Can land intensification and abandonment in Latvia be linked to key socio-economic events?

Dissertation plan

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Introduction

Land-use, as defined by human use of land (Meyer and Turner, 1992), is undoubtedly an important part of all civilisations due to the provision of natural resources (Foley *et al.*, 2005; Turner *et al.*, 2007). Human-driven land-use change through urbanisation, deforestation and agricultural expansion has placed pressure on the functioning of several ecological processes such as carbon cycling, as well as ecosystems themselves (Foley *et al.*, 2005; Turner *et al.*, 2007). Since 1850, roughly 35% of anthropogenic carbon dioxide (CO_2) emissions have resulted directly from human land-use, altering the global carbon cycle (Foley *et al.*, 2005; Turner *et al.*, 2007). Natural habitat destruction through land conversion is also one of the largest threats to terrestrial biodiversity, causing extinctions and range reductions (Foley *et al.*, 2005; Jetz *et al.*, 2007). However, habitat loss such as forest loss and habitat fragmentation have both proven to also have possible positive effects, including increased population size (Fahrig, 2017; Daskalova *et al.*, 2018).

Habitat fragmentation and destruction has primarily occurred through changes in agricultural practices (Foley and Ramankutty, 1999), with croplands and pastures covering over 40% of Earth's land surface (Foley *et al.*, 2005). Expansion is made possible through technologies produced during the 'Green Revolution,' an agricultural revolution during the mid-twentieth century that increased global food production (Foley *et al.*, 2005). However, modern practices may be compromising long-term ecosystem services (e.g. air quality and nutrient cycling) for short-term yield increases (Foley *et al.*, 2005). Scientists are therefore concerned with mitigating against the negative effects of land-use change (Foley and Ramankutty, 1999).

Countries appear to follow similar trajectories of changing land-use regimes, moving from subsistence to intensive agriculture at differing rates, depending on their socio-economic contexts (Lambin *et al.*, 2001; Foley *et al.*, 2005). However, a study in Ethiopia indicates that not all countries follow this pattern, as Ethiopia experienced deintensification within a changing socio-economic environment (Reid *et al.*, 2000). Rapid socio-economic changes are said to accelerate land-use change, with land abandonment rates high with regulation change and the establishment of new institutions (Prishchepov *et al.*, 2013). Agricultural abandonment, defined as the cessation of agricultural activities, is linked with a shift towards more intensive agriculture, with smaller farms more likely to be abandoned (Prishchepov *et al.*, 2013). With rapid shifts in the socio-economic environment, Latvia proves as an ample study site to examine the common land-use trajectory.

Satellite imagery has often been used in studies aiming to quantify influence of socio-economic events on land-use change (Reid *et al.*, 2000; Prishchepov *et al.*, 2012). However, satellite imagery cannot show land-use specifically, instead depicting land cover, which indicates solely the type of land (e.g. water, forest etc.). Algorithms must therefore be developed to effectively categorise land-use types. Such studies (Reid *et al.*, 2000; Prishchepov *et al.*, 2012) only consider the impacts of one socio-economic event, rather than several over time. Analysing if the signature of multiple socio-economic shifts can be detected through land cover change could shed light into the importance of socio-economic events as drivers of agricultural transitions on a country-scale.

In this study, I will focus on Latvia due to its quick-changing socio-economic status, making it an appropriate case study to examine if land-use change can be linked to socio-economic events. The two events I will examine are (1) the Soviet Union collapse in 1991 and (2) the addition of Latvia to the European Union (EU) in 2004. After the Soviet Union, there was an increase in abandoned land, tree cutting and percent coverage of protected areas (Prishchepov *et al.*, 2013). After joining the EU, the share of large farms (intensive) increased, while the share in small farms (extensive) decreased (Csaki and Jambor, 2009). Ultimately, this type of analysis could be replicated for other countries to outline the impacts of shifting economic status on land-use and thus, have implications for wider aspects such as ecosystem services, the economy and human movement and urbanisation across Europe and globally.

Objectives

This study aims to investigate the importance of socio-economic events as drivers of land-use change in Latvia through the use of satellite imagery. Although the importance of socio-economic events on land-use change is acknowledged (Prishchepov *et al.*, 2012), it remains unclear whether a recognisable, country-scale signature is left on the landscape. Using satellite imagery, pixel-scale analysis can be completed to determine specific land cover transitions over time, potentially unveiling a link between socio-economic events and land-use change. My findings will give insight into the homogeneity, or lack thereof, of the effects of socio-economic events on a country-scale. Results will reveal the transition patterns between each land-use type, including extensive, intensive and abandoned land. Ultimately, my study will uncover the importance of socio-economic events as a driver of land-use change in Latvia, permitting predictions about land-use under changing socio-economic conditions to be made.

Research questions and hypotheses

The specific questions I will address are as follows:

<u>Question 1</u>: Is there a clear link between key socio-economic events and land-use change in Latvia?

H_1: There is an observable, uniform link between the Soviet Union collapse and land-use change in Latvia at a country-scale. There is no homogeneous link between land-use change and the addition of Latvia to the EU at a country-scale.

H_0: There is no relationship between socio-economic events and land-use change at a country-scale.

<u>Question 2</u>: Is the strength and direction of land-use change different among extensive, intensive and abandoned land-use types?

H_1: The strength and direction of land-use change is different for extensive, intensive and abandoned land types at pixel-scale, with the transition to abandoned land strongest after the Soviet Union collapse and the transition to intensive land strongest after EU accession.

H_0: The strength and direction of land-use change is uniform across land types at pixel-scale.

<u>Question 3</u>: Is there a time lag between socio-economic events and the occurrence of land-use change? Does this differ between land-use type?

H_1: Land-use change is observed directly following the Soviet Union collapse at country-scale. There is a time lag on when land-use change is observed at country-scale following Latvia joining the EU. Time lags are different across land-use types at pixel-scale.

H_0: There is no relationship between socio-economic events and land-use change.

Predictions

I predict that there is an observable link between the Soviet Union collapse and land-use change in Latvia, due to the sharp decline of the agricultural sector, resulting in the highest level of agricultural abandonment out of all post-Soviet countries (Prishchepov *et al.*, 2012). I predict that such a link will not be observable following the addition of Latvia to the EU, as agricultural area merely increased by 3% within two years of EU accession (Csaki and Jambor, 2009). If a marked link is observed at country-scale through a homogeneous land cover transition, the socio-economic event can be seen as the main driver of land-use change. If no link is observed, heterogeneous land-use change will be seen, with different areas experiencing change with differing strengths and directions. Heterogeneous effects would signify that the socio-economic event was not the main driver of land-use change. I predict the strength and direction of land-use change will be different between land-use types, with a strong transition to abandoned land after the Soviet Union collapse and intensive land after EU accession. I predict land-use change to be observed directly (within 3 years) following the

Soviet Union collapse due to the rapid transition from a state-controlled to a market driven economy (Prishchepov *et al.*, 2013), resulting in large-scale abandonment and changes in forestry practices (Sieber *et al.*, 2015). I predict land-use change not to be observed directly following EU accession, as the largest transition to intensive agriculture will have occurred after the collapse of the Soviet Union. I therefore predict that a slow progression towards more intensive agriculture will continue following EU accession. A transition to intensive agriculture is supported by known increases in agricultural output, with increases of 10% within four years of EU accession (Csaki and Jambor, 2009). I predict time lags will be different for each land-use type at pixel-scale, depending on the region-specific factors, due to differences in urban versus rural transitions as population dispersal rates shift (Fonji and Taff, 2014).

Proposed methods of working

To examine the relationship between land-use change and socio-economic events, I will use the Google Earth Engine (GEE; Gorelick *et al.*, 2017), which is an online global spatial analysis platform. Specifically, I will be creating a classification of land-use types in Latvia to obtain land-use data, rather than solely land cover information. Using satellite data (e.g. Landsat), I will classify the area of interest (Latvia) into three categories: extensive, intensive and abandoned land. To classify the data, I will create a new layer for each land-use type with known points of each land-use type from historical records (training points). Layers then can be merged, converting each class into a value, or band. Next, I will extract the reflectance of each band and train the classifier on the known points of each land-use type (training data) and its reflectance. I will use a random forest supervised learning algorithm, which is an assemblage of decision trees. I will use this new, trained classifier to classify the rest of the imagery for each study year to uncover land-use types. I will be using data between 1978 to present time to allow for roughly the same time frame before and after each event studied. The accuracy of the classification will be assessed using a confusion matrix, as well as by using validation data. Validation data (LUCAS dataset; Orgiazzi *et al.*, 2018) will be used as new testing data to assess the error. Following this analysis, I will obtain the land-use type for each pixel in Latvia, allowing me to compute, gain, loss and change of each land-use type at pixel-scale. Maps will also be produced to visually assess change.

Proposed methods of sampling and data analysis

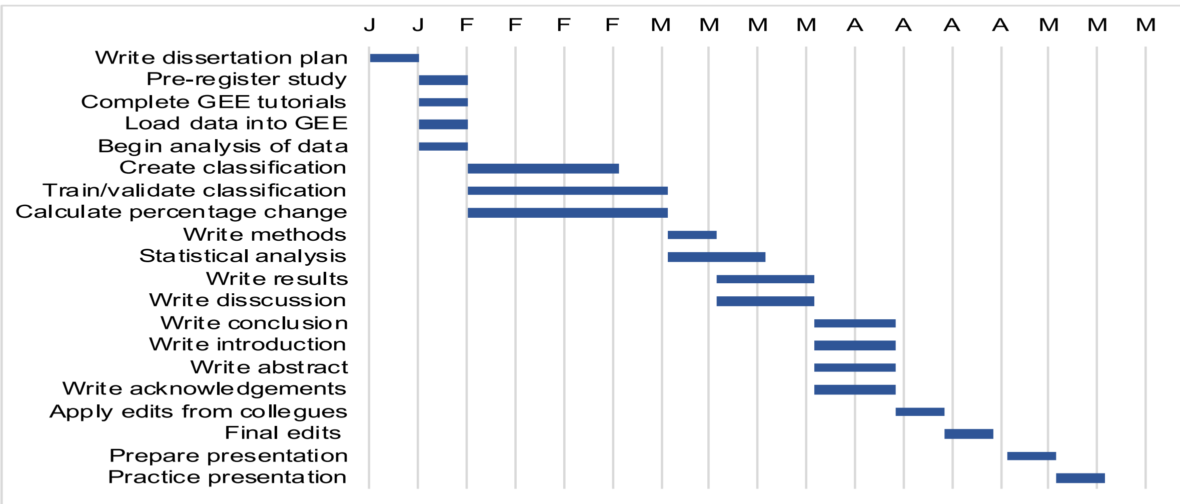
To assess the transition of each pixel, I will be using Bayesian models in the statistical programming language R (R Core Team, 2013). Bayesian models allow for priors to be set based on knowledge already obtained, improving accuracy. Spatio-temporal autocorrelation can also be accounted for, acknowledging pixels that are closer together in space and time are more likely to be similar. I will assess the strength and direction of each relationship by examining the effect sizes. The posterior distribution will be analysed to assess significance. My anticipated results are stated in my predictions section. The outputs of my dissertation can be used not only to answer my questions, but also to categorise land-use types for other purposes, such as natural resource management and agricultural planning. My algorithm can be used to create similar classifications for other countries around the world, aiding in uncovering the key drivers of land-use change globally.

Risk mitigation

As my dissertation largely rests on creation of a classification algorithm, if it becomes too time-consuming, I will resort to using pre-classified data. This would allow me to continue with my analysis. However, pre-classified data for Latvia does not include agricultural abandonment, which is a key land cover type within Latvia's socio-economic history (Yin *et al.*, 2018). I therefore will try to create my own classification. To effectively classify my data, I will use online tutorials, the help of my supervisors and the GEE user group. To ensure that I do not get too stuck, I will focus on one question at a time, so that I can have some complete results before moving on to the next task. This will prevent answering many questions to a sub-par standard rather than one question to a high standard. If I become stuck on my first question after exhausting all resources made available, I will look at pre-classified land cover change with uniform pixel size. My dissertation will be completed on a computer. To prevent data loss due to file corruption or computer damage, I will be using GitHub, a version control software, to store all my files. I will therefore be able to access them on any device. GEE code is backed up within the software, but I will also be putting my scripts on GitHub to prevent file loss.

Proposed timetable

I plan to have a full draft complete by 10th April 2019, so I have ample time to refine and edit.



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