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Drivers, constraints and trade-offs associated with recultivating abandoned cropland in Russia, Ukraine and Kazakhstan

Patrick Meyfroidt[a,b,*], Florian Schierhorn[c,d], Alexander V. Prishchepov[c,e,f], Daniel Müller[c,d,g], Tobias Kuemmerle[d,g]

[a] Georges Lemaitre Earth and Climate Research Centre, Earth and Life Institute, Université Catholique de Louvain, 1348 Louvain-La-Neuve, Belgium
[b] Fonds de la Recherche Scientifique F.R.S.—FNRS, 1000 Brussels, Belgium
[c] Leibniz Institute of Agricultural Development in Transition Economies (IAMO), Theodor-Lieser-Strasse 2, 06120 Halle (Saale), Germany
[d] Geography Department, Humboldt Universität zu Berlin, Unter den Linden 6, 10099 Berlin, Germany
[e] Department of Geosciences and Natural Resources Management, University of Copenhagen, Øster Voldgade 10, 1350 København K, Denmark
[f] Institute of Steppe of the Ural Branch of the Russian Academy of Science (RAS), Pionerskaya str. 11, 460000 Orenburg, Russia
[g] Integrative Research Institute on Transformations of Human–Environment Systems (IRI THESys), Humboldt Universität zu Berlin, Unter den Linden 6, 10099 Berlin, Germany

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ABSTRACT

Further cropland expansion might be unavoidable to satisfy the growing demand for land-based products and ecosystem services. A crucial issue is thus to assess the trade-offs between social and ecological impacts and the benefits of converting additional land to cropland. In the former Soviet Union countries, where the transition from state-command to market-driven economies resulted in widespread agricultural land abandonment, cropland expansion may incur relatively low costs, especially compared with tropical regions.

Our objectives were to quantify the drivers, constraints and trade-offs associated with recultivating abandoned cropland to assess the potentially available cropland in European Russia, western Siberia, Ukraine and Kazakhstan—the region where the vast majority of post-Soviet cropland abandonment took place. Using spatial panel regressions, we characterized the socio-economic determinants of cropland abandonment and recultivation. We then used recent maps of changes in cropland to (i) spatially characterize the socio-economic, accessibility and soil constraints associated with the recultivation of abandoned croplands and (ii) investigate the environmental trade-offs regarding carbon stocks and habitat for biodiversity.

Less cropland abandonment and more recultivation after 2000 occurred in areas with an increasing rural population and a younger labor force, but also improved yields. Synergies were observed between cropland recultivation and intensification over the 2000s. From 47.3 million hectares (Mha) of cropland abandoned in 2009, we identified only 8.5 (7.1–17.4) Mha of potentially available cropland with low environmental trade-offs and low to moderate socio-economic or accessibility constraints that were located on high-quality soils (Chernozems). These areas represented an annual wheat production potential of ~14.3 (9.6–19.5) million tons (Mt). Conversely, 8.5 (4.2–12.4) Mha had high carbon or biodiversity trade-offs, of which ~10% might be attractive for cropland expansion and thus would require protection from recultivation. Agro-environmental, accessibility, and socio-economic constraints suggested that the remaining 30.6 (25.7–30.6) Mha of abandoned croplands were unlikely to provide important contributions to future crop production at current wheat prices but could provide various ecosystem services, and some could support extensive livestock production. Political and institutional support could foster recultivation by supporting investments in agriculture and rural demographic revitalization. Reclaiming potentially available cropland in the study region could provide a notable contribution to global grain production, with relatively low environmental trade-offs compared with tropical frontiers, but is not a panacea to address global issues of food security or reduce land-use pressure on tropical ecosystems.

* Correspondence to: F.R.S.—FNRS and Université catholique de Louvain—UCLouvain, Earth and Life Institute, Georges Lemaître Centre for Earth and Climate Research (TECLIM), Place Pasteur 3, bte L4.03.08, 1348 Louvain–la–Neuve, Belgium.
E-mail address: patrick.meyfroidt@uclouvain.be (P. Meyfroidt).

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1. Introduction

With a growing population and increasing affluence, the world is facing a surging demand for food, fiber and bioenergy. In addition, land demands have increased for non-provisioning ecosystem services, including carbon sequestration and safeguarding of biodiversity. Although intensification will have to provide for most of the additional production, some further agricultural expansion will likely be unavoidable (Lambin and Meyfroidt, 2011). Land scarcity, the 2007–2008 spikes in food prices (Piesse and Thirtle 2009; Godfray et al., 2010) and the aftermath of the 2008 financial crisis led to a growing interest in identifying regions with unused or underused land reserves, and to large-scale land acquisitions (Deininger et al., 2011; Visser and Spoor, 2011; Byerlee and Deininger, 2013). However, most of the land suitable for additional cropland is covered by natural areas with high environmental value, particularly in the tropics, where multiple policies and instruments now seek to limit conversion (Lambin et al., 2014; Gibbs et al., 2015; Gasparri et al., 2015; Lehmann, 2010). Moreover, land suitable for market-oriented agriculture is often already used by smallholders or livestock herders (Lambin et al., 2013), and converting this land could incur high social costs and trigger conflicts, as highlighted through the recent debate on "land grabbing" (Borras et al., 2011). Further, various agro-environmental, socio-economic and political factors can constrain cropland expansion. A crucial issue is thus to assess the constraints and trade-offs associated with the conversion of additional land to cropland and to identify "potentially available cropland" for cropland expansion at a low social and ecological cost (Lambin et al., 2013; Eitelberg et al., 2015).

While land-use pressure has been increasing in the tropics, it has been relaxing in other world regions (Cramer et al., 2008; Meyfroidt and Lambin, 2011; Ramankutty, et al., 2010). This is particularly true across temperate developed countries, where agricultural abandonment and reforestation have become widespread due to agricultural intensification (e.g., adoption of new technologies, higher input levels), land-use policies, a larger reliance on traded agricultural commodities, and structural changes in agriculture (MacDonald et al., 2015). For example, Eastern North America underwent major reforestation trends during the 20th century (Ramankutty et al., 2010). Similarly, abandonment has been a major land-use trend in Europe, mostly over the recent decades (Hatna and Bakker 2011; Navarro and Pereira 2012; Estel et al., 2015). Abandonment has been particularly widespread in regions that are marginal for farming, including mountains (Gellrich et al., 2007; MacDonald et al., 2000), dry areas in the Mediterranean (Piquer-Rodríguez et al., 2012; Stellmes et al., 2013) and Scandinavia (Ericsson et al., 2000). However, abandonment has also occurred in areas favorable for farming due to multiple socio-economic and political dynamics (Baumann et al., 2014; van der Sluis et al., 2015).

Abandonment and natural vegetation regrowth can have mixed outcomes, depending on the context and dynamics (Meyfroidt and Lambin, 2011). Abandonment provides potential for ecological restoration, e.g., by benefiting carbon sequestration (Schierhorn et al., 2013; Kuemmerle et al., 2015; Kurganova et al., 2014) and species sensitive to land management (Cramer et al., 2008; Queiroz et al., 2014; Kamp et al., 2011). However, abandonment can also reduce water availability (Rey Benayas, 2007) and induce wildfire risk (Moreira and Russo, 2007) and salinization (Penov, 2004), and has contrasting effects on soil erosion (Ruiz-Flaño et al., 1992; Stanchi et al., 2012). Agricultural abandonment can also threaten farmland biodiversity (Plieninger et al., 2014; Queiroz et al., 2014) and cultural heritage landscapes (Fischer et al., 2012), and may amplify the geographic displacement of agriculture and its environmental impacts in more sensitive regions (Meyfroidt et al., 2010; Kastner et al., 2015). Thus, under certain conditions, recultivating parts of the abandoned agricultural land in temperate regions could be an attractive option to increase agricultural production while mitigating some of the unwanted outcomes of abandonment and of agricultural expansion in other regions.

One of the global hotspots of currently unused agricultural land is Eastern Europe and the former Soviet Union, in particular Russia, Ukraine and Kazakhstan (RUK) (Prishchepov et al., 2012; Ioffe et al., 2014; Estel et al., 2015; Kraemer et al., 2015), which held 90% of all cropland of the Soviet Union in 1991 (FAO, 2015). The dissolution of the Soviet Union and the subsequent transition from state-command to market-driven economies drastically affected agriculture (Ioffe et al., 2004). Incomplete or inadequate land reforms, loss of guaranteed markets, a dramatic decline in subsidies for inputs and the collapse of the livestock sector resulted in the widespread cropland abandonment (Ioffe et al., 2012; Prishchepov et al., 2013; Rozelle and Swinnen, 2004). From 1991 to 2000, approximately 31% or 57 million hectares (Mha) of croplands were abandoned across RUK (ROSSTAT, 2014; UKRSTAT, 2014; KAZSTAT, 2014), mainly but not exclusively in socio-economically and agro-environmentally marginal areas (Ioffe et al., 2004; Prishchepov et al., 2013). After 2000, abandonment has continued outside the Chernozem regions, especially in northern and temperate Russia (Schierhorn et al., 2013). The socio-economic mechanisms underlying post-Soviet agricultural abandonment remain weakly understood though, as most existing studies have focused on factors explaining the spatial patterns of abandonment in local contexts (but see Ioffe et al., 2004). Moreover, while yields or agro-environmental suitability, accessibility and demography have been shown to drive abandonment patterns, the importance and sign of the influence of these factors varied spatially and temporally (Baumann et al., 2011; Vanwambeke et al., 2012; Müller et al., 2013; Prischchepov et al., 2013).

With the economic recovery and increasing domestic and foreign investments in agriculture after 2000, recultivation of some abandoned croplands started, particularly in the agriculturally favorable Chernozem (Black Earth) regions in the south of European Russia, Ukraine and northern Kazakhstan. RUK have recently resurfaced as important players in the world grain market (Schierhorn et al., 2014a; Petrick et al., 2013), mainly through increases in yields, increased concentration on grain production and the offshoring of livestock production—mainly to Brazil (Prishchepov et al., 2013; Schierhorn et al., forthcoming). Recultivation of suitable, yet currently abandoned croplands could further increase the role of RUK as major grain suppliers. However, little is known about the environmental and socio-economic implications of recultivation. As approximately 10–15% of abandoned croplands have already been reverted to young forest, particularly in the temperate region (Potapov et al., 2015; Sieber et al., 2013), and a notable soil carbon sink has developed since 1991 (Kurganova et al., 2014; Schierhorn et al., 2013), the environmental and economic costs of recultivation could be substantial.

The objectives of this study were to quantify the drivers, constraints and trade-offs associated with recultivating abandoned cropland in Russia, Ukraine and Kazakhstan. We aimed to characterize the potentially available cropland, which we defined as moderately to highly productive land that could be used in the coming years for rainfed farming with low to moderate capital investments that is not under intensive use, legally protected or covered by mature forest (Lambin et al., 2013). We started with an econometric analysis of the socio-economic drivers of cropland abandonment and recultivation, which allowed us to characterize the constraints on recultivation (see a flowchart of the methodology in Fig. A1). We then combined this analysis with recent maps of cropland dynamics and carbon budgets for the region as well as