Land-Use Adaptation to Climate Change in Europe

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Abstract

This study addresses the pressing issue of land use adaptation to climate change. With unprecedented shifts in temperature, precipitation patterns, and extreme weather events, understanding how human activities, particularly land use change, will respond and adapt is essential. We assess how land use changes in Europe adapt to climate change both in the short term and long term using panel data models and long-differences analyses respectively. The study integrates data from Corine Land Cover changes observed between 1990 and 2018 and ERA5-land sub-daily climate reanalysis data spanning from 1660 to 2019. Using these detailed data at very fine spatial resolution (10km*10km) and over a long time period (1990-2018), we examine the impacts of climate on changes on land allocation between agriculture, forest, urban and other uses. Simulations of climate change scenarios will provide how the land sector will react in face of new climate conditions.

Keywords: econometric land use model, land use adaptation to climate change, short and long term adaptation

Long abstract

Motivations and objective Land use adaptation to climate change is an important issue in responding to global challenges. In the face of unprecedented changes in temperature, precipitation patterns and extreme weather events, it is essential to understand how human activities, in particular land use practices, respond and adapt. Land use plays a central role in human-environment interactions, influencing ecosystems, biodiversity and overall landscape dynamics. The IPCC report on land (Shukla et al., 2019) highlighted the central role of the land sector in mitigating and adapting to climate change. Mendelsohn and Dinar (2009) concluded that more research is needed to explore whether we are adapting or maladapting to climate change. In the case of the land sector, this is a crucial question as it has been shown that adaptation in the land use sector could increase greenhouse gas emissions in the land sector through deforestation (Lungarska and Chakir, 2018). This highlights the importance of understanding the mechanisms of adaptation in this sector in order to inform public policies that would make it possible to reconcile adaptation and mitigation in the face of climate change, while preserving the ecosystem services provided by certain land uses (agricultural production, regulation, erosion control, biodiversity conservation).

In particular, Europe is characterised by diverging trends towards land abandonment in marginal areas and intensification of agricultural and urban activities in suitable land (Kuemmerle et al., 2016). This could have several implications for public policies since such changes are expected to affect climate change mitigation and adaptation through the full range of ecosystem services that are provided. Our objective is to assess how historical climate change has affected land use change in order to inform on the effect of future land use change in the land sector.

Literature There exist an extensive literature on the impacts of climate on agriculture (Mendelsohn et al., 1994; Deschênes and Greenstone, 2007; Schlenker and Roberts, 2009; Bareille and Chakir, 2023a). The existing literature highlights the detrimental effects of climate change on agricultural yields, prompting the exploration of adaptive mechanisms to mitigate these effects (Kawasaki, 2019; Aragón et al., 2021; Chen and Gong, 2021; Jagnani et al., 2021; Ramsey et al., 2021; Cui and Xie, 2022; Amare and Balana, 2023; Bareille and Chakir, 2023b). In particular, research by Sloat et al. (2020) provides evidence of adaptation to rising temperatures through crop migration. However, most studies using empirical strategies such as Ricardian models or fixed effects panel models focus on specific aspects of adaptation. For example, (Cui, 2020b,a) examines the effects of weather conditions on corn and soybean planted area, harvested ratio, and yield.

Results show variable responses to temperature and precipitation, highlighting the importance of irrigation as an adaptive measure, especially in hotter and drier conditions.

Several studies have focused on agricultural adaptation to climate change in Europe using different methods. Some have studied Europe as a whole (Iglesias et al., 2012; Van Passel et al., 2017; Vanschoenwinkel et al., 2016; Vaitkeviciute et al., 2019), although single-country applications are more common, for example Maddison (2000), Lang (2007), Lippert et al. (2009), Chatzopoulos and Lippert (2015a), Chatzopoulos and Lippert (2015b), among others. Iglesias et al. (2012) investigate the effects of climate change in the European case using an agro-economic approach based on a statistical crop yield model, while Van Passel et al. (2017) and Vanschoenwinkel et al. (2016) favor a Ricardian approach using cross-sectional data. More recently, (Bareille and Chakir, 2023a) proposes an original method for estimating Ricardian models with plot fixed effects to control for confounding omitted variables. The results from the repeated Ricardian approach show larger benefits from climate change than those found by standard Ricardian analyses. In particular, their repeated Ricardian estimates suggest that warmer summers benefit French agriculture, in complete contrast to the remainder of the literature.

Despite some few studies on the impact of climate change on land use in rainfed counties (McWilliams, 2016) and the combination of climate econometrics and discrete choice land use models (Mihiar and Lewis, 2023), a comprehensive investigation that considers adaptation is still limited. Mihiar and Lewis (2023) integrate climate and land use economics to project future climate change impacts on land allocation in forestry, agriculture, and development. In addition, Lungarska and Chakir (2018) examine the impact of climate change on land use change in France, explicitly incorporating spatial interactions.

Contribution Previous studies has either focused over large geographic areas using aggregate data or focused on small regions with detailed data, limiting the interest of findings. Moreover, the broader analysis across agriculture, forestry, and urban areas remains underexplored. This paper aims to fill this gap by employing the most up to date methods in climate econometrics (Long differences and two-way fixed effects) to study how land use adapt to climate change in Europe at a very fine spatial resolution. By examining how historical land use changes were affected by climate variations, the study will project the effects of future climate change on land allocation, considering different scenarios and shedding light on the spatial dynamics of land use change in Europe.

Data The study integrates two primary datasets: Corine Land Cover changes from 1990 to 2018 and ERA5-land sub-daily reanalysis data spanning from 1660 to 2019 (Schimanke et al., 2022). The ERA5-land dataset provides sub-daily reanalysis information at a $0.1°\times0.1°$ resolution. The ERA5-land dataset furnishes hourly records of minimum, maximum, and average temperature, as well as total precipitation. To facilitate analysis, the data is converted into daily minimum, maximum, average and total values. We first calculate seasonal average temperature and total precipitation. We then construct seasonal temperature bins to recover the number of days within each temperature across the distribution, enabling a comprehensive understanding of temperature variations. Additionally, climate averages are derived for temperature and precipitation, representing the 15 to 30 years average of each variable, thereby forming a robust foundation for examining long-term climate trends in the region. The Corine Land Cover data record changes in land use from 1990 to 2000, and then every 6 years until 2018, in 44 land use categories at a resolution of 100 metres. For ease of interpretation, we focus on four aggregated land use categories: agriculture, forest, urban, forest and other, following the official Corine Land Cover Classification. We also subdivide agriculture into arable land, permanent crops, pasture and heterogeneous agricultural land. Finally, we calculate the total proportion of land moving into or out of each category at a resolution of $0.1°\times0.1°$ from 1990 to 2018 and for each 10 to 6-year period. The combination of these two datasets allows us to examine the effect of long-term climate change on corresponding long-term land use change at a precise resolution.

Method In line with last advances in climate econometrics, we aim to use panel models (Mérel and Gammans, 2021) in a first step, before to run long-differences analyses (Dell et al., 2014; Burke and Emerick, 2016) in a second step. The first step will inform by how much landowners respond to climate change in the short term (presumably small substitution between fallows and other agriculture uses). The second step will inform by how much landowners respond to climate change in the long term (presumably real land use changes such as changes from forest to agriculture). While we consider adaptation, our work is also based on classical models of land use economics. The use of land use share models allows us to uncover how climate change affects the relative economic returns to agriculture, forestry and development (Chakir and Lungarska, 2017). As a result, we are able, not only to measure adaptation, but also to uncover the mechanisms behind landowners adaptation.

Simulations of climate change scenarios Climate change simulations will be conducted under the Representative Concentration Pathway scenario RCP4.5 (IPCC, 2014). In Europe, the average annual temperature of the earth's surface is expected to increase by the end of the century (2071-2100 compared to 1971-2000) by 1.0 to 4.5°C according to the RCP 4.5 scenario, i.e. a greater increase to the predicted global average. The strongest warming is expected in northeastern Europe and Scandinavia in winter and in southern Europe in summer.

References

Amare, M. and Balana, B. (2023). Climate change, income sources, crop mix, and input use decisions: Evidence from Nigeria. *Ecological Economics*, 211:107892. (document)

Aragón, F. M., Oteiza, F., and Rud, J. P. (2021). Climate change and agriculture: Subsistence farmers' response to extreme heat. *American Economic Journal: Economic Policy*, 13(1):1–35. (document)

Bareille, F. and Chakir, R. (2023a). The impact of climate change on agriculture: A repeat-ricardian analysis. *Journal of Environmental Economics and Management*, 119:102822. (document)

Bareille, F. and Chakir, R. (2023b). Structural identification of weather impacts on crop yields: Disentangling agronomic from adaptation effects. *American Journal of Agricultural Economics*, forthcoming. (document)

Burke, M. and Emerick, K. (2016). Adaptation to climate change: Evidence from US agriculture. *American Economic Journal: Economic Policy*, 8(3):106–40. (document)

Chakir, R. and Lungarska, A. (2017). Agricultural rent in land-use models: Comparison of frequently used proxies. *Spatial Economic Analysis*, 12(2-3):279–303. (document)

Chatzopoulos, T. and Lippert, C. (2015a). Adaptation and Climate Change Impacts: A Structural Ricardian Analysis of Farm Types in Germany. *Journal of Agricultural Economics*, 66(2):537–554. (document)

Chatzopoulos, T. and Lippert, C. (2015b). Endogenous farm-type selection, endogenous irrigation, and spatial effects in Ricardian models of climate change. *European Review of Agricultural Economics*, 43:217–235. (document)

Chen, S. and Gong, B. (2021). Response and adaptation of agriculture to climate change: Evidence from China. *Journal of Development Economics*, 148:102557. (document)

Cui, X. (2020a). Beyond yield response: weather shocks and crop abandonment. *Journal of the Association of Environmental and Resource Economists*, 7(5):901–932. (document)

Cui, X. (2020b). Climate change and adaptation in agriculture: Evidence from us cropping patterns. *Journal of Environmental Economics and Management*, 101:102306. (document)

Cui, X. and Xie, W. (2022). Adapting agriculture to climate change through growing season adjustments: Evidence from corn in china. *American Journal of Agricultural Economics*, 104(1):249–272. (document)

Dell, M., Jones, B. F., and Olken, B. A. (2014). What do we learn from the weather? the new climate-economy literature. *Journal of Economic Literature*, 52(3):740–98. (document)

Deschênes, O. and Greenstone, M. (2007). The economic impacts of climate change: evidence from agricultural output and random fluctuations in weather. *American Economic Review*, 97(1):354–385. (document)

Iglesias, A., Garrote, L., Quiroga, S., and Moneo, M. (2012). A regional comparison of the effects of climate change on agricultural crops in Europe. *Climatic Change*, 112(1):29–46. (document)

IPCC (2014). Climate change 2014: Impacts, adaptation, and vulnerability. part a: Global and sectoral aspects. contribution of working group ii to the fifth assessment report of the intergovernmental panel on climate change. (document)

Jagnani, M., Barrett, C. B., Liu, Y., and You, L. (2021). Within-season producer response to warmer temperatures: Defensive investments by kenyan farmers. *Economic Journal*, 131(633):392–419. (document)

Kawasaki, K. (2019). Two harvests are better than one: double cropping as a strategy for climate change adaptation. *American Journal of Agricultural Economics*, 101(1):172–192. (document)

Kuemmerle, T., Levers, C., Erb, K., Estel, S., Jepsen, M. R., Müller, D., Plutzar, C., Stürck, J., Verkerk, P. J., Verburg, P. H., et al. (2016). Hotspots of land use change in europe. *Environmental research letters*, 11(6):064020. (document)

Lang, G. (2007). Where are Germany's gains from Kyoto? Estimating the effects of global warming on agriculture. *Climatic Change*, 84(3-4):423–439. (document)

Lippert, C., Krimly, T., and Aurbacher, J. (2009). A Ricardian analysis of the impact of climate change on agriculture in Germany. *Climatic Change*, 97(3-4):593–610. (document)

Lungarska, A. and Chakir, R. (2018). Climate-induced land use change in france: impacts of agricultural adaptation and climate change mitigation. *Ecological Economics*, 147:134–154. (document)

Maddison, D. (2000). A hedonic analysis of agricultural land prices in England and Wales. *European Review of Agriculture Economics*, 27(4):519–532. (document)

McWilliams, M. (2016). *Essays on the Economics of Land Use and Adaptation to Climate Change.* PhD thesis. (document)

Mendelsohn, R. and Dinar, A. (2009). Land use and climate change interactions. *Annu. Rev. Resour. Econ.*, 1(1):309–332. (document)

Mendelsohn, R., Nordhaus, W. D., and Shaw, D. (1994). The impact of global warming on agriculture: a ricardian analysis. *American Economic Review*, 84(4):753–771. (document)

Mérel, P. and Gammans, M. (2021). Climate econometrics: Can the panel approach account for long-run adaptation? *American Journal of Agricultural Economics*, 103(4):1207–1238. (document)

Mihiar, C. M. and Lewis, D. J. (2023). An empirical analysis of us land-use change under multiple climate change scenarios. *Journal of the Agricultural and Applied Economics Association*, 2(3):597–611. (document)

Ramsey, S. M., Bergtold, J. S., and Heier Stamm, J. L. (2021). Field-level land-use adaptation to local weather trends. *American Journal of Agricultural Economics*, 103(4):1314–1341. (document)

Schimanke, S., Ridal, M., Le Moigne, P., Berggren, L., Undén, P., Randriamampianina, R., Andrea, U., Bazile, E., Bertelsen, A., Brousseau, P., et al. (2022). Cerra sub-daily regional reanalysis data for europe on model levels from 1984 to present. *Copernicus Climate Change Service (C3S) Climate Data Store (CDS). Accessed*, 30. (document)

Schlenker, W. and Roberts, M. J. (2009). Nonlinear temperature effects indicate severe damages to US crop yields under climate change. *Proceedings of the National Academy of Sciences*, 106(37):15594–15598. (document)

Shukla, P. R., Skea, J., Calvo Buendia, E., Masson-Delmotte, V., Pörtner, H. O., Roberts, D., Zhai, P., Slade, R., Connors, S., Van Diemen, R., et al. (2019). IPCC, 2019: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. Technical report, Intergovernmental Panel on Climate Change (IPCC). (document)

Sloat, L. L., Davis, S. J., Gerber, J. S., Moore, F. C., Ray, D. K., West, P. C., and Mueller, N. D. (2020). Climate adaptation by crop migration. *Nature communications*, 11(1):1243. (document)

Vaitkeviciute, J., Chakir, R., and Van Passel, S. (2019). Climate variable choice in ricardian studies of european agriculture. *Revue économique*, Vol. 70(3):375–401. (document)

Van Passel, S., Massetti, E., and Mendelsohn, R. (2017). A Ricardian analysis of the impact of Climate Change on European agriculture. *Environmental and Resource Economics*, 67(4):725–760. (document)

Vanschoenwinkel, J., Mendelsohn, R., and Van Passel, S. (2016). Do Western and Eastern Europe have the same agricultural climate response? Taking adaptive capacity into account. *Global Environmental Change*, 41:74–87. (document)