LFA support in a changing climate

The interaction between the LFA support and drought periods on the use of agricultural land in Sweden

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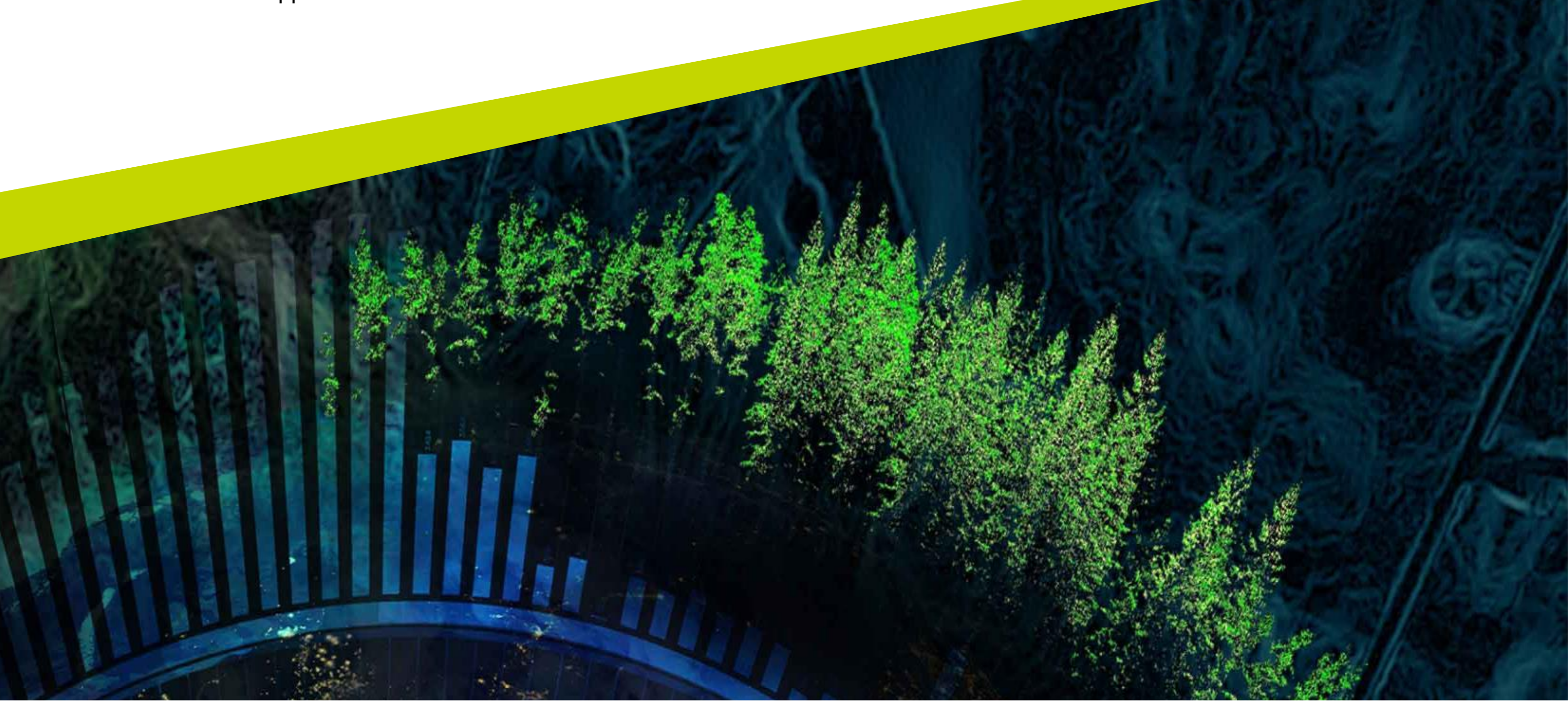

LFA support in a changing climate. The interaction between the LFA support and drought periods on the use of agricultural land in Sweden

LFA-stödet i ett föränderligt klimat. Interaktionen mellan LFA-stöd och längre torkperioder på den svenska jordbruksmarkens användning.

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Abstract

With climate change follows an expectation of more extreme weather events, such as droughts, floods and change in seasonal shifts. How climate variability might impact Swedish agriculture and interact with existing policy aiming at keeping agricultural land in production is not well understood.

This thesis performs an analysis of the interaction between climate variables such as drought and precipitation indexes and the Less Favoured Areas support policy, abbreviated as LFA, the main EU-policy aiming at keeping agricultural land in production. This is done in order to lay the foundations for an increased understanding of how increased climate shocks may impact the land transformation, the rate by which agricultural land is taken into or out of production, in Sweden. Results found that an increase in droughts was linked to a faster rate of agricultural land transformation, partly counteracted by the LFA support, which decreased the speed of land transformation. However a large share of LFA receiving hectares to overall productive hectares in a municipality was linked to faster rates of land transformation in cases of droughts, implying a sensitivity of these hectares, which the support failed to counteract.

Keywords: CAP, LFA, climate change, drought, agricultural land use

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Abbreviations

CAP	Common Agricultural Policy
EU	European Union
FADN	Farm Accountancy Data Network
FSS	Farm Structure Survey
LFA	Less Favourable Areas
LPIS	Land Parcel Identification System
LSU	Livestock Units
NUTS3	Nomenclature of Territorial Units for statistics.

1. Introduction

1.1 Problem formulation

The loss of productive agricultural land is an ongoing process identified in most countries of the European Union (EU). Between 1990 and 2021 a total of 120 million hectares of farmland are estimated to have been taken out of agricultural production in the region (Levers et al. 2018). Likewise, studies have estimated that another 10% of EU agricultural land was deemed at risk of abandonment between 2015 and 2030 (Lavalle et al. 2018). The Swedish rate of farmland abandonment largely mirrors the European one, as the amount of land under agricultural production has been steadily decreasing throughout the last century. Specifically, a total loss of 3 million hectares of productive agricultural land over the last 70 years has been recorded, corresponding to more than 30% of productive land (Statistics Sweden 2023). However, this has been partially compensated for by more capital intensive and large-scale operations, leading to an increase in harvest per hectare for many crops. (Swedish Board of Agriculture 2020)

Despite this increase in productivity per hectare, the abandonment of agricultural land poses severe threats to rural regions, notably regarding employment, biodiversity (Cooper et al. 2006) and food self-sufficiency (Shucksmith et al. 2005). Land abandonment has also been linked to increases in soil erosion and fire risks (García-Ruiz & Lana-Renault 2011) and loss of rural cultural heritage (Daugstad, Ronningen & Skar 2006). Based on these risks, land abandonment is targeted by several interventions within the European Common Agricultural Policy, (CAP). The main policy within the CAP aiming at keeping agricultural land in production is the Less Favourable Area (LFA) support policy, which aims at strengthening the economic incentives for farming in regions where it would otherwise not be economically viable due to climatic or geographical constraints (DG AGRI 2023).

In the review of the CAP in 2014, the Swedish LFA support was subject to a number of adjustments, in order to increase its efficiency and redistribute it in favour of the farms considered to be most in need of the support. Most notably, the restructuring meant that the number of different support levels went from six to fourteen, and some regions previously excluded from the support now became eligible receivers. Furthermore, the support was now given based on the cultivated area in the prevailing year, and not on levels contracted over many years. Another notable change was that areas in the north of Sweden, where expected yields are among the lowest in the country, received an approximative 100% raise in LFA support per hectare, whereas the south of Sweden generally saw a lowered payment. The exact amounts per region and production type may be found in appendixes 1 and 2.

Despite a growing literature on LFA support payments and their role in reversing land abandonment across the EU, there are few studies focusing on the recent restructuring of the LFA support scheme and how this might have impacted the rate of land transformation in Sweden. This thesis contributes to the literature by examining the influence of LFA payments on agricultural land use and in Sweden. The analysis is based on a municipality-level sample, spanning the years 2009-2018, aggregating population-based farm-level observations, which permits an analysis of how changes in the LFA policy influence the rate of transformation of Swedish agricultural land, ito and away from productivity.

A second contribution of the thesis is the focus on land use change in the face of increasing climate variability, taking a specific focus on the drought of 2018. To date there is little empirical evidence on how recent droughts in Europe has affected land abandonment trends, but studies have shown much scope for such effects in the context of developing countries (Markonis et al. 2021). Much like the European case, the long-term consequences of the drought in Sweden are still unclear, due to a lack of systematic studies, but the Swedish Board of Agriculture assessed the drought to have caused large economic and environmental damage (Swedish Board of Agriculture 2019). Resolving this uncertainty in a Swedish and European context is of key importance to understand the effectiveness of policy, such as the LFA, in reversing land abandonment in times of increasing climatic risks and variability (Soussana et al. 2012).

1.2 Aim and objective

Given the above stated challenges and risks regarding land abandonment, and our lack of research on climate change and its interaction with existing policy such as the LFA, this study will have a dual objective. The first objective is to create an understanding of the impact of the restructuring and expansion of the LFA support in 2014, on Swedish agricultural land use transformation, the percentage change in productive hectares between two years. Secondly, this analysis will be used in order to pursue the second objective of the study, to increase the understanding of the interaction between the LFA support and climate shocks, such as the drought of 2018, on the rate of Swedish agricultural land use transformation. These two objectives are highly interconnected, as increasing climate shocks creates a need for policy to be adapted in order to guarantee fit and efficiency (Soussana et al.

2012). The two programme-period scope of this study will thus allow for an analysis of the effect of the restructuring of the LFA support in relation to its efficiency in case of droughts, making it one of the first studies to produce a similar analysis in a Swedish context.

The first part of the study will be pursued in order to answer the research question:

What impact did the restructuring of the Swedish LFA support in 2014 have on the rate of farmland transformation in Sweden?

The hypothesis related to this first research question is that the restructuring, which increased both the overall hectares eligible for support, as well as an the amount in support per hectare for the northernmost regions of Sweden, had a decelerating effect on the rate of farmland transformation. This is in line with previous studies concluding that LFA support sustains agricultural land use in areas under geographical constraints (Takayama et al. 2019).

The second part of the study, regarding the connection between the LFA support and the drought of 2018 will be studied through the research question:

Did the LFA support contribute to stabilizing the rate of farmland transformation in Sweden during the drought of 2018?

This second research question is studied in line with the hypothesis that high shares of LFA support receiving hectares in a municipality are linked to a decelerating effect on the transformation of agricultural land. Primarily, this hypothesis is formulated in line with previous literature (Takayama et al. 2019) and the first hypothesis, assuming that the LFA support has a stabilizing effect on hectares under agricultural production. Furthermore, regions receiving the most LFA support, found in the north of Sweden, saw less extreme deviances from mean temperatures than in the south of Sweden during the drought of 2018 (Swedish Board of Agriculture 2019). Northern Swedish agricultural land might therefore have been less impacted by the drought better than the rest of the country.

This study aims to fill a gap in the literature by expanding our comprehension of the effect of LFA payments on agricultural land use change on a small-scale Swedish level. Earlier studies of the LFA support in a Swedish context have been performed on the much larger NUTS3-regions, thereby losing part of the sensitivity due to possible small scale regional variations. Furthermore, previous studies made on a similar geographic level have mainly been performed in countries with a different climate and/or economic situation, such as Spain, the Czech Republic and Italy. While these studies have been highly relevant for the establishing of the theoretical framework used in this study, the conditions for farming in these countries vastly differs from the Swedish case, which may in turn affect the impact of the LFA support.

This study may also serve as guidance for future restructurings of the CAP, as it is one of the first studies on the LFA support able to encompass all of the program period of 2014-2020 in the studied timespan. As the policy is to be reviewed every six years, this is a relevant contribution, considering that the next review, will be made in a world facing a different set of climate challenges than the previous CAP. Adding to our understanding of the relationship between climate change and the CAP is thus necessary, in order to lay the foundational knowledge needed for the creation of an efficient and well-adapted LFA policy.

1.3 Disposition

Part one of this study has presented the research question and its contextualization. This will be followed by a literature review, in section two. The third part of the study presents the method, describing the structure of the LFA support in closer detail, and the mathematical model used to answer the research questions, as well as the data and variables integrated in said model. Section four will present the results of the performed regression, which will be developed upon under section five, the discussion part.

2. Literature Review

Agricultural land abandonment is a well-studied process, having been the subject of numerous papers in recent years. The literature presented below has been categorized into three primary areas of study: (1) contributing factors to land abandonment, (2) the effect of different LFA schemes on land abandonment, (3) studies of the impact of the drought of 2018.

The first category, concerning the process of land abandonment was approached through the reading of Levers et al., (2018) who study the spatial variations of what factors contribute to land abandonment in a number of European countries. Using satellite imagery to determine areas of land abandonment, in combination with a computerized machine learning system, the study identifies six all-encompassing factors contributing to land abandonment: high unemployment rates, negative migration balance, strong land-abandonment-trends, traditions of low intensive management, in this case especially connected to field size and livestock density, and low soil quality.

Terres et al., (2015) study contributing factors to land abandonment of a socio-economic character on European level. Based on data from FADN and FSS, they produce a composite indicator of the land-abandonment risk, through summing up identified contributing factors, weighted by the quality of the data in the concerned regions. Farms with very specialized activities were deemed at the highest risk of abandonment. Additionally, Sweden was deemed a country at extra high risk of large-scale land abandonment, due to the overall high average age of farmers and low population density.

These sources have been particularly important in the construction of the regression model used in this study, as they provide indications of what control variables should be incorporated in the study.

The second category of literature studied, on the effect of different LFA policies on land transformation, was mainly studied through a paper by Takayama et al. (2019), performing a difference in difference estimation on a number of Japanese communities, out of which a sample received LFA support, over the span of five years. Results from this study concludes that the support prevented farmland abandonment, but had only a marginal effect on the transformation of abandoned land into productive agricultural land.

Furthermore, this area of study also included one paper by Zavalloni et al (2021). This study of farmland abandonment in relation to the LFA support, and public goods provided by farming, was performed in a marginal area in Italy. The method is based on the mathematical modelling of six different scenarios, in which the overall welfare is calculated by adding the farmers' income to the environmental utility generated by each scenario. Their findings show that land abandonment is partially counteracted by LFA payments, and that an increase in the support would slow down land abandonment especially in the sectors employing arable land and grassland. Furthermore, the study also notices that an overall increase in prices result in slower land transformation, both away from agricultural land, and towards it.

Renwick et al, (2013) performs a scenario study where the given baseline scenario of the existing CAP 2008, is measured against three other scenarios, and then analysed based on how these different scenarios may affect land abandonment rates. Scenario 1 removes the whole of pillar 1 in the CAP, scenario 2 assumes a WTO-level trade liberalization agreement, and scenario 3 combines the two. Their findings state that the impact of trade policy on land abandonment is rather limited, but that the CAP does have a noticeable, albeit small, decelerating impact on the rate of land abandonment. They also conclude that the impact of the CAP differs between the studied regions, as this very broad policy tool fails to take regional diversities into account. One conclusion derived from this is therefore that there might be a need for policies with smaller and more specific targets, when combatting land abandonment.

The latter part of this study, developing the connection between the LFA support and land under agricultural production during and after the drought of 2018, was studied through two main articles. The first article, by Rakovec et al. (2022), contextualizes the drought of 2018, relating it to other multi-year droughts in Europe over the last 250 years. Through studying the soil moisture index, SMI, they determine the drought of 2018 to have been an exceptional event, in that it lasted for a period longer than two years and covered a larger part of the continent than most previous droughts. The study further presents a future scenario, modelled on data from 1766-2020, implying that droughts of the same or greater magnitude than the one of 2018 are to be expected within the future and that agricultural policy needs to be adapted accordingly.

One paper, by Wiréhn (unpublished), is one of the first studying the effects of the drought of 2018 in a Swedish context. Basing her research on surveys and workshops, Wiréhn concludes that there is a latent demand for climate data and projections among Swedish farmers. This implies that while farmers see the need for this kind of data, few actually uses it, due to low knowledge of its' existence and high knowledge thresholds in order to use it in a practical way.

These two studies have been important, both as they provide an understanding of the consequences of the drought both on European, and Swedish level, but also as they motivate this study in a very concrete sense. The expected increase in droughts, and the Swedish farming community's lack of accessible information on how to access and use climate projections justifies a direct need of more knowledge about the effects of climate change on agriculture.

3. Methodology

3.1 Structure of the LFA support

The Swedish adaption of the LFA support is a monetary support paid out to farmers, based on their geographical location and hectares of agricultural production. Below follows a detailed description of the structure of the LFA support, to facilitate the reader's understanding of its underlying mechanisms, based on Strömberg et al (2022).

Based on the pre-existing parish borders, the Swedish LFA support is motivated by one main restricting biophysical condition, namely low average temperatures. The impact of this restricting biophysical condition was calculated through studying the average yields of the 13 most common cash crops in Sweden. If the expected yield of all 13 crops were 80% or lower than the EU and national average yields, agricultural land in the parish was classified as eligible for LFA support. The support is internally differentiated, with a number of different support levels, based on the number of days in a year that each parish has an average temperature above the reference temperature of five degrees Celsius. The support is also differentiated by agricultural activity. In the LFA policy post the 2014 restructuring the support is structured into 6 categories. Production type 1-3 is calculated on hectares of fodder production per Livestock Unit (LSU), where type 1 is of highest intensity and type 3 the most extensive. Type 4 and 5 concerns crop production and unproductive land is classified as type 6, non-eligible for support. Pork and chicken production are exempted from the support.

This study encompasses two different program periods of the CAP, as the policy is revisited approximately every six years. The studied years 2009-2014 fall under the CAP 2008, and the associated LFA structure. In 2014 the policy was updated and the year 2015 a designated transition period, during which support amounts were increased somewhat, yet lower than after 2015. The following studied time period, 2016-2019 fall under the CAP 2014 structure. This restructuring of the CAP and consequently the LFA support entailed an increase in the number of hectares and types of production eligible for the support, as well as a monetary increase for the northernmost regions in the country. More precise details of this restructuring may be found in the appendixes 1 and 2.

3.2 Data

A considerable amount of the data used in this study have been collected through the Swedish board of agriculture's statistical database. This includes data on LFA support levels, hectares of agricultural land receiving LFA support, as well as actual amounts of support paid out to each respective municipality.

Another important source of data was provided by the Land Parcel Identification System (LPIS) database. The Swedish LPIS provides data on any agricultural field in Sweden having received some type of subsidy in each year over 2002-2022 indicating that the field is in active use (including in temporary fallow). The Swedish LPIS has comprehensive coverage of approximatively 99.7% of Swedish arable land, with only 10,900 ha identified outside of the system, most of which are part of very small land holdings. Main data collected from the LPIS were total hectares under any kind of agricultural production, number of farms, production characteristics and number of employees. For this study, the data from the LPIS was aggregated to municipal level in order to obtain a measure of the number of hectares of land in active use in each municipality each year over the study period used (2009-2018).

The last focus of the study, on weather conditions' impact on farmland use, are accounted for by data on the number of consecutive dry days and precipitation in mm during the growing season, per municipality, collected from the Copernicus E-OBS datasets.[1]

Data used for control variables of a socio-economic character, such as population density per municipality were found on Statistics Sweden's database. Although not a primary focus of the study, these factors are important to control for as they have, in previous studies, shown to have significant impact on the rate of agricultural land transformation.

Most compiled data was then turned into shares in order to make it more comparable between differently sized municipalities. This eventually produced the list of variables presented below:

[1] Detailed information on the climate indices used from the E-OBS dataset can be found on https://surfobs.climate.copernicus.eu/dataaccess/access_eobs_indices.php.

Table 1. Description of variables in performed regressions

Variables	Description
Y	Dependent variable, the percentage change in productive hectares between year t and t-1 per municipality
LFA_Paid	SEK paid in LFA support per LFA receiving hectare in the municipality
Year	Categorical variable used to study the impact of the support per year
Share_LFA_ha	Share of hectares receiving LFA support of total hectares under agricultural production in the municpality
CDD	Average number of consecutive dry days during the growing season in the municipality
Prcptot_Growing	Total amount of precipitation in mm throughout growing season in the municipality
Lag_CDD	Lagged (t-1) variable of CDD_Climate
Employees	Average number of people employed per farm in the municipality
Avg_Size	Average size of farms in the municipality, total productive hectares divided by number of farms
Population_density	Number of people per km^2 in the municipality
Share_Animal	Share of farms with a specialization in animal production (animal production corresponding to more than 50% of the turnover) in the municipality
Share_Organic	Share of organically cultivated hectares to total hectares under production in the municipality

3.3 Model Specification

To answer the previously formulated research questions, the chosen approach was to specify a Fixed Effect (FE) panel model. The main advantage of the FE model is that it uses panel data to control for omitted variables that differ across municipalities, but are presumed constant over time. This permits a model that captures the change in key aspects such as LFA policy, land use and drought conditions over time, and how these might influence the dependent variable, the rate of change of agricultural land in active use. The panel data model used in this study is specified to examine both cross-sectional (municipality) and time (year) effects, which can be either fixed or random. To verify the fit of the FE model against the Random Effects (RE) model, a Hausman test (Hausman & Taylor 1981) was performed[2], showing a better fit for the FE model which was then opted for in the following estimations.

In order to study the impact of the LFA support as well as the drought of 2018's effect on agricultural land transformation, a first model was specified:

$$\Delta Y_{i,t} = \alpha + LFA\_paid_{i,t} + LFA\_share_{i,t} + CDD_{i,t} + \boldsymbol{C}_{i,t} + \mu_i + \tau + \epsilon_{it} \quad (1)$$

With the dependant variable defined as $\Delta Y_{i,t}$, the percentage change of hectares of agricultural land in production in municipality i, between t and $t-1$. Building on the model employed by Takayama et al. (2019), $LFA\_share_{i,t}$ denote the amount of hectares receiving LFA support as a share of total amounts of hectares under agricultural production in a municipality, while the variable $LFA\_paid_{i,t}$ denotes the amount of support paid per hectare, for each municipality *i*, and time *t*. The variable $CDD_{i,t}$ denotes the drought index defined inte the list of variables above, and $\boldsymbol{C}_{i,t}$ a vector of time-varying control variables, measuring the share of farms specialized in animal production, share of hectares organically cultivated, number of employees, average farm performance and population density, at municipal level. The municipally fixed-effects are denoted μ_i and time controlled for by τ. The first-difference transformation eliminates individual fixed effects and significantly reduce any serial correlation (Baltagi and Kao, 2001). Finally, ε_{it} denotes the error term with all usual properties.

In a second step, Eq. (1) is estimated including a number of interaction variables. *LFA_paid* was interacted with the time control variable *year* in order to allow for an investigation on the effect of the restructuring of the support and its transition period. Furthermore, in order to study the impact of the LFA support's efficiency and effect in case of droughts, and other climatic shocks, *LFA_share* was interacted with the two climate variables *CDD* and *Prcp_tot*. A second model was thus specified:

$$\begin{aligned}\Delta Y_{i,t} = {} & \alpha + LFA\_paid_{i,t} * year \\ & + LFA\_share_{i,t} * CDD_{i,t} + LFA\_share_{i,t} * Prcp\_tot_{i,t} + \boldsymbol{C}_{i,t} + \mu_i + \epsilon_{it}\end{aligned} \quad (2)$$

[2] This generated a χ^2 value of 13.46, and a p> χ^2 .3273, indicating that the fit of the RE model cannot be outruled. Yet, upon estimating the models using both RE and FE specifications, the FE model produced results with considerably higher R^2-values, and was thus the opted for model.

3.4 Data limitations

Due to data availability, there are some limitations to the empirical approach taken in this study. First, the analysis is performed at the municipal level, which is a commonly used and relatively disaggregated geographical unit in Sweden. However, the LFA support is based on a parish level. Due to confidentiality of key control variables measuring the number of farms and the economic performance of farms (eg. Net turnover), the data on parish level was not accessible, and the decision was thus made to aggregate it to municipal level in order ot avoid ecological fallacy (Steel & Holt 1996).

Second, the variables measuring the number of agricultural companies active in each municipality is collected from Statistics Sweden and therefore includes only those whose main main source of net turnover comes from agricultural production. This means that companies whose main source of net turnover comes from e. g. forestry while their secondary source of net turnover comes from agricultural production are excluded from the data. Furthermore, the LFA support is not given to hectares reserved for pork or chicken production, yet these activities are encompassed within other variables such as *Share_Animal* and *Share_Organic*. While these two sectors are both smaller in numbers of enterprises and less land intense than grazing cattle, it still risk creating a skewness in the results. Conclusively, there are some problems with this study's variables to be considered when interpreting the results.

Third, as data on the LFA support is collected on the location of the agricultural enterprise, and not the exact location of the field, which is used in the LPIS, there are instances where the LFA support is accounted to a municipality in which the field concerned is not located. This circumstance produced one extreme outlier, Dorotea municipality, with 8 times more hectares receiving LFA support, than actual hectares under agricultural production. For the other municipalities, this share never amounted to past 2, and Dorotea was thus removed from the study.

4. Results

4.1 Results from the regression

Firstly, the following descriptive statistics were produced:

Table 2. Descriptive Statistics

Variable	Obs	Mean	Std. Dev	Min	Max
Y	2601	-.0624232	.4425728	-8.16755	.9366368
Share_LFA_ha	2601	.2232242	.3135102	0	1.976764
CDD	2588	23.05588	1.433756	19.85313	29.74209
Prcp_tot	2588	337.0321	63.39144	228.7597	547.4928
Paid_per_ha	2601	3500.823	13065.15	0	361315.4
Year	2601	2013.5	2.872778	2010	2018
Share_organic	2585	.0581147	.0708646	0	1.012842
Share_animal	2585	.1682638	.1087962	0	.6666667
Avg_ha	2585	605.4885	1998.091	12.55	35649.14
Employees	2601	89.71526	125.3201	0	1850.8
Population_density	2601	145.4466	516.5183	0	5818.6
Lag_CDD	2588	23.04734	1.414808	19.85313	29.74209

As defined in this study, the dependent variable, the rate of farmland transformation, can be both positive and negative, in case more land was taken out of, or put into production between two years. Hence this study's analysis and conclusions being limited to the rate of transformation of agricultural land, and not purely land being taken out of production. The above presented summary statistics does however show an overall trend of decreasing productive land, with a coefficient of -.0624232 , corresponding to an average decrease of 6.24% per year and municipality, over the total sample.

One notable aspect of the summary statistics is the maximum value of *paid_per_ha*, which at 361315 SEK largely surpasses any amount of LFA support paid out per hectare. This is probably due to the anomaly previously presented related to Dorotea municipality, where a farm is registered within one municipality but the cultivated field is in another. This incidence being a one time outlier however, was left in the data.

When performing the two regressions defined as Eq. (1) and Eq. (2), in section 3.3, the following results are found:

Table 3. Results from performed regressions

	Baseline model		Interaction model	
	Coeff.	Std. err	Coeff.	Std. err
Paid_per_ha	9.43e-07	7.04e-07	.0002725***	.0000646
Year[3]	-.0419523***	.0040467		
Year*Paid_per_ha				
2011			-.0001811**	.0000793
2012			-.0001021	.0000789
2013			-.0000981	.0000778
2014			-.0000315	.0000793
2015			-.000268***	.0000643
2016			-.0002705***	.0000646
2017			-.0002709***	.0000646
2018			-.0002737***	.0000645
Share_LFA_ha	-.6455475***	.0520574	-5.736049***	.990278
CDD	-.0219887	.0335667	-.0123418	.0399542
Prcp_tot	.0028054	.0020522	.0040144*	.0021361
Share_LFA_ha*CDD			.1761181***	.0349485
Share_LFA_ha*Prcp_tot			.002935***	.0009817
Share_organic	-1.081381***	.2669514	-.9774958***	.2646939
Share_animal	.9487962***	.2289168	.9182342***	.2646939
Avg_ha	.0000359***	.0000113	.0000334***	.0000111
Employees	.0001441*	.0000876	.0001588*	.0000871
Population_density	.0008199**	.0003857	.0004932	.000388
Lag_CDD	.0546647	.0358504	.0038021	.0411608
Constant	-1.293107	1.162423	-1.293107	1.162423

*** p<0.01, ** p<0.05, * p<0.1

[3] For visibility resons, the indexed variable *Year* was removed from the table. For comprehensive results, see appendix 3.

The two performed regression models produced several significant variables, in combination with an R^2 of 13.32% for the baseline model, and 17.73% for the interaction model, respectively. This indicates while the model offers some answers to the research questions, it is also somewhat lacking, and conclusions derived from the model should be treated accordingly. Nonetheless, most significant variables show an expected behaviour in their effect on the dependent variable.

The first research question, regarding the effect of the restructuring of the LFA support in 2014, was studied through the variable *Paid_per_ha.* In the baseline model, this variable is not significant, as opposed to the interaction model where it is significant to 99%. Yet, both models produced positive coefficients indicating that there is a connection between higher amounts paid in LFA support per hectare and a higher rate of land transformation. While this would indicate that the support not only fails in keeping agricultural land under production, but also speeds up the transformation of agricultural land, these results might be due to the internal variations of the support. As the support is weighted so that farms met with the lowest average temperatures and expected harvests are receiving the highest amount of LFA support per hectare, this connection may therefore be interpreted not as the support actively contributing to farmland abandonment, but rather as the support not fully outweighing the challenges met by some farms.

When studying the interaction of *Paid_per_ha*, with the time-variable *year,* we may identify the differing effects of the LFA from before 2014, the transition period of 2015 and subsequently the new structure of the LFA support from 2016 and onwards. The interaction variable has the base-year 2010, which allows for a natural analysis of the effect of the LFA support as time progresses. The interaction of *Paid_per_ha* shows a 95%-level of significance with year 2011, and a negative coefficient, implying that the support this year was connected to a lowered rate of land transformation compared to 2010. After this, 2012 through 2014 are all insignificant with negative coefficients. The years 2015-2018, corresponding to the transition period and the following new structure of the support, are all significant to a degree of 99% and produces much higher, negative coefficients than their earlier counterparts. This indicates that the restructuring of the LFA support in 2014 is connected to a decrease in the rate of transformation of agricultural land, compared to the previous policy structure, implying that the restructuring at least partially achieved its' goal of keeping agricultural land in production. However, this should be interpreted carefully as 2014 was not only the year of the restructuring of the LFA support, but of the whole CAP. This means that there might be some effects spilling over from other policy within the CAP, into the interaction-variable, which are not accounted for in this study.

This answers my first research question with an answer in line with the hypothesis stated in section 1.2, as well as the findings of Takayama et al. (2019), that the restructuring and expansion of the LFA support seemingly had a decelerating effect on the rate of farmland transformation in Sweden.

The main variable studying the second research question, *Share_LFA_ha,* did in both models end up highly significant with a negative coefficient. This implies that a higher share of LFA eligible hectares in a municipality, to overall productive hectares, can be linked to a slower rate of transformation of agricultural land in the studied time period. This would indicate that the LFA policy at least partially achieved its' goal of keeping agricultural land in active production. However, the main findings from this variable comes from its' interaction with the variables *CDD* and *Prcp_tot.* Both of these climatic variables show low significance by themselves, yet when interacted with *Share_LFA_ha,* this variable shows a high level of significance and positive coefficients. This implies that when faced with extreme weather conditions, municipalities with a larger share of LFA hectares will generally see a more extensive transformation of productive land, than municipalities with a low share of LFA hectares.

This provides an answer to my second research question, regarding the impact of climate shocks, notably the drought of 2018, on productive agricultural land and its interaction with the LFA support. While the hypothesis assumed that LFA hectares would be kept under production to a larger extent than non-eligible hectares, due to the support incentivizing production as well as the LFA hectares being present to a larger extent in the least drought-affected regions, no indication of this could be found in the regression results. Counter to the hypothesis, results indicated that a high share of LFA hectares in a municipality was connected to an increasing rate of agricultural land transformation during drought-periods.

Most of the control variables show, in line with previous literature, expected behaviour. The variable *Share_animal*, studying the effect of niche farming, is significant and positive. This indicates that a high share of animal production in the municipality is correlated with a faster rate of land transformation. This is in line with the findings of Zavalloni et al., (2021), stating that the more niche the agricultural activities, the higher the risk of land abandonment, as well as the current observable development we may identify in the Swedish agricultural sector – with the number of animal farms decreasing more rapidly than mixed or arable farms (Swedish Board of Agriculture 2023c).

The other variable studying the type of production's impact on the rate of agricultural land transformation, *Share_organic,* is highly significant and shows a negative coefficient. This indicates a link between high shares of ecological production, and a slower rate of agricultural land transformation, in a municipality. While this is not motivated in previous literature, there might be a connection between the higher prices paid for ecological produce, the fact that organic farms on average have a higher degree of self-sufficiency (Swedish Board of Agriculture 2023b), and their, in this study indicated, resilience in case of external shocks.

The control variable adjusting for the size of the farm, *Average_ha* turned out positive, and significant. This indicates that the larger the farms are on average, in regards to productive hectare, the more they contribute to an increased rate of land transformation. This result is interpretable in two ways. As stated in Levers et al. (2018), in cases where large hectares are synonymous to extensive grazing, this can be linked to an increased rate of agricultural land being taken out of production. However, larger farms also have certain options when planning their production that smaller farms don't. For example, when expecting a low harvest, larger farms may chose to employ less seasonal workers, or put less hectares under production, in order to increase their profit margins. A small farm with no employees and less hectares may not have these options. The positive coefficient of this variable should therefore not necessarily be understood as larger farms being a larger contributor to agricultural land transformation than small farms, as the hectares taken out of production may be cultivated the year following, but possibly as large farms having more options on how to adjust their production compared to smaller farms.

The other control variable studying the effect of the farm size, *Employees,* is however negative, with a 95% level of significance. While the instinctive interpretation of this is counter to the *Average_Ha*, that large farms are more stable in amounts of cultivated hectares than smaller farms, this might be due to other reasons such as not a perfect correlation between farms cultivating many hectares and having more employees. The negative coefficient connected to this variable might therefore be due to farms with many employees being able to cut down on working hours for these, instead of cultivating hectares in case of uncertainty.

Interestingly, the lagged drought index, *Lag_CDD*, turned out negative and significant. This would indicate that there might be a small impact of droughts between one year and the following, speeding up the rate of land transformation, but this effect could not be proven by this test and should thus be interpreted carefully.

The variable controlling for population density, *Population_density,* was not significant, yet showed a positive coefficient. This is in contrast to the findings of Terres et al. (2015) who argues that Sweden's low population density make us at especially large risk of land abandonment. The positive coefficient produced in this study however, indicates a possible link between increasing population density and increasing rates of agricultural land transformation, thus the arguments of Terres et al. (2015) cannot be confirmed by this thesis. However, this might be linked to urban expansion, where increase in population density causes higher demand for land, entailing higher land prices creating incentives for farmers to sell their land. Control variables adjusting for land prices were included in earlier versions of the presented econometric model, yet were removed due to them reducing the fit of the model.

5. Discussion

The objective of this study was to investigate the effect of the restructuring of the LFA support in 2014 on the transformation rate of Swedish agricultural land, and the subsequent interaction between the support and the drought of 2018 on hectares under agricultural production. Even though there were some problems with the model, limiting the amount of conclusion we are able to draw from it, there were some notable findings.

Primarily, the results from this study indicate that the restructuring of the LFA support contributed to stabilizing the use of agricultural land in Sweden. As shown by the results, the contribution of the LFA support after the restructuring in 2014 was much larger and significant in stabilizing agricultural land under production, than in the years before the restructuring. This is in line with my first hypothesis, even though a considerable amount of further research should be done in order to properly verify this connection. However, the second hypothesis, that LFA hectares were kept in production to a larger extent than others during the drought of 2018, could not be proven by this study. In fact the opposite, a large share of LFA hectares in a municipality was related to larger changes in productive hectares in case of climatic shocks, was one of the main findings from the regression. This indicates that the support might not be as efficient as wished for, in view of an expected increase in climate shocks with the progression of climate change.

These results are of high relevance for policy makers, as they are among the first comprehensive studies on the LFA support's interaction with climate change on Swedish national level. The results indicate that LFA hectares are, despite of the monetary support farmers receive from keeping them in production, especially sensitive to climate shocks are interesting in view of upcoming restructurings of the LFA. When the program period for the current CAP comes to terms, climate change is expected to have progressed, and the amount of climate shocks increased both in magnitude and number with it, thus possibly weakening the stabilizing effect of the LFA support on Swedish agricultural land transformation.

It is however important to keep the study's limitation in mind, as to not apply too much significance to the results. Primarily, there is a notable limitation in the municipal scale of the study, considering that the LFA support is calculated on parish-level. Further research could do well by studying the LFA support on the administrative region on which it is based, as this would allow for a more fine-tuuned analysis.

Furthermore, this study spans only the year of the drought, in order to study the long term effects of the drought, a longer time-span would have been preferred. This would further have allowed a number of different, and possibly more interesting, dependent variables, such as sliding averages spanning many years, permitting an analysis of when the effect of the restructuring of the CAP and the drought really hit Swedish agriculture. The short time-span applied in this study considerably limited these options, but was necessary as adding years to the studied scope would have demanded a third focus of the study, notably the effects of the Covid-19 pandemic on the Swedish agricultural sector. Due to the limited possible scope of a bachelor thesis, this was not included, but would be an interesting topic for future research.

6. Conclusion

Results from this study point towards an LFA support partially attaining its’ goal of keeping Swedish farmland in production, yet falling short in case of climate shocks. These findings are of large interest to policy makers, yet more studies are necessary in order to fully understand the interaction between the LFA support policy and climate change.

Given the large uncertainty in regard to future climate change, and the possibility of cumulative and exponential effects in respect to the extreme weather events treated in this essay, the results derived from this study should be interpreted with great caution. While results were largely significant, it is not certain these could be applied to future contexts where climate change has progressed further. Thereby, complementary scenario studies, on the progression of land abandonment and its interaction with increasing climate shocks both in magnitude and occurrence would be of great interest and relevance to this study.

Finally, in a changing word, with international trade patterns recently disrupted by both pandemics and wars, it is important we expand our knowledge on how best to keep Swedish agricultural land in production. As recent events have shown us, the world may change from one day to another, and sustaining the resilience of Swedish farmers and farmland are therefore of utmost importance. This study may hopefully contribute to an increased understanding of this problem.

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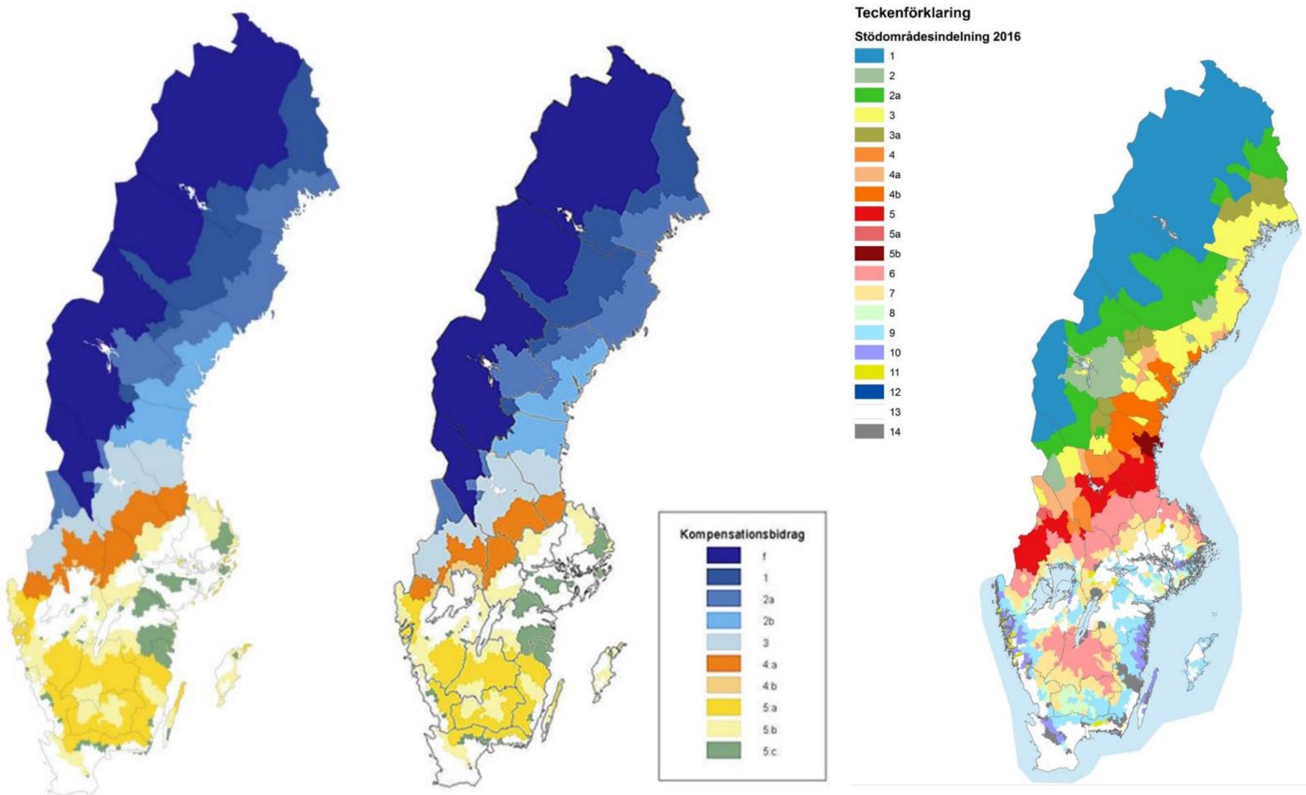
Appendix 1

Visualizations of the support areas of CAP 2008 (left), the transition period of 2015 (middle) & the CAP 2016-2019 (right).



(Strömberg et al 2022)

Appendix 2

Amounts received in LFA support per agricultural activity and support region within the different CAP programming periods.

Table 4. Support levels for pastures in CAP 2005

Stödområde	under 90 ha	över 90 ha
1 och F	2 550	1 275
2–4:a	1 950	975
4:b	950	475
5:a	1 350	675
5:b	760	380

Table 5. Support levels for cereal production in CAP 2005

Stödområde	under 90 ha	över 90 ha
1–3 och F	1 000	500
4:a	500	250

Table 6. Support levels for potato production in CAP 2005

Stödområde	under 90 ha	över 90 ha
1–3 och F	1 750	875

(Swedish Board of Agriculture 2007)

Table 7. Support levels for all types of production during the transition period of 2015

Stödområde 2015	Typ 1	Typ 2	Typ 3	Typ 4	Typ 5
1	3 900	2 300	1 000	1 100	500
2:a	3 600	2 000	900	1 100	300
2:b	3 600	1 800	900	1 100	300
3	3 500	1 500	600	1 100	300
4:a	1 700	600	250	600	0
4:b	600	300	0	300	0
5:a	1 500	700	250	600	0
5:b	1 100	400	0	600	0
5:c	1 000	400	0	500	0
5:d	1 200	400	0	600	0

Table 8. Support levels for all types of production in CAP 2014

Stödområde 2016	Typ 1	Typ 2	Typ 3	Typ 4	Typ 5
1	5 400	2 600	1 000	1 200	400
2	4 100	2 300	1 000	1 200	300
3	3 900	2 100	800	1 200	250
4	3 300	1 700	700	1 200	250
5	3 000	1 500	600	1 200	250
6	2 100	1 000	300	800	0
7	1 600	700	250	800	0
8	1 200	600	250	600	0
9	800	400	0	700	0
10	600	300	0	800	0
11	1 000	400	0	800	0
12	1 600	500	0	700	0

(Strömberg et al, 2022)

Appendix 3

Table 9. Comprehensive results from performed regressions

	Baseline model		Interaction model	
	Coeff.	Std. err	Coeff.	Std. err
Share_LFA_ha	-.6455475***	.0520574	-5.736049***	.990278
CDD_climate	-.0219887	.0335667	-.0123418	.0399542
Prcp_tot	.0028054	.0020522	.0040144*	.0021361
Share_LFA_ha*CDD_climate			.1761181***	.0349485
Share_LFA_ha*Prcp_tot			.002935***	.0009817
Paid_per_ha	9.43e-07	7.04e-07	.0002725***	.0000646
Year	-.0419523***	.0040467		
2011			.0693284	.0698276
2012			-.027622	.0692915
2013			-.0494404	.0687473
2014			-.008995	.0699842
2015			-.1529713***	.0615698
2016			-.0684028	.0594078
2017			-.098813*	.059848
2018			-.1418456**	.0624691
Year*Paid_per_ha				
2011			-.0001811**	.0000793
2012			-.0001021	.0000789
2013			-.0000981	.0000778
2014			-.0000315	.0000793
2015			-.000268***	.0000643
2016			-.0002705***	.0000646
2017			-.0002709***	.0000646
2018			-.0002737***	.0000645

Share_organic	-1.081381***	.2669514	-.9774958***	.2646939
Share_animal	.9487962***	.2289168	.9182342***	.2646939
Avg_ha	.0000359***	.0000113	.0000334***	.0000111
Employees	.0001441*	.0000876	.0001588*	.0000871
Population_density	.0008199**	.0003857	.0004932	.000388
Lag_CDD	.0546647	.0358504	.0038021	.0411608
Constant	-1.293107	1.162423	-1.293107	1.162423

*** p<0.01, ** p<0.05, * p<0.1

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