NEWS & VIEWS

S. STREET/ALAMY

End of agriculture — an abandoned collective farm in Belarus.

GLOBAL CHANGE

Carbon in idle croplands

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The collapse of the Soviet Union had diverse consequences, not least the abandonment of crop cultivation in many areas. One result has been the vast accumulation of soil organic carbon in the areas affected.

The formal dissolution of the Soviet Union in December 1991 triggered the most widespread and abrupt episode of land change in the twentieth century. The institutional changes produced socio-economic dislocation throughout the former Soviet Union and its client states. The agricultural sector was hit particularly hard, with large tracts of cultivated land being abandoned and reverting gradually to grassland. This, in turn, had serious effects on the dynamics of carbon, water and biomass.

Writing in *Global Biogeochemical Cycles*, Vuichard and colleagues[1] describe a modelling study aimed at exploring the plausible trajectories of carbon accumulation, above and below ground, following land abandonment. Their study area spanned roughly 171,000 square kilometres in the agricultural regions of Ukraine, Belarus and the European portion of the Russian Federation.

The balance sheet for carbon accounting includes, first, the current stocks of carbon in a landscape, including live and dead plant parts above and below ground, an array of soil-dwelling organisms, and partially decomposed and transformed organic materials. The second component is the flux of carbon into and out of the landscape. Primary input of carbon comes through photosynthesis and the fixing of carbon dioxide into simple sugars — a process called primary production. Output includes CO_2 waste from the metabolic processes (respiration) of animals, plants and microbes as they go about the business of living in that landscape. respiration — constitutes the net ecosystem productivity (NEP). But there are other sources of flux to consider: the physical transport of organic materials by wind, water, humans and other animals, and the loss of carbon from the landscape through fire. Of these, it is the human use of the products of photosynthesis — food, fibre and wood — that results in transport of organic matter from the landscape in which it grew. It is the NEP of an area less its harvest (and eventual consumption elsewhere) that constitutes the net biome productivity (NBP) of a landscape or a region. In croplands the NBP is found mostly below ground, in the form of carbon that is locked into the soil as partially decomposed molecules that resist further transformation.

Vuichard and colleagues[1] linked models of ecosystem processes and of crop production to calculate the amount of carbon sequestered in the soil as grasses replaced crops. The region they targeted — 40° to 60° N by 20° to 60° E — has been estimated[2] to include much of the former Soviet Union's croplands abandoned during the 1990s. To calculate the NBP resulting from cessation of cultivation, the authors confronted several challenges. I will touch on only two.

First, the models required estimates for growing-season weather at high temporal resolution. Vuichard *et al.* accomplished this by adding six-hourly variability data to monthly averages and then re-sampling to half-hour resolution. Although this recipe can produce

more quixotic than our statistical cartoons permit. Second, simulating cultivation regimes during the Soviet period required detail about the management practices applied. The authors finessed a dearth of data by extrapolating trends in fertilizer applications, estimating irrigation applications, and delimiting the possible outcomes with three management extremes: no added nitrogen, no tillage, or limited crop-residue inputs to the soil.

Running the coupled models to simulate the abandoned croplands from 1991 to 2000, Vuichard and colleagues estimate that carbon was sequestered in soil on a grand scale. The net accumulation rate, however, has fallen from an initial annual high of 105 grams of carbon per square metre to a mean of 47 ± 33 g C m^{-2} yr^{-1}. These results compare favourably with rates from an empirical study[3] of a small number of fields at an experimental station near Moscow: 132 ± 21 g C m^{-2} yr^{-1} for the first 15 years after the cessation of cultivation, decreasing thereafter to 70 ± 8 g C m^{-2} yr^{-1}. The spatial pattern of NBP showed the greatest accumulation in the northwestern sector of the study region, decreasing sharply to the southeastern sector, where dry conditions led to net carbon loss rather than gain.

Overall, Vuichard and colleagues[1] calculate a carbon sink in the abandoned croplands of the former Soviet Union of 8 Tg C yr^{-1}, which pales in comparison with the sink of roughly 270 Tg C yr^{-1} for the vast Russian forests[4]. However, the sink strength of the abandoned land

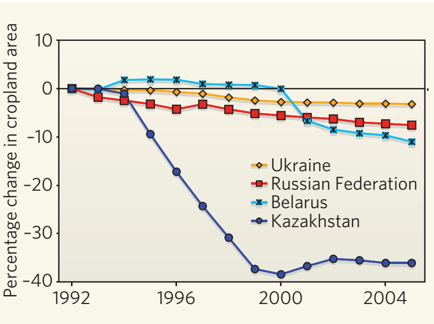

Figure 1 | Change of the area in arable land and permanent crops following the collapse of the Soviet Union. The relative abandonment in Kazakhstan is much greater than in the Russian Federation, but the areal difference is only 25% greater (127,010 km^2 compared with 101,270 km^2). Note the initial increase in croplands in Belarus following independence and the sharp contraction after 2000. (Baseline year is 1992. Source ref. 15.)

of the Russian forests (31 g C m^{-2} yr^{-1}) (ref. 5). In contrast, the average annual carbon sink for all of Europe between 1990 and 2100 has been projected at 17–38 Tg C yr^{-1}, or merely 2–3% of the European Union's CO_2 emissions over the same period[5].

The magnitude of the estimated accumulation is sensitive to the cropland management practices before the abandonment of agriculture. But, in the absence of better ground data, the modellers must resort to a 'sensitivity analysis' that explores possible rather than likely outcomes. Given the current interest in Europe and North America in turning annual croplands into perennial grasslands for the production of cellulosic ethanol, or to sequester carbon, this study offers a cautionary note: land-use history must be considered when framing and refining potential carbon sinks.

Vuichard and colleagues' focus on European Russia misses a more complicated story of agricultural land-use change in the wake of the break-up of the Soviet Union[6,7]. Cessation of agriculture has been patchy in Russia, resulting in an archipelago of communities that are threatened by isolation[8]. Moreover, abandonment of arable land was far more prevalent in Kazakhstan[9], the heart of the Virgin Lands Program launched in the mid-1950s by the Soviet leader Nikita Khrushchev (Fig. 1). This led to another profound period of land-cover change aimed at reducing the risk of famine by spreading cereal production into Asian Russia[10].

Finally, this study[1] underscores the need to improve representations of land-cover and land-use dynamics if we expect to provide credible guidance about effective strategies for adapting to and mitigating climate change[11]. The incorporation of agriculture into climate models continues to advance[12,13], but considerable challenges remain. To capture the spatial heterogeneity and temporal dynamics of human land-use, we need to move beyond the static land-cover classes that were once a solution to the problem of limited

the growth and development of vegetation across the land surface reveals distinctive patterns — 'land-surface phenologies' — that relate to land use, vegetation type, climate and recent weather, and can indicate land-cover change[9]. Assimilating land-surface phenologies into models can forge the link that is required to feed back the changing state of vegetation to atmospheric processes[14]. ■

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ALZHEIMER'S DISEASE

A prion protein connection

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More than 20 million people worldwide have Alzheimer's disease, yet its causes remain mostly uncertain. Fresh findings provide molecular clues, linking this disease to another neurodegenerative disorder.

Investigations of the causes of Alzheimer's disease yield one culprit time and time again: abnormal build-up of amyloid-β (Aβ) peptides in the brain. Small, soluble aggregates of Aβ — Aβ oligomers — impair memory by disrupting memory-related functions of synaptic junctions between neurons[1–3]. But whether specific receptors mediate these adverse effects has remained unknown. In this issue, Laurén *et al.*[4] (page 1128) show that the prion protein might mediate the pathogenic effects of Aβ oligomers.

The prion protein (PrP) is anchored to the cell membrane and associates with membrane microdomains called lipid rafts. It occurs in at least two conformational states. The cellular form, PrP^{C}, is involved in maintaining the brain's white matter, and in regulating this tissue's innate immune cells, responses to oxidative stress and neuron formation[5]. The highly pathogenic form, PrP^{Sc}, is a misfolded version of PrP^{C} and is resistant to enzymatic degradation. PrP^{Sc} is the main cause of a group of fatal neurodegenerative disorders called transmissible spongiform encephalopathies that includes Creutzfeldt–Jakob disease and mad cow disease[6].

Aβ binds to and influences the function of many cellular proteins[7]. Laurén *et al.*[4] therefore set out to identify proteins with greater affinity for Aβ oligomers than for freshly solubilized, putatively monomeric and non-toxic Aβ. Their unbiased genome-wide screen yielded PrP. Interaction between Aβ oligomers and PrP did

the authors did not explore whether PrP^{C} misfolds into a PrP^{Sc}-like conformation on binding to Aβ oligomers.

Synaptic connections between neurons can be strengthened through a phenomenon called long-term potentiation (LTP), which provides a measure of synaptic plasticity related to learning and memory — two faculties that are compromised in Alzheimer's disease. To investigate what effect Aβ–PrP^{C} interaction might have on LTP, Laurén *et al.* studied this process in slices of mouse hippocampus, a brain region crucial to learning and memory. They find that Aβ oligomers inhibit LTP in hippocampal slices from normal mice, but not in hippocampal slices from mice lacking PrP^{C}. Similarly, LTP was not affected by Aβ oligomers in hippocampal slices from normal mice in which Aβ–PrP^{C} interaction was blocked. So PrP^{C} seems to be a main receptor for Aβ oligomers, mediating their deleterious effects on synaptic function.

The authors appropriately note, however, that they cannot exclude the existence of other receptors for Aβ oligomers, because PrP ablation reduced the binding of Aβ oligomers to neurons by only 50%. Alternative receptors might include the transmembrane proteins APLP1 and 30B, but, compared with PrP^{C}, both of these showed much lower affinity and selectivity for Aβ oligomers[4]. Similarly, compared with PrP^{C}, another Aβ-binding protein, RAGE, showed much lower affinity and selectivity for Aβ oligomers. However, earlier work indicated that disrupting Aβ–RAGE