Land Cover Change induced by Civil Conflict and Forced Displacement

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Short abstract

Many countries that are heavily reliant on agriculture face civil wars and forced displacement that may negatively impact agricultural productivity and output. Using satellite imagery data combined with datasets on violent events and migration patterns, we resort to geographic regression discontinuity methods along the Syria-Turkey border to analyze cropland gains and losses during the Syrian Civil War between 2009 and 2017. Despite both sides of the border having similar climatic and geographical conditions and initial 2009 land cover, we find significant cropland abandonment only the Syrian side of the border, especially in Aleppo and Ar-Raqqah governorates. In parallel, the Turkish side gains similar amounts of cropland, especially in Sanliurfa and Mardin provinces. The arrival of unskilled Syrian refugees to work on the marginal cropland is the probable reason for this expansion.

Preliminary and incomplete.

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Long abstract

1. Introduction

Countries most exposed to conflict, violence, and forced displacement are clustered at the low end of the income distribution and heavily reliant on agriculture (McGuirk and Burke, 2020). This is a source of vulnerability as civil conflict and displacement tend to negatively impact agricultural productivity, leading to severe income loss, malnutrition, and even famine. In addition to the direct exposure to violence, food insecurity is in fact one of the main reasons why people are forced to move during episodes conflicts. This paper contributes to the literature that focuses on the relationship between conflict and agricultural outcomes by assessing the impact of the Syrian Civil War on cropland in both Syria and neighboring countries such as Turkey (which accepted millions of refugees). Our empirical analysis employs large datasets constructed from satellite imagery as well as georeferenced data on violence and population displacement. We use geographic regression discontinuity methods to identify the impact of the conflict on both sides of the Syria-Turkey border. As expected, we find that cropland declined during the conflict in Syria, especially near-violent prone areas. However, we also find an almost symmetric increase on the Turkish side of the border and argue that this result is due to an increase in the agricultural labor supply in Turkey, caused by the massive refugee inflow that made it economically possible to convert previously unused land into cropland.

Due to security problems, most research on the Syrian Civil War's effects on agricultural production has relied on secondary sources and imperfect measures. The Food and Agriculture Organization of the United Nations (FAO) estimates that fighting in Syria caused $16 billion of lost agricultural and livestock production (FAO, 2017). A World Bank (2017) study shows that vegetation cover decreased in Syria during the war. It is noticeable that Syria had been a net exporter of wheat in the prior 20 years (excluding drought years) but the production of this crop fell to 1.5 million tons, approximately 55 percent lower than the pre-conflict average of 3.4 million tons (2007–11) (FAO and WFP 2016). It is believed that the decline in agricultural output was likely due to the destruction of infrastructure as well as forced displacement: Of the pre-war population of 22 million people in Syria, more than 6 million have been internally displaced, and more than 5.6 million people have fled abroad. Most have ended up in neighboring countries, with Turkey hosting the largest number of registered Syrian refugees – currently 3.6 million.[2]

With its high frequency and moderate spatial resolution, Moderate-resolution Imaging Spectroradiometer (MODIS) satellite data are useful to accurately track changes in land cover over time around the world. The data shows that the Syria-Turkey border, drawn by the Ankara Treaty in 1921, along the 37th parallel, from the Mediterranean Sea in the west to the tripoint with Iraq in

[2] Lebanon is the country that hosts the largest number of refugees per capita, with 1.5 million Syrian refugees versus the pre-war population of around 5 million.

the east, is relatively arid.[3] The climate and pre-war land cover show minimum variation across the border, allowing us to use geographic regression discontinuity methods. Since the Syrian Civil War broke out in 2011,[4] there has been violent events on the Syrian side, leading to displacement of millions of refugees across the border into Turkey. Even though refugees are now spread out across the country and concentrating in big urban areas such as Istanbul, Syrian refugees continue to form a significant population share of Turkish provinces near the border. As a result, the total population in the southeast region of Turkey has increased by almost 20 percent during the Syrian civil war, with the working-age population increasing by about 23 percent.

The paper is organized as follows: Section 2 presents the land cover data and discusses the spatial organization of agriculture in Syria. Section 3 describes the magnitude of transitions into and out of cropland in buffer zones along the Syria-Turkey border. Section 4 presents the econometric approach. Section 5 presents descriptive statistics and estimation results. Section 6 concludes.

2. Data

Our main dataset is constructed from satellite imagery published as the MODIS Land Cover Type Product (MCD12Q1), which supplies global maps of land cover at annual time steps and 500-meter spatial resolution for the period 2001-2019. We use Category 12 from the land cover categories in the University of Maryland (UMD)'s Land Cover Type 2 Annual classification, which makes if possible to identify pixels where at least 60% of the area corresponds to cultivated land (see Table 1). [5]

3. Spatial organization of agriculture in Syria

Map 1 shows that most of Syria is too arid for agriculture, being either desert or covered by sparse native grasslands. Croplands are limited to an arc of land stretching along the western Mediterranean coast and eastward following the northern border with Turkey, and the basins of the Orontes and Euphrates rivers. Wheat is the most important cereal grain grown in this area, representing nearly 60 percent of total cultivated agricultural land. The country's non-irrigated rainfed croplands are most predominant in the three northern provinces of Aleppo, Ar Raqqah, and

[3] The annexation of Hatay province by Turkey in 1939 changed the border on the Mediterranean coast. See Map 1.

[4] The Arab Spring protests marked the beginning of a new era in the Syrian Arab Republic in 2011. The unrest in Syria, part of a wider wave of the 2011 Arab Spring protests, grew out of discontent with the Syrian government and escalated to an armed conflict after protests calling for President Bashar al-Assad's removal were violently suppressed. In 2011, the Islamic State of Iraq and the Levant (ISIL) joined the rebellion against President Bashar al-Assad in Syria, where it found a safe haven and easy access to weapons. Four major sides have fought for control in Syria – the Syrian government and its allies, the conglomeration of groups known broadly as the opposition, Kurdish-led forces, and ISIL. In winter 2014, ISIL's territory grew to include Aleppo and the northern Syrian border, as well as Hit in the Al Anbar Governorate, Iraq.

[5] https://developers.google.com/earth-engine/datasets/catalog/MODIS_006_MCD12Q1#bands

Al Hasakah. Agriculture in the eastern governorates of Lattakia, Tartous, and Idlib consists of citrus fruits, apples, olives, and vegetable cultivation. We see some wheat cultivation also in Rural Damascus and the southern governorates of Dar'a and Quneitra, in an area known as Hawran.

For the study, we focus on the border region along the 37th parallel, ignoring the border around the Hatay province. The area of interest consists mostly of grasslands, croplands, barren lands, and some urban areas. This region has very few forests, water bodies (except the artificial lakes of the massive dams), or wetlands. For simplicity, we aggregate the 16 categories in the UMD classification scheme into three: Water, Cropland, and Other. Map 2 shows land-use type changes between 2009 and 2017 in this region. The light green pixels are for areas that remain croplands (when comparing the two dates); the red pixels represent the areas that were croplands but are no longer croplands, and the dark green pixels are the new croplands (conversions of other land-cover categories into cropland). White areas are other types of land (mostly barren lands or grasslands) that were not croplands initiallu. We find that most of the abandoned cropland (red pixels) is located around the Euphrates river on the Syrian side of the border in Aleppo and Ar-Raqqah governorates. In contrast, most of the newly developed cropland (dark green) is in Turkey, within the Sanliurfa and Mardin provinces.

The climate varies from the humid Mediterranean coast, through a semi-arid steppe zone, to arid desert in the east. Syria consists mostly of an arid plateau, although the northwest regions along the Mediterranean coast and surrounding the Hatay province of Turkey are fairly green. Al-Jazira in the northeast and Hawran in the south are important agricultural areas (see Map 3). The country's waterways are of vital importance to its agricultural development. The longest and most important river is the Euphrates, which represents more than 80 percent of Syria's water resources. In 1973, Syria completed the construction of the Tabqa Dam on the Euphrates River upstream from the town of Raqqa. The dam created a reservoir named Lake Assad (Buhayrat al Assad), a body of water about 80 kilometers long and averaging eight kilometers in width. It is the largest body of water – natural or man-made – in the country.

Finally, note that Syria is divided into fourteen governorates, which are further divided into 65 districts, or *manatiq*, including the city of Damascus.[6]

[6] The same administrative structure - governorates and districts - is used in Iraq, Jordan, and Lebanon, as legacies of the administrative system of the Ottoman Empire that lasted until the end of World War I. In Turkey, there are 81 provinces and 973 districts. These districts are shown in Map 3 for Syria and its neighboring countries and colored according to the percentage of their total area that is covered by cropland.

4. Empirical approach

We assess the changes in land cover along the Syria-Turkey border.[7] More specifically, we analyze transitions into and out of cropland on each side of the border by creating eight buffers around the border, four on each side, with a width of 0.25 degrees which is approximately equal to 27 km (see Map 4). The reason for focusing on the border region is that the geography, climate, and pre-war land-cover patterns show remarkable continuity. Especially, the areas of the two middle buffers share the same weather and are similar in total area as well as cropland area before the civil war.

We regress a binary variable (loss or grain) for either the transition into cropland or out of cropland, using the following specification:

$$Y_i = \alpha + \sum_{b=1}^{7} \beta_b \,.\, 1_b(i) + \epsilon_i$$

where Y_i is the type of transition of cell i under investigation, $1_b(i)$ takes value 1 if cell i is in buffer b (omitting the Northern buffer in Turkey) and ϵ_i is the error term.

We estimate the regression using logit or probit. We also use ordinary least squares to compare the results (even though OLS ignores the discreteness of the dependent variable and does not constrain probabilities to be between zero and one). For the time being, in order to reduce computational complexity, we only pick one pixel in every 5 rows and columns in the gridded data. This reduces the number of sampled pixels to 16,860 that are split evenly among individual buffers (we have approximately 2,100 sampled pixels per buffer in our sample). We also create longitude (vertical) bins to select smaller regions of the border, as shown in Map 5.

We also plan to apply other geographic regression discontinuity analysese and difference-in-differences.

[7] For a discussion of the creation of the border in 1921 along the 37th parallel as a result of the Ankara agreement between the nationalist government in Ankara and France - the mandatory power in Greater Syria at the time, see: https://www.researchgate.net/publication/295125268_The_border_line_between_Syria_and_Turkey_1921-1929

5. Empirical results

5.1. Descriptive statistics:

Transitions out of cropland between 2009-2017

Cropland losses, as shown in Figure 1a, are represented by pixels that were categorized as croplands in 2009 but were not categorized as croplands in 2017. Figures 2a and 2b show the size and the proportion of 2009 croplands that were maintained and that were lost in 2017 inside each buffer zone. First, we see that cropland sizes and shares are very similar on either side of the border, especially among the four buffer zones closest to the border. There is a clear pattern across the border whereby cropland has decreased in Syria much more than in Turkey: Whereas between 20-35 percent of the 2009 cropland is lost by 2017 on the Syrian side, the losses are only around 4 percent on the Turkish side. Looking at total areas under cultivation, there has been more cropland abandonment in Syria in the buffers close to the border than further away.

Transitions into cropland between 2009-2017

Cropland gains, as shown in Figure 1b, are represented by pixels that were categorized as croplands in 2017 but were not previously categorized as croplands in 2009. Figures 3a and 3b show the size and proportion of 2017 croplands that were gained since 2009 inside each buffer zone. It is striking that there has been more cropland gains on the Turkish side of the border than on the Syrian side both in total area and percentage of previously cultivated area: Whereas the “new” cropland is only 2-4 percent of the 2017 cropland in Syria, there is over a ten percent expansion on the Turkish side. There is also a clear pattern on the Turkish side, where there was more cropland increases in buffere close to the border than further away. .

a. Estimation results

Table 3 presents the summary statistics for 2017 croplands.

The main regression results are presented in Table 4 for both the cropland losses (first three columns) and gains (last three columns). The OLS, logit, and probit regressions are in the respective columns. Each buffer zone (except the northernmost zone in Turkey) is accounted for by a dummy variable. In the table, negative distances to the border correspond to buffer zones in Syria and positive distances correspond to buffer zones in Turkey.

It is visually easier to display the results via coefficient plots. Figure 4 presents the OLS (left panel) and the logit coefficients (right panel) for the cropland loss model. Each coefficient for Syria is significantly larger than the corresponding coefficient in Turkey which are not statistically different than zero. The econometric analysis confirms the visual observation from the satellite data (Map 2). Once we cross into Syria from Turkey, there is a rapid loss of cropland even though initial conditions, climate, and rainfall are quite similar. The results indicate that being on the Syrian side leads to 18-32% higher probability of losing croplands compared to the Northern buffer in Turkey. We find no clear effect of distance from the border and this effect holds for the first three longitude bins, but not for the last.

The Syria-Turkey border area is rather long, and the region we are analyzing covers approximately 500 kilometers. While the climate does not change as we move North-to-South, there is a possible change in the West-to-East direction. In addition to changes in temperature and rainfall, there is variation in proximity to the Euphrates river, the main source for irrigation. In order to control for such potential variation, we divide the area into four vertical zones (Map 5) and perform the same analysis separately for each longitude bin. The results are presented in Table 5. We see that the same results are maintained with almost no significant loss on the Turkish side but statistically significant losses on the Syrian side, especially between the 38-40th longitudes. These are the areas around the Euphrates river that are exposed to military confrontations.

We perform the parallel analysis for cropland gains. The two buffer zones on the Turkish side of the border (that are closest to the border) have positive and significant coefficients (Figure 6). The magnitude of the coefficients implies that being on the Turkish side leads to 8-9% higher probability of gaining croplands compared to the Northernmost zone in Turkey. Again, we find no clear effect of distance from the border, but a clear effect for what side of the border are pixels in. We replicate the analysis for separate longitude bins. We find the positive effect on the Turkish side to again hold for the two middle bins, but not for the first and last ones (Figure 7).

The three models (OLS, logit, and probit) led to almost identical predicted probabilities for the buffers, as shown in the two panels of Figure 8. Figure 8a shows how the predicted probability of losses is significantly higher on the Syrian side, while Figure 8b shows how the predicted probability of gains is significant on the first two Turkish buffers closest to the border.

6. Conclusion

We have shown that crossing the border into Syria leads to greater losses, and being on the Turkish side close to the border leads to higher gains. The main difference between the two regions is the presence of violence, and civil conflict on the Syrian side – climate, rainfall, and initial land-cover conditions were almost identical in 2009. While cropland loss is to be expected, the more unexpected result is the consistent cropland gain on the Turkish side. We will further investigate whether this can be explained by the increasing available (relatively unskilled) agricultural labor force in Turkey due to the arrival of Syrian refugees.

Our proposed plan to roll out this research includes:

- Roll out of other spatial regression discontinuity analyses and differences-in-differences
- Inclusion of control variables (elevation, precipitation, temperature)
- Introduction of variables that could capture the mechanisms behind these changes in land cover, including (i) proximity to violent events from Uppsala Conflict Data Program (UCDP) data and (ii) Population movement and data on refugees and IDPs to explain cropland gains in Turkey
- Estimation of temporary versus permanent effects
- Estimation of extensive versus intensive margin cropland analysis
- Estimation of outcomes beside cropland changes (e.g., nighttime lights)
- Estimation of overall economic impacts
- Running regression using all the pixels in the sample
- Carrying out a similar analysis for Iraq between ISIS-controlled areas and non-ISIS controlled areas, accounting for endogenous borders

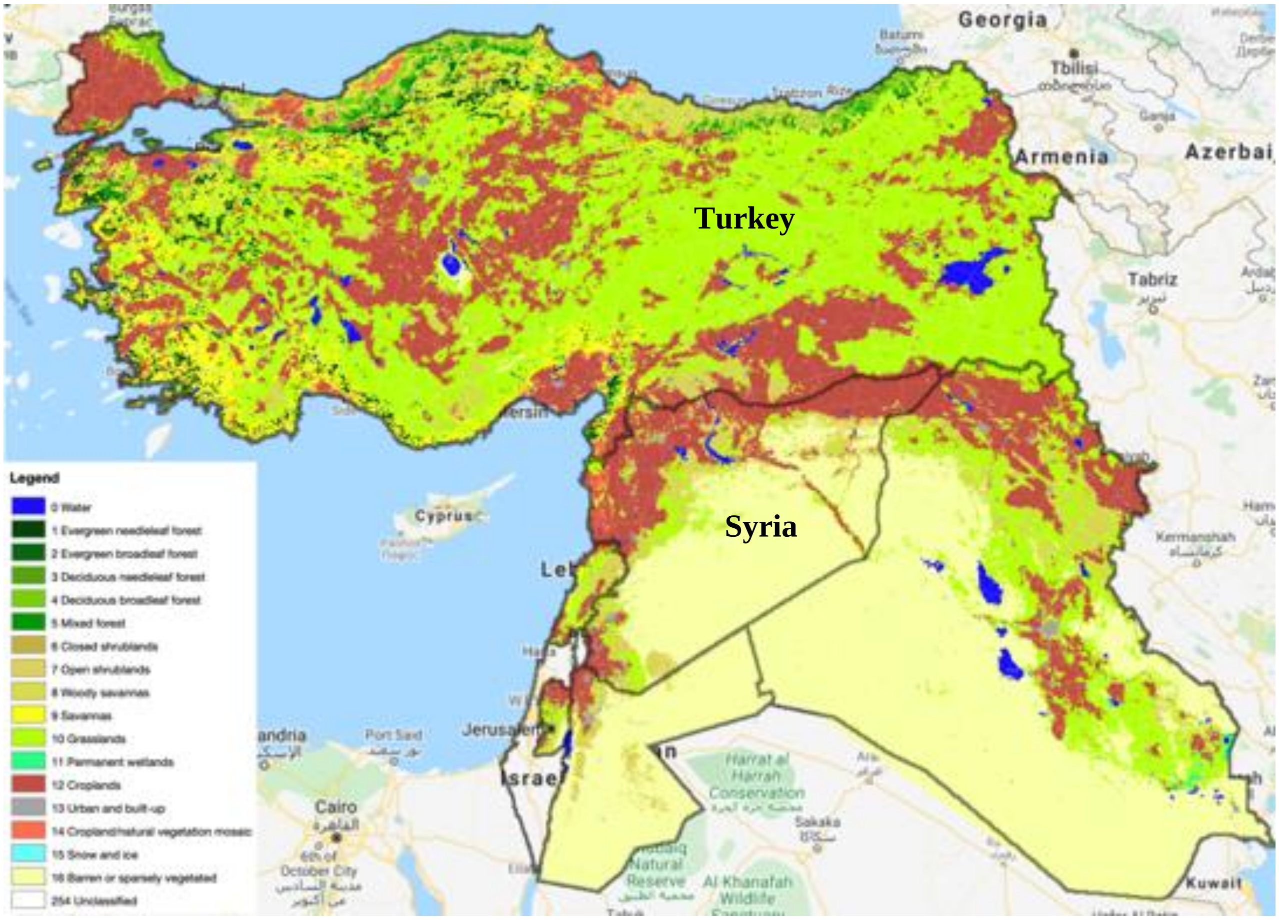
7. References

McGuirk, E., & Burke, M. (2020). The Economic Origins of Conflict in Africa. *Journal of Political Economy*, Volume 128, Number 10.

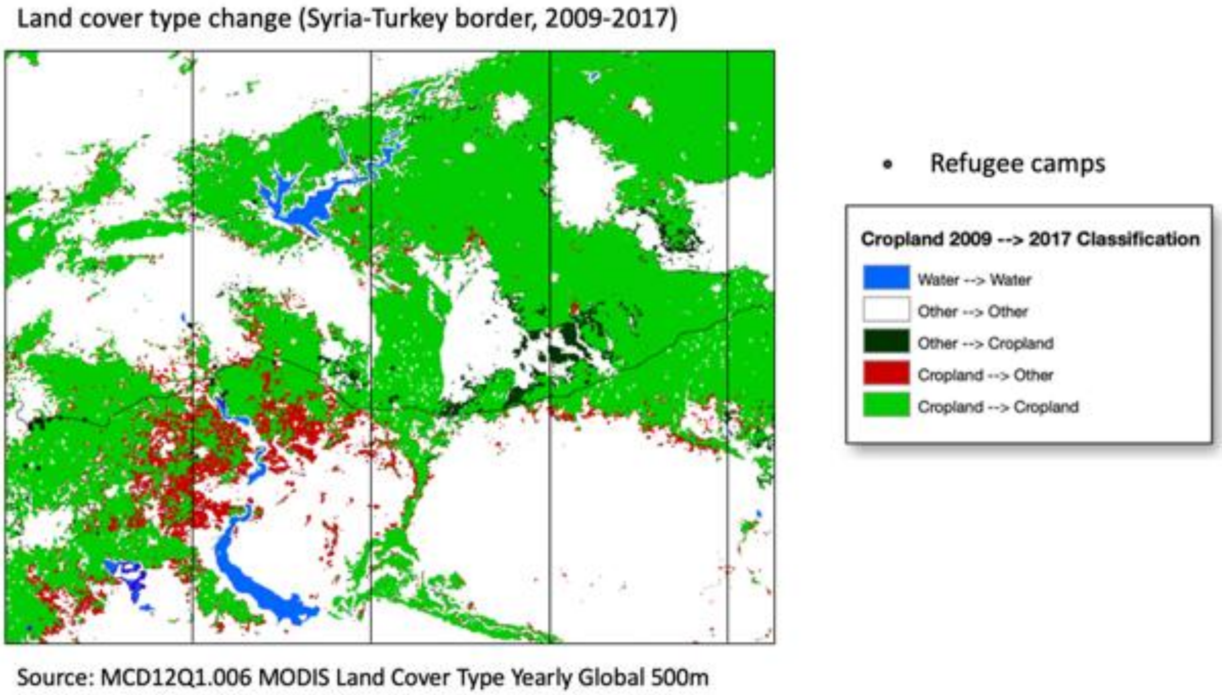
FAO (2017). Counting the Cost: Agriculture in Syria after six years of crisis.

World Bank (2017). The Toll of War: The Economic and Social Consequences of the Conflict in Syria. World Bank, Washington, DC.

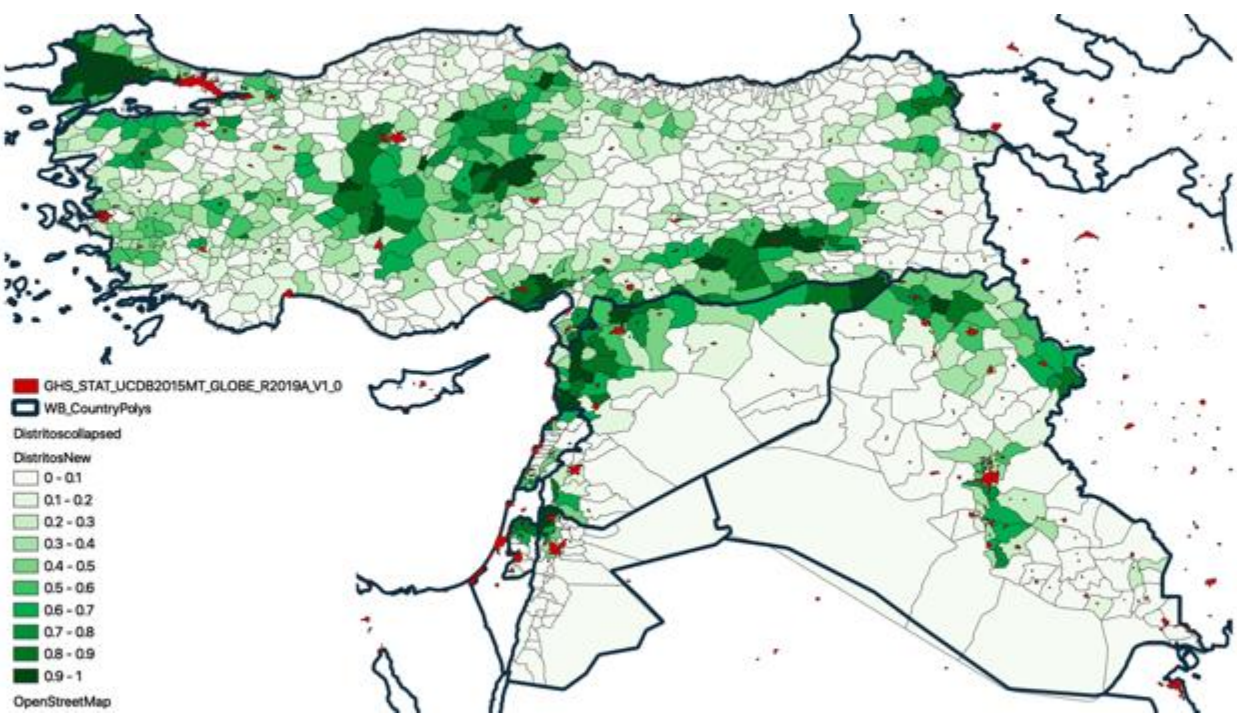
Map 1: MCD12Q1.006 MODIS Land Cover Type 2 for 2019



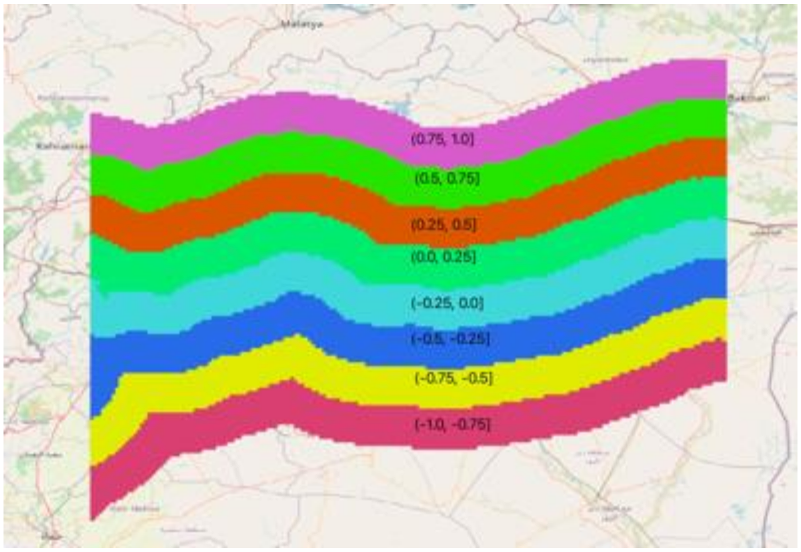
Map 2: Land Cover Type Change (2009-2017)



Map 3: Percentage of district area covered by cropland (average value for 2001-2019)



Map 4: Buffer areas (as distance to the Syrian-Turkey border)



Map 5: Longitude bins

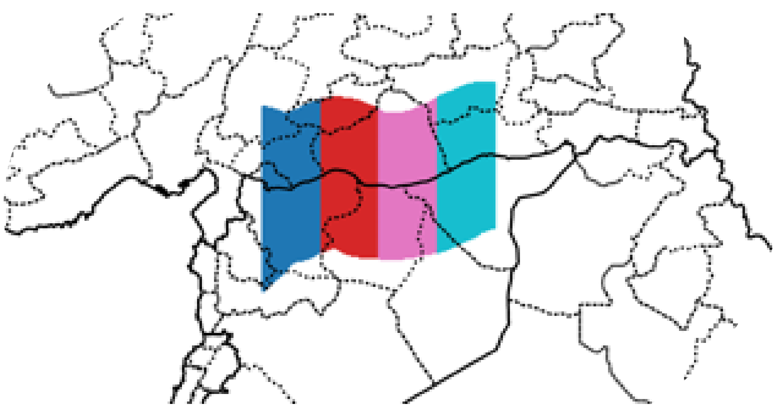


Table 1: Land Cover Type 2: Annual University of Maryland (UMD) classification

Value	Description
0	Water Bodies: at least 60% of area is covered by permanent water bodies.
1	Evergreen Needleleaf Forests: dominated by evergreen conifer trees (canopy >2m). Tree cover >60%.
2	Evergreen Broadleaf Forests: dominated by evergreen broadleaf and palmate trees (canopy >2m). Tree cover >60%.
3	Deciduous Needleleaf Forests: dominated by deciduous needleleaf (larch) trees (canopy >2m). Tree cover >60%.
4	Deciduous Broadleaf Forests: dominated by deciduous broadleaf trees (canopy >2m). Tree cover >60%.
5	Mixed Forests: dominated by neither deciduous nor evergreen (40-60% of each) tree type (canopy >2m). Tree cover >60%.
6	Closed Shrublands: dominated by woody perennials (1-2m height) >60% cover.
7	Open Shrublands: dominated by woody perennials (1-2m height) 10-60% cover.
8	Woody Savannas: tree cover 30-60% (canopy >2m).
9	Savannas: tree cover 10-30% (canopy >2m).
10	Grasslands: dominated by herbaceous annuals (<2m).
11	Permanent Wetlands: permanently inundated lands with 30-60% water cover and >10% vegetated cover.
12	Croplands: at least 60% of area is cultivated cropland.
13	Urban and Built-up Lands: at least 30% impervious surface area including building materials, asphalt and vehicles.
14	Cropland/Natural Vegetation Mosaics: mosaics of small-scale cultivation 40-60% with natural tree, shrub, or herbaceous vegetation.
15	Non-Vegetated Lands: at least 60% of area is non-vegetated barren (sand, rock, soil) or permanent snow and ice with less than 10% vegetation.

Table 2. Summary statistics for 2009 croplands

Summary statistics for 2009 croplands					
Variable	Obs	Mean	Std. Dev.	Min	Max
Cropland Loss	7,524	0.1265	0.33	0	1
Buffer (-1.0, -0.75]	7,524	0.0336	0.18	0	1
Buffer (-0.75, -0.5]	7,524	0.0731	0.26	0	1
Buffer (-0.5, -0.25]	7,524	0.1075	0.31	0	1
Buffer (-0.25, 0.0]	7,524	0.1958	0.40	0	1
Buffer (0.0, 0.25]	7,524	0.1655	0.37	0	1
Buffer (0.25, 0.5]	7,524	0.0812	0.27	0	1
Buffer (0.5, 0.75]	7,524	0.1673	0.37	0	1
Buffer (0.75, 1.0]	7,524	0.1760	0.38	0	1

Table 3. Summary statistics for 2017 croplands

Summary statistics for 2017 croplands					
Variable	Obs	Mean	Std. Dev.	Min	Max
Cropland Gain	6,930	0.0517	0.22	0	1
Buffer (-1.0, -0.75]	6,930	0.0267	0.16	0	1
Buffer (-0.75, -0.5]	6,930	0.0597	0.24	0	1
Buffer (-0.5, -0.25]	6,930	0.0801	0.27	0	1
Buffer (-0.25, 0.0]	6,930	0.1713	0.38	0	1
Buffer (0.0, 0.25]	6,930	0.1903	0.39	0	1
Buffer (0.25, 0.5]	6,930	0.0974	0.30	0	1
Buffer (0.5, 0.75]	6,930	0.1812	0.39	0	1
Buffer (0.75, 1.0]	6,930	0.1932	0.39	0	1

Table 4. Estimation results from the regressions.

m1=losses, m2=gains

Variable	m1_ols	m1_logit	m1_probit	m2_ols	m2_logit	m2_probit
Buffer (-1.0, -0.75]	0.260***	3.120***	1.537***	-0.0168	-0.956	-0.38
	(0.021)	(0.257)	(0.12)	(0.017)	(0.73)	(0.276)
Buffer (-0.75, -0.5]	0.258***	3.109***	1.530***	0.0086	0.28	0.121
	(0.016)	(0.235)	(0.102)	(0.012)	(0.311)	(0.135)
Buffer (-0.5, -0.25]	0.325***	3.422***	1.720***	0.012	0.373	0.162
	(0.014)	(0.227)	(0.096)	(0.011)	(0.274)	(0.12)
Buffer (-0.25, 0.0]	0.184***	2.700***	1.291***	-0.0192*	-1.207***	-0.473***
	(0.012)	(0.225)	(0.093)	(0.009)	(0.359)	(0.135)
Buffer (0.0, 0.25]	0.0388**	1.245***	0.535***	0.0808***	1.454***	0.682***
	(0.012)	(0.248)	(0.103)	(0.008)	(0.189)	(0.084)
Buffer (0.25, 0.5]	0.00793	0.398	0.162	0.0894***	1.540***	0.727***
	(0.015)	(0.338)	(0.138)	(0.01)	(0.205)	(0.095)
Buffer (0.5, 0.75]	0.0255*	0.956***	0.402***	0.0122	0.378	0.164
	(0.012)	(0.257)	(0.106)	(0.009)	(0.221)	(0.095)
_cons	0.0166	-4.081***	-2.129***	0.0276***	-3.561***	-1.917***
	(0.009)	(0.215)	(0.085)	(0.006)	(0.167)	(0.07)
Statistics						
N	7,524	7,524	7,524	6,930	6,930	6,930
ll	-1903.9	-2399.51	-2399.51	729.53	-1301.6	-1301.6

Figure 1a

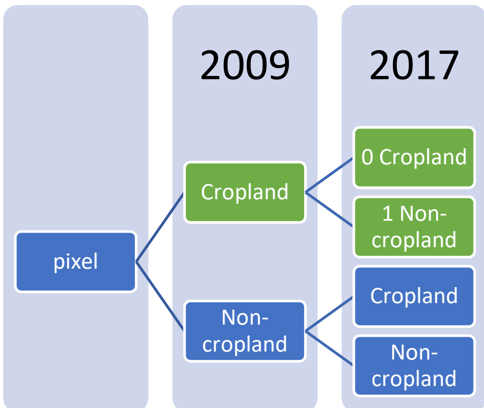


Figure 1b

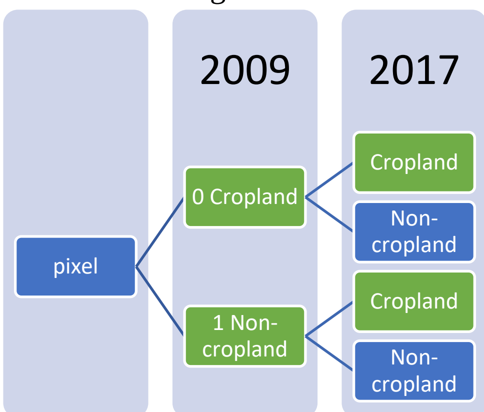


Figure 2a

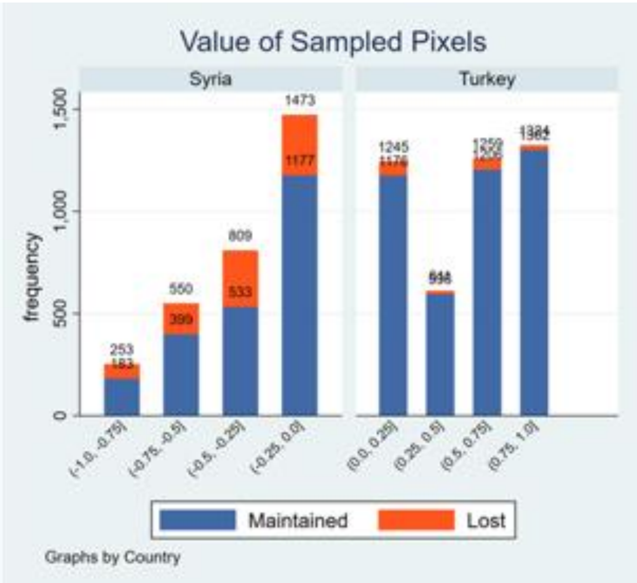


Figure 2b

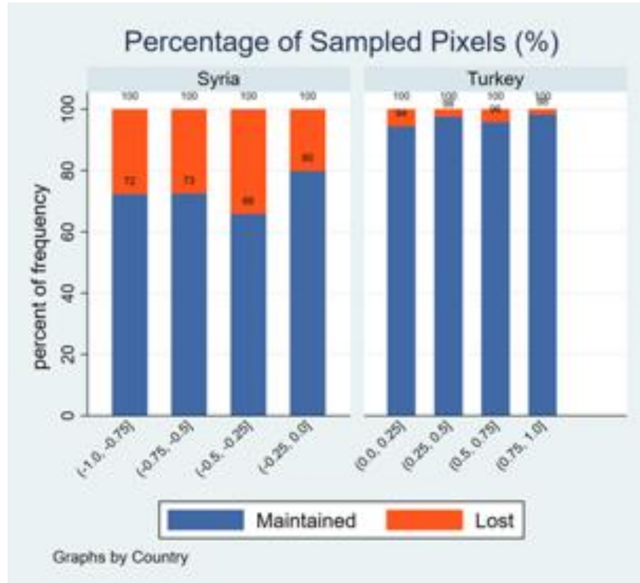


Figure 3a

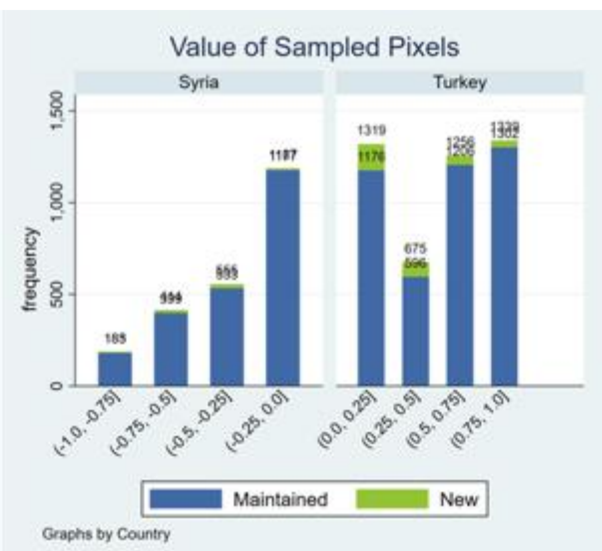


Figure 3b

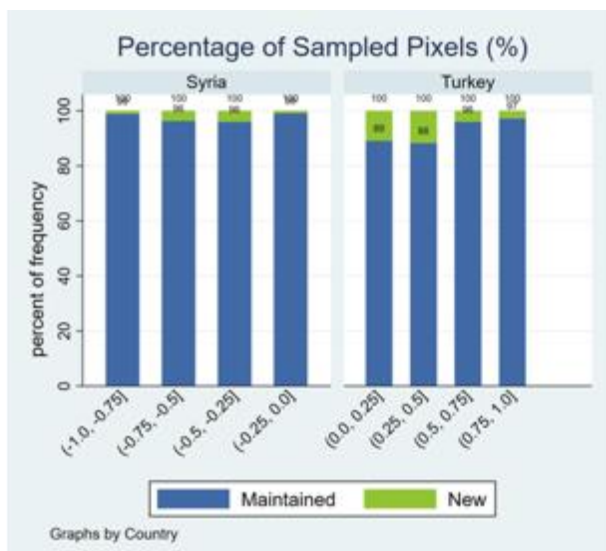


Figure 4. Coefficients of buffer areas for cropland losses.

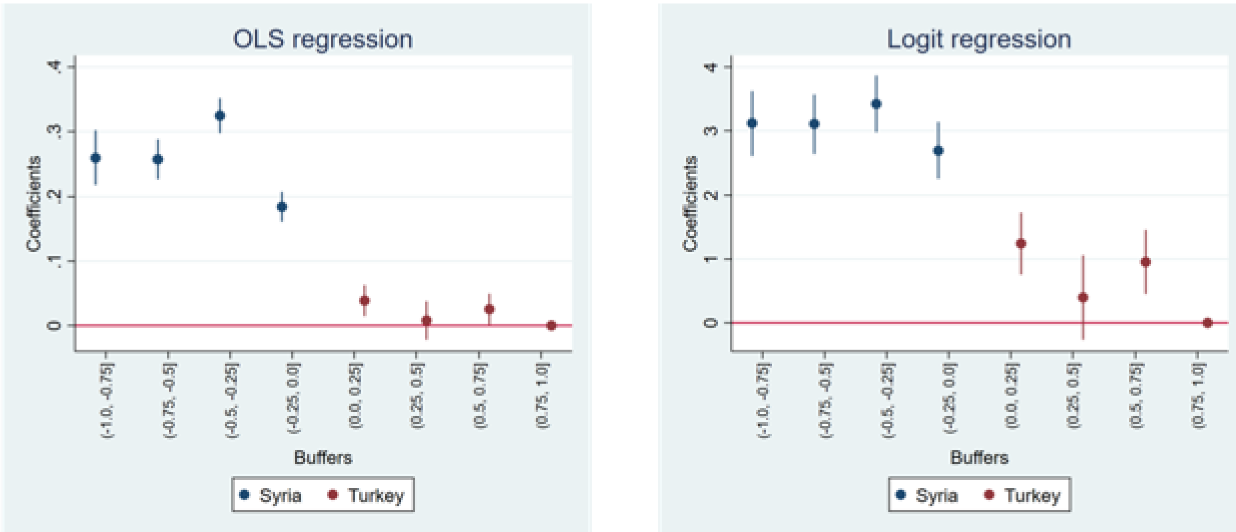


Figure 5. Coefficients of buffer areas for cropland losses for different longitudes

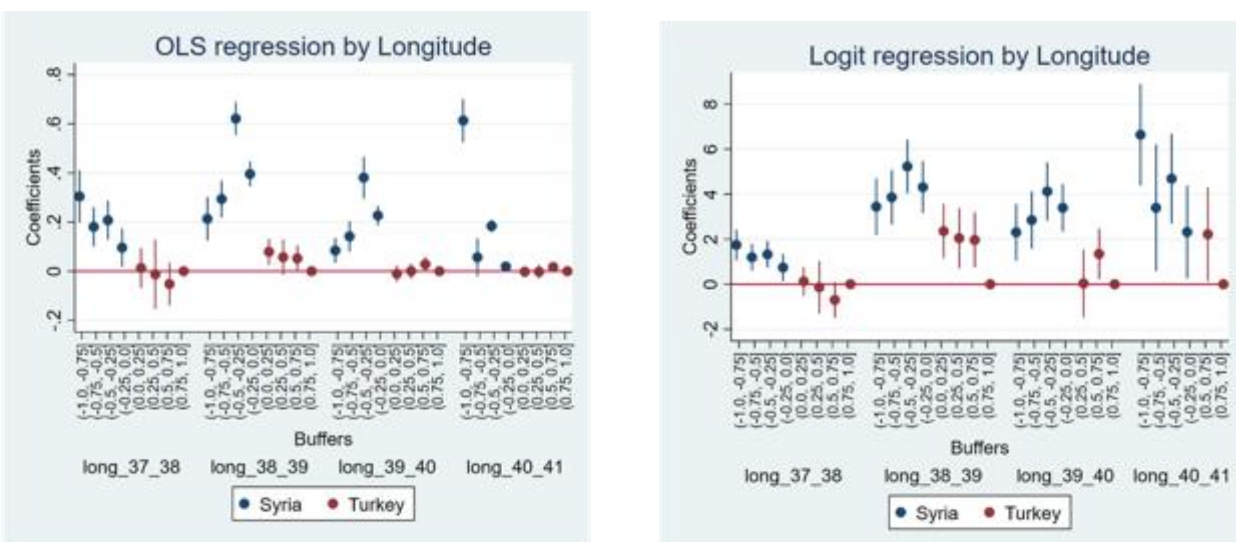


Figure 6. Coefficients of buffer areas for cropland gains.

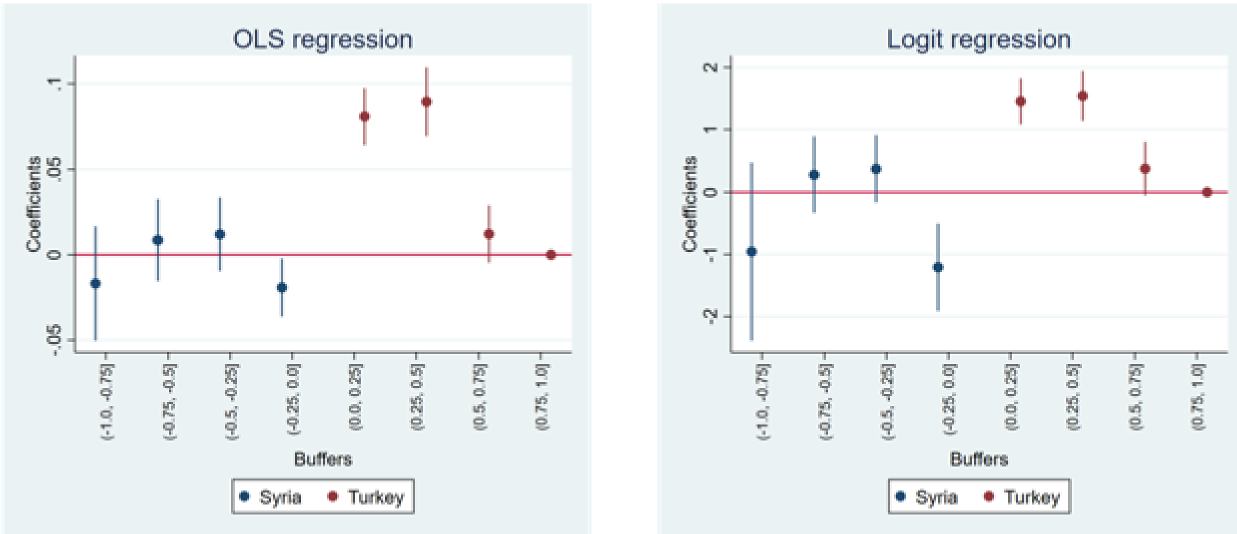


Figure 7. Coefficients of buffer areas for cropland gains for different longitudes

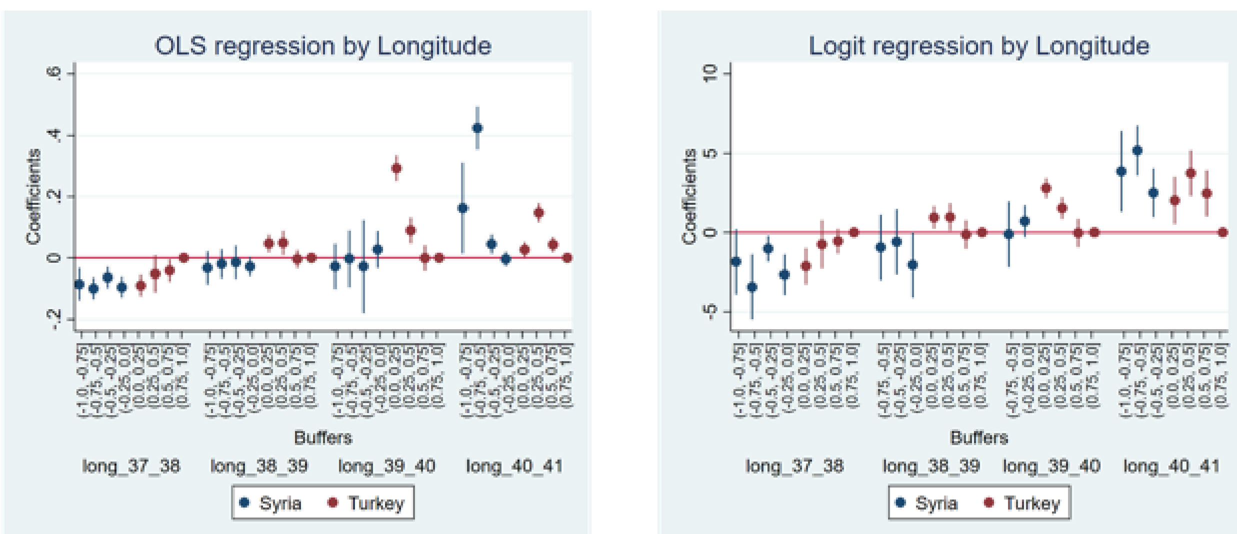


Figure 8. Predicted Probabilities of Cropland Loss and Gain across different models

Figure 8a.

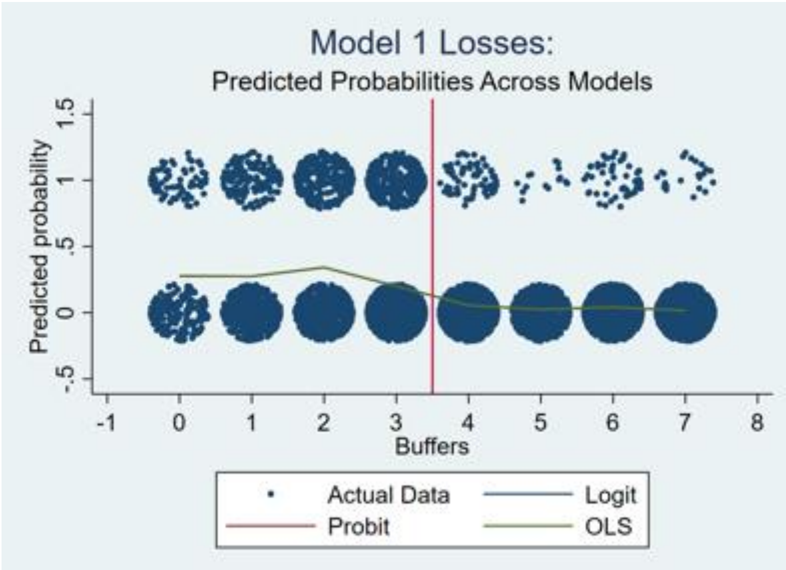


Figure 8b.