate farm capital (e.g. building, equipment, machinery).
- Farmers access to arable land can be increased through government support programs, such as rent cost sharing, and long term rental contracts through leasing. Care should be taken for deforestation.
- Educational and financial support programs for livestock operators can be established to increase the number of cattle holdings.

Principal Component Analysis

Principle component analysis can be used to further analyze the structure of the independent variables used in a regression, especially when they are correlated with each other.

In the current study we use principle component analysis to see if the independent variables can be grouped in different categories, reflecting different components. In addition to the *FertilizerN*, which is the amount of nitrogen fertilizer used in Morocco, as it is the main fertilizer used by the farmers. The results of the principal component analysis is reflected in table 3 below.

Table 3. Results of the Principal Component Analysis

Variable	Comp1	Comp2	Comp3
Credit	0.526	0.004	0.213
Capital	0.531	-0.195	0.061
Cattle	0.479	0.319	0.494
ArableLand	-0.350	0.686	0.446
FertilizerN	-0.310	-0.629	0.713
Component	Eigenvalue	Proportion	
Comp1	3.32	0.67	
Comp2	1.009	0.20	
Comp3	0.554	0.11	
N	17		

All the variables have positive and similar effect on the first component, which could reflect the positive effect of productive assets and inputs on value of agricultural production created. On the other hand, *FertilizerN* variable has the largest and positive on component 2, differentiating itself from variables such as capital. Hence, the second component could reflect the influence of variables input on value of agricultural product produced. To measure the influence of

component one and two on the resilience of the farmers, we now use these components as independent variables in the regression analysis did in the previous section. The results of the regression analysis for resilience measured as the percentage change in the value of total agricultural production is represented in the table 4 below. The regression is overall statistically significant at 1 percent significance level (i.e. p-value is 0.002) and the adjusted R-squared is 0.496. The first principal component PC1 (i.e. productive assets and inputs) has positive and statistically significant effect on the resilience of the farmers. However, the second principal

Table 4. Regression Analysis Results for Resilience with Principal Components

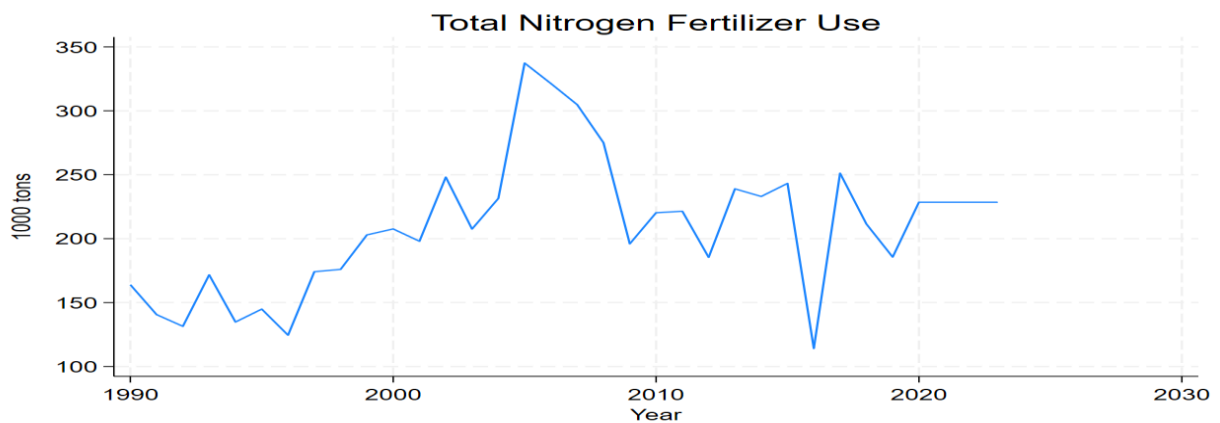
<i>Dept. Variable: % Change in Value of Total Agricultural Production</i>				
<i>Variable</i>	<i>Coeff.</i>	<i>Std. Err.</i>	<i>t-Stat</i>	<i>p-Value</i>
<i>Δ PC1: Productive</i>				
<i>Assets</i>	0.12348062	0.0449729	2.75	0.018
<i>Δ PC2: Variable</i>				
<i>Inputs</i>	0.0121387	0.0308063	0.39	0.700
<i>Δ PC3: Variable</i>				
<i>Inputs</i>	0.1053579	0.320082	3.29	0.006
<i>Constant</i>	-0.0091792	0.0295239	-0.31	0.761
<i>N</i>	16			
<i>Adjusted R²</i>	0.459			
<i>F(3,12)</i>	5.25			
<i>p-Value</i>	0.015			

component PC2 (i.e. variable inputs) has negative and statistically significant effect on the resilience of farmers. In Morocco, nitrogen fertilizer is not domestically produced and it is imported from other countries. Hence, heavily reliance on import dependent inputs could make farmers more susceptible to external shocks. Farmers reliance on imports dependent nitrogen fertilizer can be decreased through promoting organic farming and use of animal manure as a fertilizer. To check the robustness of our results, we also do a regression with resilience measured as the percentage change in value of agricultural production per hectare. The results from that regression are presented in table 5 below. The regression is overall statistically significant and the value of adjusted R-squared is 0.322. The results from this regression is confirmative of the results from the previous regression. The principal component one (i.e. productive assets and inputs) have positive and principal component two (i.e. variable input) has negative influence on the resilience of farmers. To further analyze the use of import dependent variable input nitrogen fertilizer, in figure 8 below total use of nitrogen fertilizer in Morocco is represented. We see that overall there is an increase in total use of nitrogen fertilizer over time in Morocco, especially after 1996, but there are significant yearly fluctuations. For example in 2020, during the COVID-19 there is a significant decrease in nitrogen fertilizer use. The Ukraine and Russian War could also negatively influence the supply of nitrogen fertilizer for Morocco. Since, nitrogen fertilizer is one of the major inputs in plant production, significant decreases in its use can cause significant yield losses. This again signifies the promotion of organic farming and manure as a crop nutrient.

Table 4. Regression Analysis Results for Resilience per Hectare with Principal Components

Dept. Variable: Change in Value of Agricultural Production per Hectare				
Variable	Coeff.	Std. Err.	t-Stat	p-Value
ΔPC1: Productive Assets	0.110753	0.035485	3.12	0.009
ΔPC2: Variable Inputs	-0.005013	0.024307	-0.21	0.840
ΔPC3: Variable Inputs	0.0613464	0.025256	2.43	0.032
Constant	-0.007360	0.023296	-0.32	0.757
<i>N</i>	16			
<i>Adjusted R²</i>	0.431			
<i>F</i> (3,12)	4.79			
<i>p</i> -Value	0.020			

Figure 8: Total Use of Nitrogen Fertilizer in Morocco

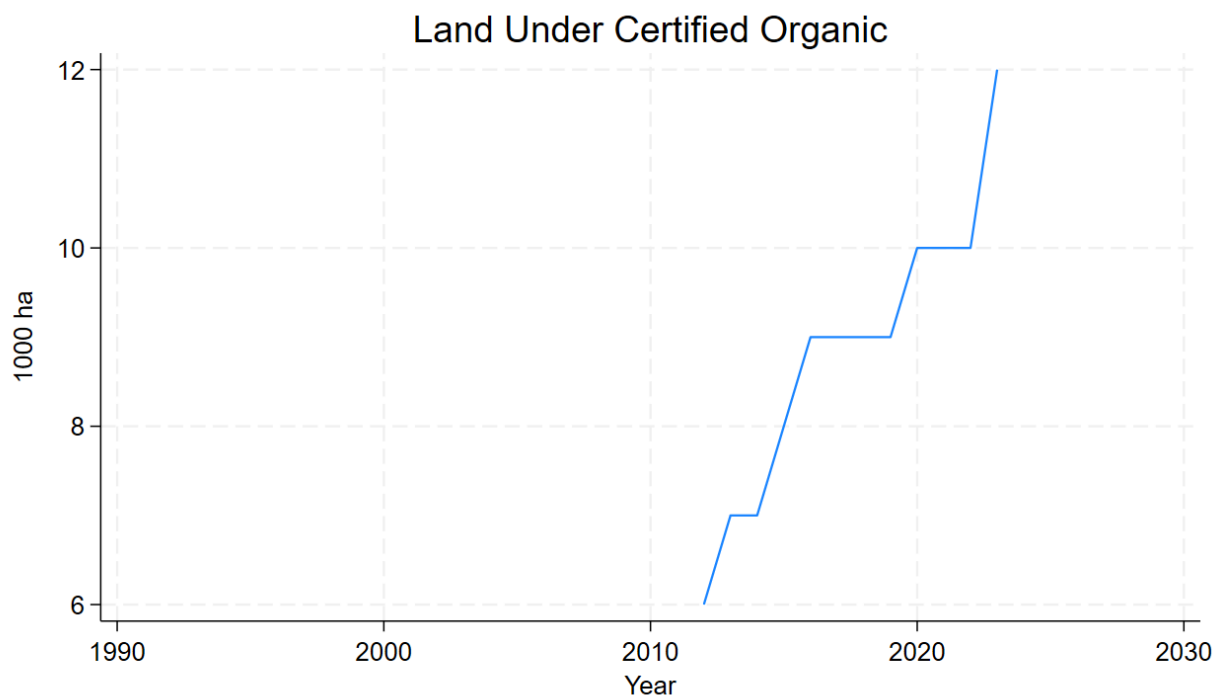


Policy Implications

- Farmers' reliance on especially import dependent variable input can be decreased through alternative production systems, such as organic farming and use of manure.
- Multi-year cost share programs can be developed to help farmers with the cost of organic production and yield decreases due to use of manure.

Land area over which organic production is done in Morocco further analyzed in figure 9 below. Based on the available data, the certified organic production is done over 2,300 ha in 2013 and increased to 6,500 ha in 2019. Then, with the start of COVID-19 pandemic, starts to decline in reaches to 3,300 ha in 2022. Organic production is crucial for sustainable agriculture and provides a niche marker premium for the farmers, which enhances revenues generated. Organic production is not input intensive, but relies heavily on market premium to become profitable.

Figure 9: Land Area under Certified Organic Production in Morocco

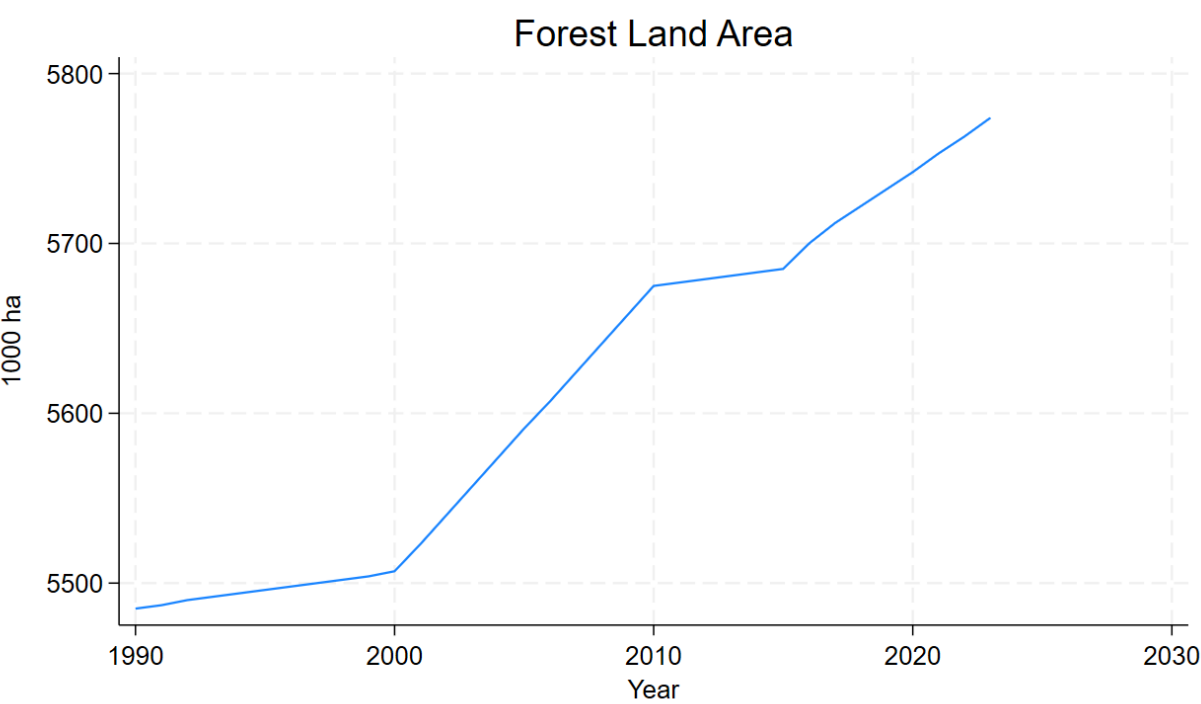


With the start of COVID-19, it is high likely that the producers could not obtain price premium in the market due to income losses caused by the COVID-19. Organic production enhances resilience of farmers both to climate related shocks and price shocks to fertilizers and other chemical input. Hence, it is important to increase organic production to enhance resilience of farmers. Government educational programs can be made to educate public about the benefits of organic products, cost share programs can be made to cover part of the costs of converting from conventional agriculture to organic agriculture. Also marketing support programs can be developed to connect farmers to different market outlets, such as those in big cities and even to international markets.

Implications for Sustainability

In the regression analysis in the previous sections, it was found that as farmers' access to arable land increases, the resilience of farmers increases. However, care should be given as this land does not come from deforestation. Forest land is critical both sustainable agriculture and income generated for the farmers as a productive asset. Hence, increasing the forest land enhances farmers' resilience to economic and climate shocks. Forest land area in Morocco is represented in figure 10 below. We see that forest land area steadily decreased from 9.3 million ha in 1990 to 8 million ha in 2022. Hence, there is a significant deforestation occurring in Morocco. This land conversion is likely to be done to generate land for agriculture. However, this deforestation makes farmers more prone to soil erosion, draught, lost habitat, and more CO₂ emissions. Strict regulations should be applied to prevent deforestation. A market based approach could be to educate public to generate market premium for crops produced without deforestation, which is currently in the European Union. Farmers could be trained to export to European Union market. Another approach could be to generate market for forestry products produced by the farmers.

Figure 10: Forest Land Area in Morocco



Source: FAOStatistics (2025)

IX. CONCLUSION

The objective of this study is to measure the resilience and identify the factors that influence the resilience of the family farms and small-scale producers in the OIC member countries. With the identified factors policy recommendations will be provided to strengthening the resilience of the family farmers and small-scale producers. While proposing recommendations to improve resilience, environmental and social sustainability will also be considered. Resilience of farmers was defined as ability of farmers to continue to produce agricultural products and continue to support their livelihoods after an economic, environmental or a social shock has occurred. We measured the continuation of agricultural production and generating income from this production with total value of agricultural production and the value of agricultural production per hectare at the national level. We specifically used the yearly percentage change of total value of agricultural production and the yearly percentage change of value of the agricultural production per hectare to see if the system is resilient. Non-negative changes in the face of shocks imply resilience.

Desk based case studies of resilience of family farmers and small-scale producers in the agriculture and food sector in Senegal, Türkiye, and the United States was conducted. Percentage change in total value of agricultural production in Senegal, Türkiye, and the United States were analyzed. The positive and zero values during the external shocks indicated that the agricultural production system was resilient. On the other hand, the negative values during the external shocks indicated the non-resilience of the system. For Senegal, we saw both positive and negative values, especially between 1990 and 2010. Hence, resilience of farmers can show variation from one year to another. Farmers can be resilient to external shocks in one year and

non-resilient in the following year. Hence, the resilience of the farmers to external shocks should be checked regularly.

Regression analysis was conducted to identify the factors that influence the resilience of farmers in Senegal, Türkiye, and the United States. In Senegal, it was found that as the fixed capital formation in agriculture increases, the resilience of farmers increase. Hence, as farmers have higher access to capital, such farm infrastructure, machines and equipment, farmers can generate higher agricultural production value, which strengthens their resilience to external shocks. It was also found that as the farmers access to arable land increases, farmers' resilience to external shocks increase. On the other hand, for the United States, off-farm income was found as an important factor that influence resilience of farmers. Hence, generating alternative sources income is an important factor to hence resilience of farmers.

In the second regression model, where the resilience was measured as the percentage change in value of agricultural production per hectare, in addition to capital and arable land variables, number of cattles variable is also statistically significant and has a positive coefficient for Senegal. Hence, as the number of cattles farmers have increases, farmers' resilience also increases. Raising cattle provides additional and higher income to farmers, which is like an income diversification and a safety net against external shocks.

Based on the regression results, we recommend the following policies to strengthening the resilience of family farmers and small-scale producers;

- Financial support programs, such as cost share programs, can be established for farmers to accumulate farm capital (e.g. building, equipment, machinery).

- Farmers access to arable land can be increased through government support programs, such as rent cost sharing, and long term rental contracts through leasing. Care should be taken for deforestation.
- Educational and financial support programs for livestock operators can be established to increase the number of cattle holdings.
- Farmers' reliance on especially import dependent variable input can be decreased through alternative production systems, such as organic farming and use of manure.
- Multi-year cost share programs can be developed to help farmers with the cost of organic production and yield decreases due to use of manure.
- Organic production is crucial for sustainable agriculture and provides a niche market premium for the farmers, which enhances revenues generated. Organic production is not input intensive, but relies heavily on market premium to become profitable.
- Strict regulations should be applied to prevent deforestation. A market based approach could be to educate public to generate market premium for crops produced without deforestation, which is currently in the European Union. Farmers could be trained to export to European Union market. Another approach could be to generate market for forestry products produced by the farmers.

X. REFERENCES

- Dillman, D. A. 2000. *Mail and Internet Surveys: The Tailored Design Method*, John Wiley & Sons, Inc., New York.
- Griliches Z. 1957. "Hybrid Corn: An Exploration in the Economics of Technological Change." *Econometrica*, 25(4), 501-522.
- Meuwissen, M, P. H. Feindt, A. Spiegel, C. Termeer, and E. Mathijs. 2019. "A Framework to Assess the Resilience of Farming Systems." *Agricultural Systems*, Volume 176.
- Wooldridge, J. M. 2010. *Econometric Analysis of Cross Section and Panel Data*, Second Edition, MIT Press, Cambridge, Massachusetts.