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Large-Scale Reduction in the Extent of Agriculture around Stopover Sites of Migratory Geese in European Russia between 1990 and 2015

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Abstract: Stopover sites are vital to the state of the population of many migratory bird species. The greater white-fronted goose *Anser albifrons* is the most numerous Eurasian goose species, and migrates on a broad front over European Russia. Stopover and staging sites have specific habitat requirements. They are located near open water, have nearby (<5 km) foraging areas, must be open, and lie at least 500 m from the nearest woodland. Extensive agricultural land abandonment in European Russia since 1990 is leading to widespread land cover changes, and may be lowering the availability and perhaps the suitability of stopover sites for greater white-fronted geese. To measure the extent of land cover change, we compiled Landsat images of three areas in European Russia over which geese migrate. The images were taken May 1990, 2002 and 2014, and used to create a scene that covered completely each area in each of these years. We classified each pixel into one of six land cover classes (LCCs: urban, water, arable, grass, peat bog and forest), and tallied the number changing LCC between the successive maps. For ground truthing, we made field visits in June 2014 to 150 locations chosen randomly in advance, and among them, 64 identified as stopover sites recently used by geese. At each, we assessed vegetation composition and cover, successional stage and the duration (in years) since agriculture on the site had been abandoned. The extent of arable land that changed to another classification 1990–2014 was 56%, and was matched closely by the increase in the extent of the 'grassland' and 'forest' categories, as expected if agricultural abandonment allows vegetation succession to proceed. The magnitude of change around identified stopover sites was similar to that in the areas as a whole. The extent of land cover change in the northern part of European Russia is making migration by greater white-fronted geese more challenging, which is consistent with the documented southward shift in stopover site usage. This could lead to abandonment of the route across northern European Russia altogether, in favour of a longer migration around the expanding boreal forest, which is inhospitable for goose species.

Keywords: goose migration; land use change; old-field succession; Russia; trend analysis

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1. Introduction

Migratory species face challenges not only on breeding and non-breeding areas, but also along migratory pathways [1]. A typical long-distance avian migrant spends most of the annual cycle on non-breeding grounds, a few months on breeding areas, and one or two months underway in migration. Long-distance migrants must have some flexibility [2], and there are many established records of migrants altering routes or wintering areas [3]. Conditions along migration routes are nevertheless crucial because migrants need to be able to rest and feed to replenish fuel loads [4,5].

The loss and degradation of stopover sites is considered an important cause of population decline [6–8]. Shorebirds, for example, utilize specific stopover sites during migration, and the protection of such sites forms the basis of shorebird conservation in the Americas (Western Hemisphere Shorebird Reserve Network, e.g., [9,10]. Stopover degradation is especially acute on the East-Asia Australasia Flyway, and several species were strongly and negatively affected [11–13]. The Central Asian Flyway may have already lost about 90% of its avian migrants as compared to half a century ago [14]. Spring migration is critical to the breeding success of waterfowl [15] and stopovers are also important for Arctic geese [16]. Even passerine, raptor and waterfowl species that migrate on broad fronts, utilizing many and widely dispersed locations for stopover, could be affected by landcover change if it is rapid and widespread.

The greater white-fronted goose *Anser albifrons* is the most numerous (~1.3 M individuals; [17]) Eurasian goose species. It migrates on a broad front over European Russia between breeding areas in the Arctic and seaboards of the North Sea where it overwinters [18]. Like other goose species (e.g., lesser white-fronted geese *Anser erythropus*, bean geese *Anser fabalis*, red-breasted geese *Branta ruficollis*), stopover and staging sites where they rest and replenish fat reserves [15,19] are located near open water where geese can safely roost, and must lie within ~5 km of arable land, pastures or meadows where they can forage [20–24]. The sites must be open and lie at least 500 m from the nearest woodland ([22]; pers. obs.). In spite of these specific requirements, such places are not rare in European Russia, and [25] identified some 1800 sites in the region known to be used by greater white-fronted geese.

Some goose species (e.g., barnacle goose *Branta leucopsis*, snow goose *Anser caerulescens*) became so numerous over recent decades that they could be considered overabundant (sensu [26]). Population growth was driven by their adaptability to large-scale agriculture landscapes along migration routes and in wintering areas, which provide abundant habitat and food in the form of high-quality grasses and agricultural leftovers [27–31]. The decline and stricter regulation of hunting since the 1970s undoubtedly also contributed to this [32,33]. Some populations are now so large and dependent on agriculture that damage is significant in some places [34,35], leading to conflict with farmers [27,36,37]. The snow goose is even alleged to damage tundra habitats surrounding breeding colonies [38,39].

The landscape of European Russia has been changing for over a century. The area devoted to agriculture reached its maximum extent about 1920, after which collectivization, mechanization and productivity gains began to reduce the area used. The decline in area accelerated as the political upheaval around the dissolution of the USSR in 1991 [40] made farming unprofitable over vast areas [41,42]. Censuses at ten-year intervals in nearly 350 municipal districts confirmed that the human population of rural areas and the numbers of livestock declined continually over at least the past six decades, and rapidly since 1990 [42]. Widespread abandonment of agricultural land resulted, and that led to rapid change in landcover as abandoned fields undergo succession. Strong effects on wildlife and biodiversity are anticipated as succession leads to woodland encroachment and forest development [43–45].

In this paper, we investigate further one of these possible effects, [25], (see also [29]) documented a southward shift in the occurrence of migratory Atlantic greater white-fronted geese across European Russia since 1960, an effect that became stronger after 1990. They hypothesized that this southward shift was due to extensive land abandonment and consequent goose habitat degradation, especially in northern portions of the country. The close association of greater white-fronted geese with agriculture means that the amount and perhaps the quality of habitat in the vast swath of territory along its migration route declined, making migration directly over the northern part of European Russia challenging enough to affect the migratory route. We utilize remote sensing to measure directly the extent to which land cover changed since 1990, to estimate the rate at which succession to woodlands is proceeding, and to assess whether these changes are greater around known goose stopover sites than on the landscape as a whole.

2. Materials and Methods

We assessed landcover in three areas located in Novgorod (56.33° N, 44.01° E), Tver (56.86° N, 35.92° E) and Yaroslavl (57.63° N, 39.88° E) provinces in northern European Russia (Figure 1). Greater white-fronted geese migrate through these areas, as substantiated by many recoveries of metal leg rings, colour rings and data from other tracking devices [25]. We compiled cloud-free Landsat images made during May (the period of northward goose migration) in 1990, 2002 and 2014 to create a scene that covered completely each of three areas. These years were selected based on the availability and quality of photos, minimal need for geometric corrections, and accessibility for a ground truthing visit (made in 2014; see below). We used Landsat 5 photos for the 1990 set (due to the low quality and limited availability of later sets for that year), Landsat 7 images (to avoid additional corrections for SLC-off) for 2002, and Landsat 8 images for 2014.

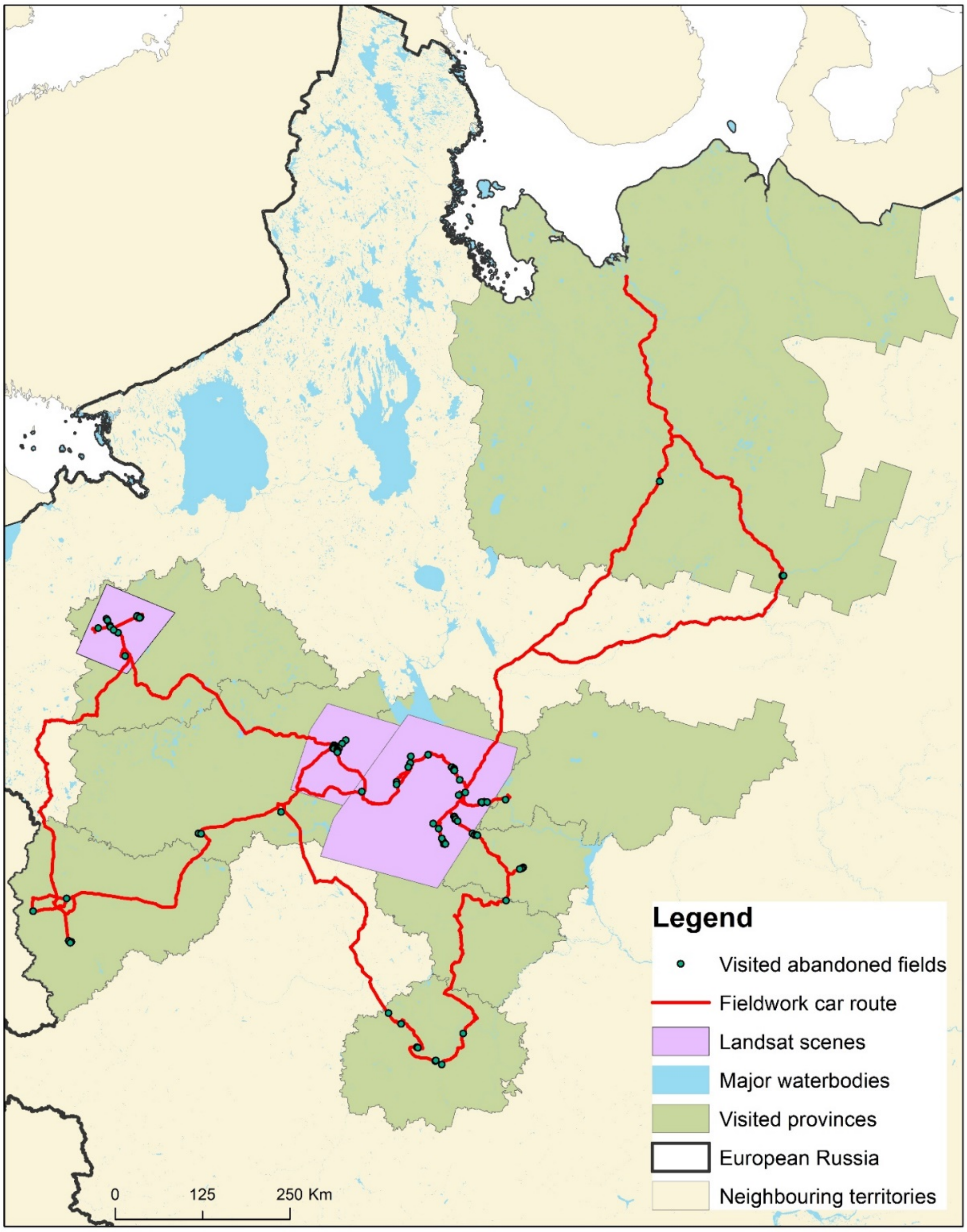


Figure 1. PA map of the study area featuring the selected Landsat scenes in European Russia, the stopover sites visited for ground truthing, and the entire travel route in June 2014 in red. Novgorod lies furthest to the west, Tver in the middle and Yaroslavl furthest to the east.

To develop land cover maps, we classified each pixel from each of the three scenes in each of the three years into one of six classes (urban, water, arable, grass, peat bog and forest) using a supervised land classification (Google Earth Engine; accessed 5 January 2018) run with the 'Random Forests classification algorithm' [46,47]. For classification training, we identified up to 20 sites for each land cover class on the 2014 Landsat 8 scenes (Figure 2).

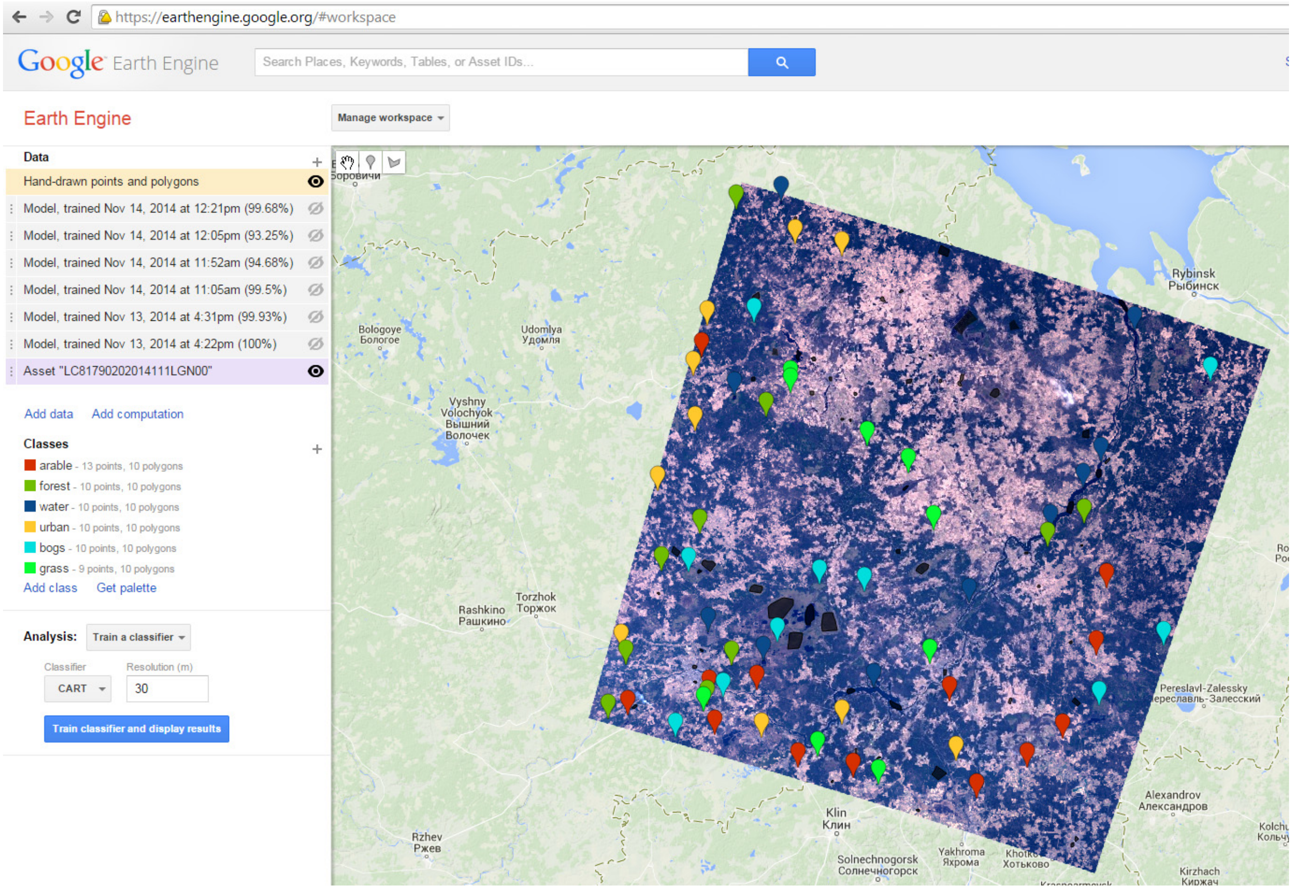


Figure 2. An example of the training set used to perform a supervised classification of the selected Landsat 8 scenes; this one was in Tver Province. In the background map, blue denotes open water and water bodies, dark green is forested area, and light green is agricultural land. The balloons on the Landsat image represent sampling areas; their colours stand for different land cover classes of which the explanation is given in the legend at the left-hand site of the map.

Ground truthing was accomplished in June 2014, during field visits made (by automobile; see route in Figure 1) to 150 locations chosen randomly in advance (with the restriction that sites lie within 5 km of the nearest road), and among them, 64 were identified by [25] as stopover sites recently used by geese. At each site, we took 360° digital photographs to assess vegetation composition and cover. We estimated based on the successional stage (Table 1) and interviews in the neighbourhood (as reported in [42,43]) how many years previously agriculture on the site was abandoned, and hence, established the classification of that site in the Landsat scenes used in our analysis. The scenes (nine in all) were exported in GeoTIFF format with a standardized pixel size of 30 m × 30 m (pixel size differs between Landsat 5, 7 and 8), imported to ArcMap (ESRI ArcGIS 10.5), reclassified to the six established classes and clipped to the respective spatial extents of the three scenes.

Table 1. Summary description of the successional stages of agricultural fields after abandonment.

		Coverage		
Years Abandoned	**Grass**	**Herbs**	**Shrubs**	**Trees**
up to 2 years	~95%	——	5% or less	0%
3–5 years	up to 50%		remainder	5%
up to 10 years	10–30%	70–90%		
11–15 years	10%	up to 90%	10%	
16–20 years	none	up to 70%	up to 30%	

The history (crops grown, year of abandonment) of many fields was determined by interviewing people living in the neighbourhood; see also [43]. The transition to woodland was well underway within two decades (Table 1).

We tallied the number of pixels in each of the six land cover classes (hereafter LCC) in each scene as a whole as well in a radius of 5 km around each of the 64 stopover sites, 5 km being the maximum distance which geese travel to forage from a stopover site [19–22]. We placed buffers around waterbodies, settlements, railways and roads (30–150 m depending on magnitude of disturbance; detailed in [42] to exclude from classification areas from which geese were subject to disturbance. We estimated the buffer sizes based on measures made for pink-footed geese by [48]. We conducted sensitivity analyses to evaluate the sensitivity of our results to these buffer distances by (a) varying the minimum size of the water body from 20 ha up to 100 ha in steps of 20 ha; (b) altering the size of the buffer around stopover sites from 5 to 4, 10 or 15 km; and (c) by doubling the disturbance distances. This sensitivity analysis showed that outcome of the classifications were not affected [42].

We tallied the number of pixels in each of the six LCCs in each scene as a whole, as well in the 5 km buffer around each stopover site. The instantaneous rate of change for each of the six land cover classes over the intervals 1990–2002, 2002–2014 and 1990–2014 was calculated as

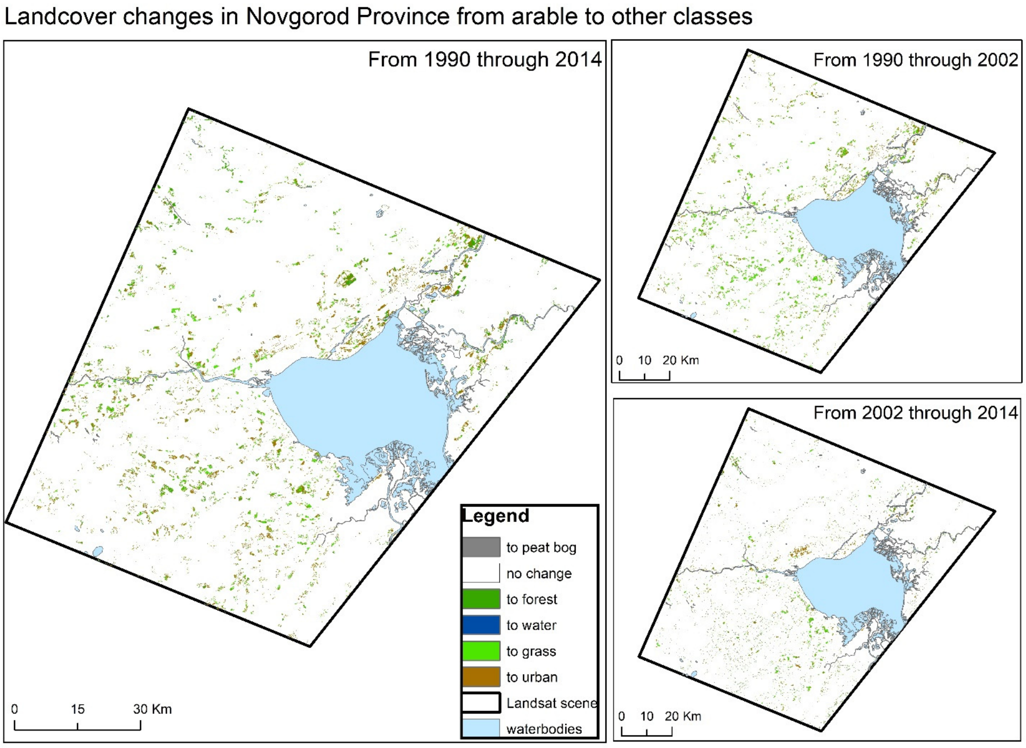
$$\frac{ln\ (N_{i,t+n}) - ln\ (N_{i,t})}{n}$$

where $N_{i,t}$ is the number of pixels in land cover class i in year t, and $N_{i,t+n}$ is the number of pixels n years later. Rate units are ln number of pixels per year. Rates were calculated at both the scene and stopover levels. Statistical analyses were performed in R (v. 3.2.2, R Core Team 2016). All spatial analyses and data visualisation were carried out in ArcMap (ESRI, ArcGIS v. 10.5).

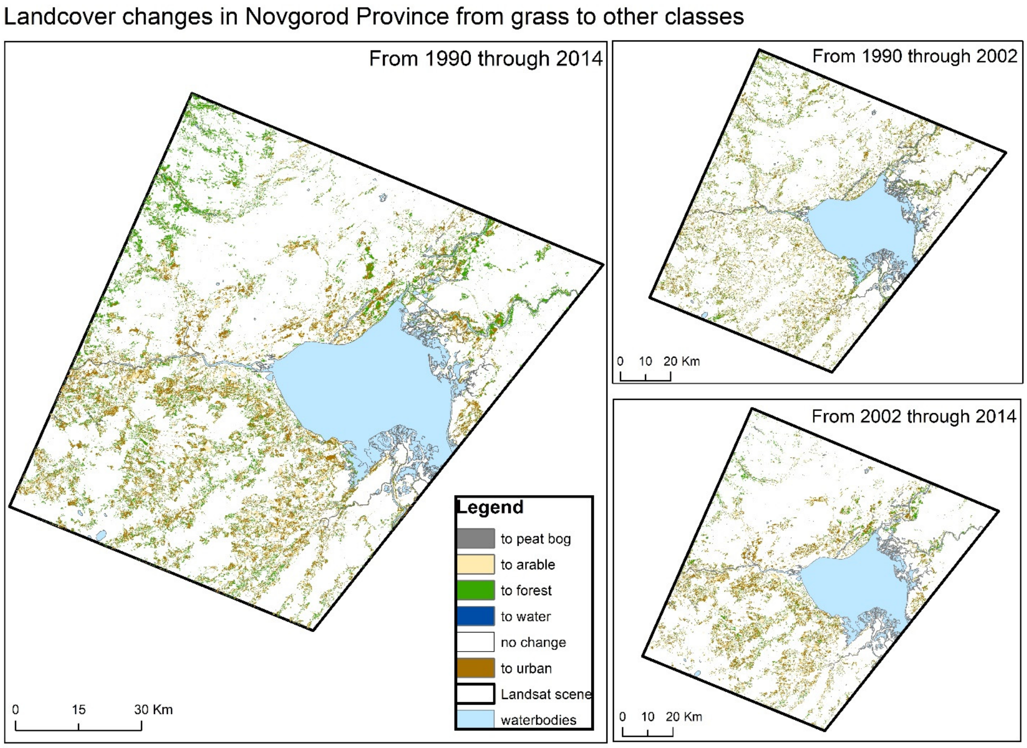
3. Results

Based on ground-truthing, the accuracy of the automated land classification procedure exceeded 90%. Most misclassifications were made between land cover classes (LCCs) with similar reflectance. The LCCs 'urban' vs. 'arable' and 'water' vs. 'peat bog' were most easily confused. Changes between successive scenes in the extent of the 'water' and 'peat bog' were partially attributable to this source of error but were not very relevant to our analyses. Arable fields were misclassified as urban in some analyses, but most were located well outside urban areas, and could be corrected [42].

The total number of pixels in the Yaroslavl/Tver scene (Figure 1) was 29.52 M, and in Novgorod 12.48 M, for a combined area of 42.00 M pixels. Each pixel represented a 30 m $\times$ 30 m area, so the total area was 37,800 km^2. The changes in land cover classes between 1990 and 2002, and between 2002 and 2014 were shown in 'difference maps', illustrating which and how each pixel changed LCC. The difference maps are depicted in Figure 3a,b and Figure 4a,b for the Novgorod scene and stopover sites, respectively.

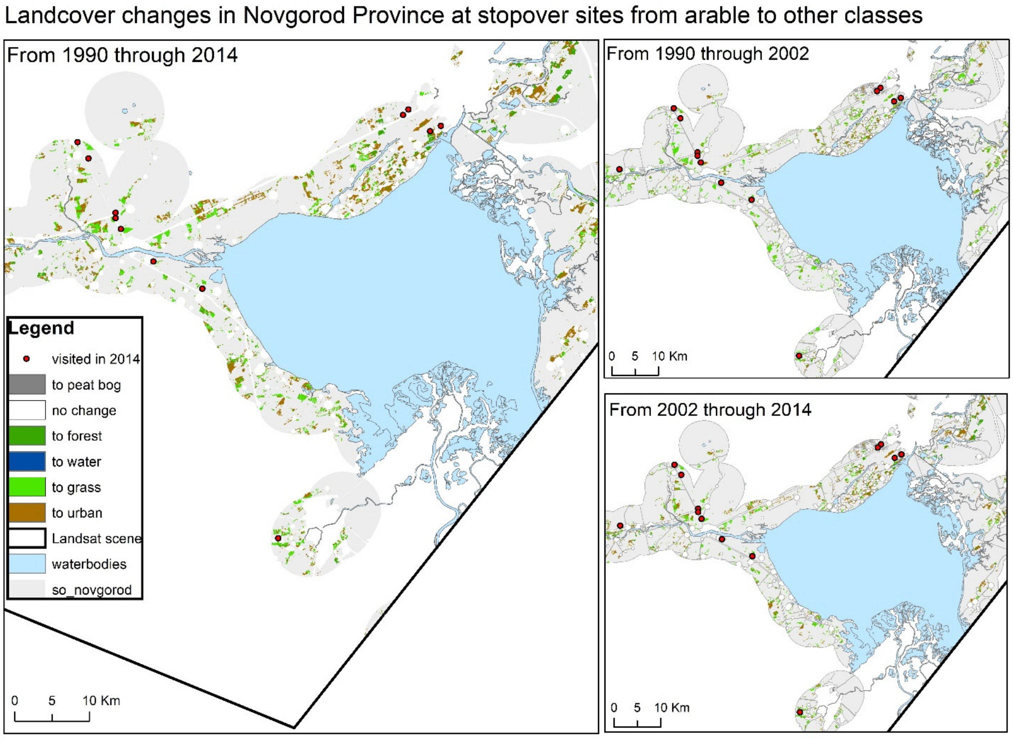


(**a**)



(**b**)

Figure 3. (**a**) Difference map calculated from the Landsat scenes in Novgorod Province. The map on the left features transition from arable landcover to all other classes, 1990–2014. The two smaller maps on the right highlight similar transitions 1990–2002 (upper) and 2002–2014 (lower). (**b**) Difference map calculated from the Landsat scenes in Novgorod Province. The map on the left features transition from grass landcover to all other classes, 1990–2014. The two smaller maps on the right highlight similar transitions 1990–2002 (upper) and 2002–2014 (lower).



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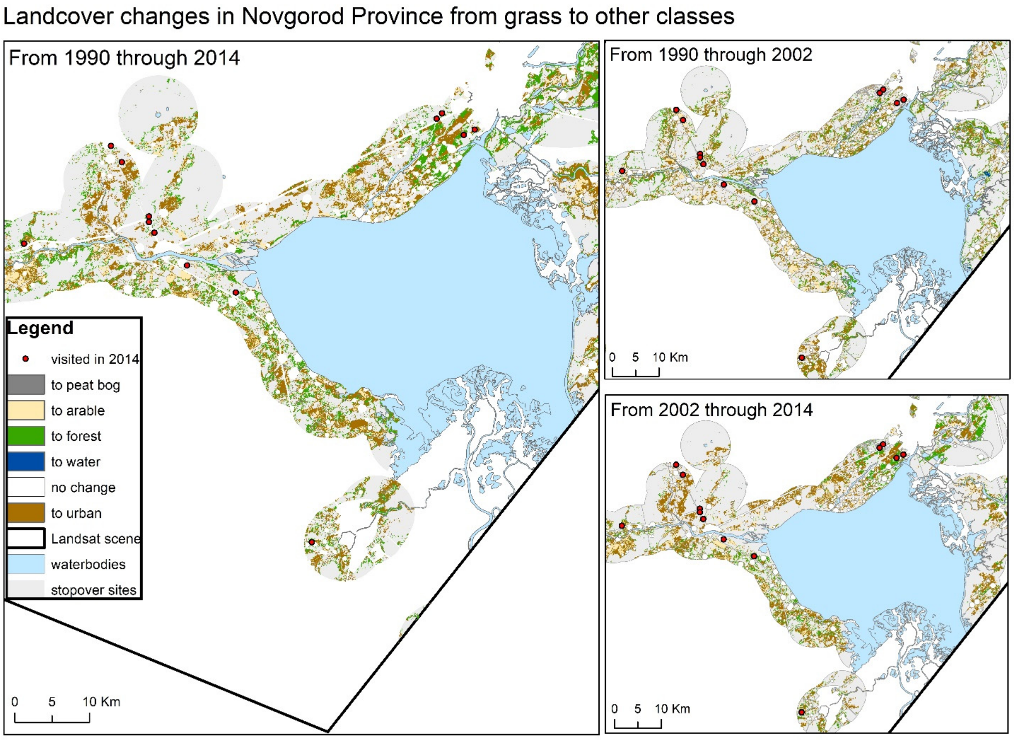

(**b**)

Figure 4. (**a**) Difference maps at stopover sites calculated from the Landsat scenes in Novgorod Province. The map on the left features transition from arable landcover to all other classes, 1990–2014. The two smaller maps on the right highlight similar transitions 1990–2002 (upper) and 2002–2014 (lower). (**b**) Difference maps at stopover sites calculated from the Landsat scenes in Novgorod Province. The map on the left features transition from grass landcover to all other classes, 1990–2014. The two smaller maps on the right highlight similar transitions 1990–2002 (upper) and 2002–2014 (lower).

We summarised the LCC analysis at scene level in Table 2, showing the area of each of the six land cover categories in 1990, 2002 and 2014 (due to the partial overlap of their images, we combined Tver and Yaroslavl for presentation purposes; compare Figure 1). The results showed that the extent of arable land declined by 43.3% during the 24 years from 1990 to 2014 (from 21.68 M to 12.30 M, or by 9.38 M pixels), amounting to an annual rate of −0.024. The rate of decline was stronger in Yaroslavl/Tver (−0.037) than in Novgorod (−0.007). Table 2 also shows that the rate differed between the periods 1990–2002 and 2002–2014. In contrast to the decline in arable land, the area of grassland increased from 27.0 M to 30.8 M (3.8 M pixels or 14%), amounting to an annual rate of 0.005. The area of forest increased from 49.5 M to 52.0 M (2.6 M pixels or by 5.2%), amounting to an annual rate of 0.002. Together, these increases were equal to 68% of the decline in arable land.

We summarised the analysis of changes around stopover sites in Table 3. The results were similar to those reported for the area analysis. The overall amount of arable land declined by 47.2%, from 6.61 M to 3.49 M (~2.2 M), amounting to an annual rate of −0.027. The decline was stronger in the Yaroslavl scene (−0.035) than in Novgorod (−0.017), and the rates differed between 1990–2002 and 2002–2014 (Table 3). In contrast, the area of grassland increased by 12.5%, (from 7.6 M to 8.6 M, ~1.0 M), amounting to an annual rate of 0.005. The area of forest increased by 11.7% (from 11.6 M–12.9 M, ~1.3 M pixels), amounting to an annual rate of 0.005. Together, these increases exceed by ~4% the estimated loss in arable land around stopover sites. The increase in 'urban areas' can nearly completely be ascribed to an increase in allotment gardens and small houses ('*dachas*').

Table 2. Landcover in European Russia in 1990, 2002 and 2014. The scenes for Yaroslavl and Tver provinces are combined (see Methods and compare Figure 1). LCC is land cover class, and rates are rates of change. We report the number of pixels ($\times 10^6$) yielded by the supervised classification (Google Earth Engine) for each landcover class in the 1990, 2002 and 2014 Landsat scenes. The annual rates of change in landcover classes for the periods 1990–2002, 2002–2014, and 1990–2014 are also given. The number of pixels in the Yaroslavl/Tver scene is 107.66 M, and in Novgorod 19.76 M (total 177.80 M pixels).

						Rates	
SCENE	LCC	1990	2002	2014	1990–2002	2002–2014	1990–2014
Yaroslav/Tver	urban	15.05	18.12	15.92	0.016	−0.011	0.002
	grass	23.08	21.49	28.82	−0.006	0.024	0.009
	water	48.13	37.68	63.7	−0.020	0.044	0.012
	forest	40.65	41.25	41.36	0.001	0.000	0.001
	arable	13.83	11.72	5.71	−0.014	−0.060	−0.037
	bog	10.24	11.3	9.91	0.008	−0.015	−0.003
Novgorod	urban	1.71	2.39	2.88	0.028	0.016	0.022
	grass	3.92	2.99	1.96	−0.023	−0.035	−0.029
	water	2.56	2.63	2.33	0.002	−0.010	−0.004
	forest	8.83	9.8	10.68	0.009	0.007	0.008
	arable	7.85	4.91	6.59	−0.039	0.025	−0.007
	bog	1.95	1.46	1.25	−0.024	−0.013	−0.019
combined	urban	16.76	20.51	18.8	0.017	−0.007	0.005
	grass	27.00	24.48	30.78	−0.008	0.019	0.005
	water	50.69	40.31	66.03	−0.019	0.041	0.011
	forest	49.48	51.05	52.04	0.003	0.002	0.002
	arable	21.68	16.63	12.3	−0.022	−0.025	−0.024
	bog	12.19	12.76	11.16	0.004	−0.011	−0.004

Table 3. A comparison at the scene and stopover levels of the change in land cover classes from 1990–2014. Shown is the % of the total area represented by each LCC (in 1990), the % change in area, and the annual rate of change. The loss of arable land exceeds 40%, with a rate of change much higher than any other LCC. These figures are higher around stopovers than on the scene as a whole. The rates of forest and urban gain are higher around stopovers than on the scene as a whole. The total areas of scene and stopover are 177.80 M and 42.00 M pixels, respectively.

	% of Total Area		% Change in Area		Annual Rate	
	SCENE	STOPOVER	SCENE	STOPOVER	SCENE	STOPOVER
urban	9.43%	22.33%	12.20%	49.70%	0.005	0.017
grass	15.19%	18.17%	14.00%	12.50%	0.005	0.005
water	28.51%	7.45%	30.30%	0.20%	0.011	0
forest	27.83%	27.55%	5.20%	11.70%	0.002	0.005
arable	12.19%	15.74%	−43.30%	−47.20%	−0.024	−0.027
bog	6.86%	8.74%	−8.40%	−19.60%	−0.004	−0.009

4. Discussion

The greater white-fronted goose population of the East Atlantic Flyway (Africa Eurasian Flyway) showed an enormous increase in recent decades [17,49], similar to other herbivorous Arctic breeding birds [50]. In this study, we demonstrated that land cover changed extensively since 1990, and that much of the arable land on which greater white-fronted geese rely was lost in northern Russia since 1990. The extent of land cover change around stopover sites is similarly large (compare Tables 3 and 4). The loss of stopover sites may explain population declines of some bird species, including geese [6–8], but the large decrease in the number of good stopover sites and the reduction in their desirable qualities from 1990 to 2014 evidently did not have a negative impact on the greater white-fronted goose population in north-western Europe, which increased greatly over this period.

Our results showed that extensive areas of agricultural land were abandoned in northern European Russia over recent decades (e.g., [40,41,51]). As our study areas were within the boreal forest zone where forests were cleared historically to support agricultural expansion, succession back to forest is to be expected. This old-field succession takes about fifteen years (Table 1; [43,52]). The extent of arable land that changed to another classification during 1990–2014, documented in both the Yaroslavl/Tver and Novgorod Landsat images, was a stunning 56%. This is matched closely by the increase in the extent of the ‘grassland’ and ‘forest’ categories, as expected if the cause of the change was abandonment which allows succession to proceed. The rates of decline in arable land are an order of magnitude greater than the changes for any of the other five land cover classes. Much of this land use change is related to the removal of subsidies to agriculture after the collapse of the USSR and the economic depression that followed. Grain production in the north of Russia was largely halted, resulting in abandonment of arable fields, or their conversion to other crops. Livestock numbers also plummeted [25].

The impact of these changes is more acute for the spring than for the fall migration of geese. The spring migration takes more time (on average 83 days) and sweeps across nearly the whole of European Russia north of Moscow. The fall migration is quicker (on average 42 days) and uses a relatively narrow corridor over Lake Ladoga towards Poland [53]. In contrast to Western Europe, where geese forage largely on well-fertilized pastures, geese in Russia hardly use grasslands on either the spring or fall migrations. In spring, high quality grass is rarely available, because it emerges from under the snow yellow and mature; and spring fires are too late to produce young, nutritious grass for migrating geese (pers. obs.). Cereals (wheat, barley, oats, rye), stubbles [54,55] or potato and sugar beet leftovers from the previous harvest [56] instead form their typical foods. In the fall, grasslands are generally severely under-grazed, as a consequence of greatly reduced cattle and horse grazing [25]. Longer, mature grass is less desirable as food for geese [57,58].

Table 4. Landcover at 64 stopover sites for greater white-fronted geese in European Russia in 1990, 2002 and 2014 only. Data for goose stopover sites from Yaroslavl and Tver provinces are combined (see Methods). LCC is land cover class, and rates are rates of change. We report the number of pixels ($\times 10^6$) meeting our criteria for a stopover sites yielded by the supervised classification (Google Earth Engine) for each landcover class in the 1990, 2002 and 2014 Landsat scenes. The annual rates of change (natural log of the number of pixels per year) in landcover classes for the periods 1990–2002, 2002–2014 and 1990–2014 are also given. The total number of pixels in the Yaroslavl/Tver scene is 29.52 M, and in Novgorod 12.48 M (total 42.00 M pixels).

						Rates	
SCENE	LCC	1990	2002	2014	1990–2002	2002–2014	1990–2014
Yaroslav/Tver	urban	4.03	5.4	4.26	0.024	−0.020	0.002
	grass	6.33	5.59	7.86	−0.010	0.028	0.009
	water	2.47	2.03	2.55	−0.016	0.019	0.001
	forest	9.76	10.34	10.58	0.005	0.002	0.003
	arable	3.77	2.88	1.61	−0.022	−0.048	−0.035
	bog	3.16	3.26	2.65	0.003	−0.017	−0.007
Novgorod	urban	5.35	6.91	9.78	0.021	0.029	0.025
	grass	1.30	1.04	0.72	−0.019	−0.031	−0.025
	water	0.66	0.69	0.587	0.004	−0.013	−0.005
	forest	1.81	2.07	2.34	0.011	0.010	0.011
	arable	2.84	1.72	1.88	−0.042	0.007	−0.017
	bog	0.52	0.45	0.31	−0.012	−0.031	−0.022
combined	urban	9.38	12.31	14.04	0.023	0.011	0.017
	grass	7.63	6.63	8.58	−0.012	0.021	0.005
	water	3.13	2.72	3.137	−0.012	0.012	0.000
	forest	11.57	12.41	12.92	0.006	0.003	0.005
	arable	6.61	4.60	3.49	−0.030	−0.023	−0.027
	bog	3.68	3.71	2.96	0.001	−0.019	−0.009

Other explanations for the southward shift were not compelling. Spring hunting, which is normal in European Russia, has a negative effect on migratory geese [59–61], but it has apparently not increased since 1990. In fact, the total number of people, especially in the countryside but also in all regions of the country other than the largest cities (Moscow and St. Petersburg); declined [25]. It is thus probable that the hunting pressure actually decreased and, hence, is unlikely to explain the southward shift.

Reference [62] suggested that increased competition for food at spring stopover sites in the Baltic could explain the recent change in barnacle goose *Branta leucopsis* northbound migration. The idea that food competition at stopover sites and perhaps also on wintering grounds stiffened appears plausible [63] and could play a role in the spring migration of the greater white-fronted goose. Not only are crop residues disappearing from the landscape, but stopover sites are also increasingly hemmed in by forest and are encroached upon by shrubs, which is perceived as dangerous by geese [64] because it provides cover for predators.

Herbivorous Arctic geese in the 21st century are strongly affected by the policies and politics of humans, via their effects on farm subsidies, fertilizer prices and changes in political philosophy. The demographic decline in Russia is so strong [25] that we anticipate the land use changes that we described here could have very long-lasting effects. The spring migration during which greater white-fronted geese customarily spent some two months in northern Russia on their way to the Arctic breeding grounds [53] will present, we think, an increasing obstacle for these geese. Stopover sites will continue to degrade and may disappear, save for some areas close to a few northern towns where agriculture is able to persist (see [25], though geese will be in easy reach of hunters there. Geese have two possible counter-strategies, namely (i) to speed up their migration (as the barnacle geese have: [62], which will mean, as a consequence, that they spend longer in Western Europe (thus exacerbating competition there: [62,63], or (ii) to shift to a migration route already in use, from Hungary through Southern Russia, across the Urals and thence, following the Ob and other Siberian rivers towards the Arctic. At present, the second alternative appears to be favoured.

5. Conclusions

Land use change was extensive in European Russia since the dissolution of the USSR in 1991 led to the loss of state support for agriculture. Agricultural land abandonment on a massive scale resulted, which has since been speedily reverting to forest. The greater white-fronted goose *Anser albifrons* and perhaps other goose species that migrate over European Russia between breeding and wintering areas rely on access to forage on agricultural lands, and may be finding that crossing this vast expanse became more challenging as the availability and suitability of suitable habitat continues to decline, especially in northern parts of the country.

Many instance of long-distance avian migrants adjusting migration routes and schedules were described in the literature. Greater white-fronted goose may adjust their schedule as, for example, barnacle geese have: [62,63]. Or they might to shift to a migration route that some already use, detouring around the (expanding) boreal forest by using ever-more southern routes across Russia and the Urals, and thence following the Ob and other Siberian rivers northwards towards the Arctic. At present, this alternative appears to be chosen.

To mitigate the negative effects of old field succession in abandoned agricultural lands on migratory geese, it would be important to maintain some agricultural fields in a productive state in the Important Bird Areas of NW Russia, especially away from large towns where, otherwise, hunters would have easy access to them. For this, the focus should be on clearing up fields from shrubs and trees, maintaining fields under crops of which the left-overs can be used by migrating geese, and maintaining grasslands/pastures through mowing these minimally once a year, but a higher frequency would be better. Hay should not be left behind to prevent proliferation of herb growth because geese need young grass. These activities should be carried out in conjunction with an increased visibility on social media of the beauty of migrating geese and other wildlife, which can be carried out in partnership with other local cultural and historical attractions, tapping into the current federal rural infrastructure development and medium/small towns' revitalization programmes; for this foreign funding is not needed and neither is additional legislation. Considering the current foreign travel restrictions, increased interest in domestic and nature travel creates an enabling environment to generate domestic tourist income.

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Ethics Statement: No goose was shot at or killed for this study but location data on the recovery of leg bands (rings) that were used for goose migration studies were sourced for the study. Information from local villagers in Russia on land use was collected in open discussions, and no payments or gifts were given or asked for.

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