

How climate change influences landscape change

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Abstract: Climate change has been consistently identified as the key global environmental issue in recent debates on the subject, and global and supra-national climate change-related policies have grown in importance as a driving force of landscape change.

This paper provides a description of potential changes in landscapes that may have resulted from the implementation of international climate policy initiatives, and characterises the actual influence of these policies on current landscape changes in central Poland over recent years.

Key words: landscape change, climate change, climate policy, central Poland

Introduction

Understanding landscape change requires a better recognition of the underlying causes, called driving forces, keystone processes or drivers of landscape change (Bürgi et al., 2004). "Driving forces are the forces that cause observed landscape change, i.e. they are influential processes in the evolutionary trajectory of the landscape" (Bürgi et al., 2004). Brandt et al. (1999) identified five major groups of driving forces: socioeconomic, political, technological, cultural and natural. These forces do not work singly but in conjunction with one another, with varied temporal and spatial ranges of influence.

Keeping the above complexity in mind, in this paper we limit our analysis of landscape change in central Poland to a specific driving force, i.e. to global and supra-national (European) climate change-related policy, and we ask: have the current concerns on climate change led to substantial effects in the landscape?

The ways climate change drives landscape transformation are manifold. Pedroli et al. (2009) identify three impacts of climate change on landscapes: (i) the direct effects of natural agents, such as heat waves, floods, droughts, storms, and altered habitats; (ii) adaptation measures to adjust socio-economic and biophysical systems to changing conditions; (iii) mitigation measures to limit the degree of future warming by curbing greenhouse gases. Erhard (2009) adds the impacts of the interactions of the direct climatic stimuli and adaptation and mitigation actions with other effects of human land use and management to this list. To highlight the cascading pattern of the impact and reaction to climate change the concept of first- and second-order adaptation within socio-ecological system was introduced (Birkmann 2011). Actual and potential climate stimuli and their effects on landscapes have been discussed by landscape researchers (Starkel & Kundzewicz 2008, Vos et al., 2008; Opdam et al., 2009, Nadaï & van der Horst 2010, Dale et al., 2011).

This paper aims to assess the influence of international and supra-national (European) climate change-related policy on landscapes in Poland and is organised as follows. First, the nature of current global climate change concerns is discussed, followed by the presentation of potential landscape changes that might result from the international policies adopted to mitigate climate change. Second, major landscape change processes that have been operating in central Poland during the last few years are described. Next, local changes brought about specifically by the implementation of climate change-related international policies are analyzed, and

finally, possible future changes in the landscapes due to the implementation of the climate policy measures are briefly discussed.

Study area

Central Poland in this study approximates to the Łódź Province (województwo), located in the middle of Poland, that has an area of 18 220 km² and ca. 2.55 million inhabitants, with urban dwellers accounting for 66% of the total. Łódź, with ca. 720 000 inhabitants, is the main city of the region.

Central Poland is a flat and undulating glacial plain consisting of Quaternary till and fluvioglacial sands, with eolian material in places and Mesozoic rocks outcropping in the south. The altitude varies between 120 m and 250 m. The area is a water divide, and it therefore lacks large streams. The major rivers, the Warta and the Pilica River, flow on the periphery of the province.

Agricultural land accounts for about 71%, forest 21%, and the built-up area 5% of the region (GUS 2010).

Methods

During several years experience of land-use mapping and detailed field observations of biophysical and socio-economic phenomena in different parts of central Poland (Krysiak 1999, 2006, 2008; Majchrowska 2002) the authors have gained insights into many dimensions of change of the landscape. Direct observations allowed the identification of some important qualitative landscape changes that cannot be seen on maps.

We adopted a descriptive approach to characterise the recent transformations of these landscapes. The examples were selected mainly in the rural areas of central Poland to illustrate changes of the landscape over few recent years.

International policy on climate change and its effects on landscapes

Global scale concerns (NEAA 2009) seem to concentrate on climate change and warming that, according to the United Nations Intergovernmental Panel on Climate Change (IPPC), has become more certain and more serious (Climate Change 2007).

In response to the IPCC First Assessment Report, highlighting the link between anthropogenic greenhouse gas (GHG) emissions and potential global climate change, the United Nations Framework Convention on Climate Change (UNFCCC) was signed in Rio de Janeiro in 1992. Its primary aim was to stabilise "GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (Art. 2. UNFCCC 1992). Under the Kyoto Protocol, a complement to the Convention, 37 industrialised countries and the European Union agreed to reduce their collective emissions of six key GHG by an average of 5% against 1990 levels over the five-year period 2008-2012.

Modern technology uses large amounts of energy, and the burning of fossil fuels to produce energy is the main source of anthropogenic GHG emissions and climate change. With energy-related CO₂ accounting for 61% of global GHG emissions (World Energy Outlook 2008), the energy sector plays the central role in mitigating climate change. Consequently, climate change concerns have been linked to issues of adequate level of energy supply, improvement in energy use efficiency and low-carbon technologies of power generation.

The European Union adopted in December 2008 the energy and climate change legislation package, based on the international commitments made under the Kyoto Protocol. It includes binding targets to reduce EU-27 GHG emissions by 20% by 2020 compared to 1990 levels; to increase renewable energy's share of the market to 20% by 2020 (including a 10% share of biofuel in transport), and cut energy consumption by 20% through increased efficiency and conservation in use by 2020.

Efforts to achieve these targets bear considerable risks for landscapes, mainly in terms of land use change and development of new conspicuous elements in landscapes. Some potential implications for landscapes to be brought both by non-renewable (tab.1) and renewable energy (tab.2) sectors are tabulated below.

Table1. Landscape changes due to the deployment of climate-change mitigation measures in non-renewable energy sector

Energy sector	Operation	Implications for landscape
Coal or other fossil fuel-fired power stations	extension of existing power stations and development of objects in new locations	growth of industrial area – power generation buildings and permanent installations and accompanying equipment, for example for CCS; electricity transformers and overhead transmission lines; new coal mines including open cast mines
Nuclear power stations	new objects and technologies	growth of industrial area – power generation buildings and permanent installations; large demand for water for cooling; nuclear risk concern

The most serious landscape changes are likely to include the construction of nuclear power stations, new, more effective coal-fired power plants, dams, and wind farms as well as other renewable energy developments and associated infrastructure, like transformer stations and overhead electricity transmission lines.

Embarking on large scale bioenergy production could result in converting forests to biofuel cropland. Expanding and intensifying arable crop production to satisfy both food and fuel demand would have serious implications for biodiversity and damage soil and water resources.

To reach energy efficiency targets, new architectural design of passive and low-energy buildings would appear.

Table 2. Landscape changes due to the deployment of climate-change mitigation measures in renewable energy sector

Energy sector	Operation	Implications for landscape
Biomass	production of biomass	crop biomass new plants (sometimes exotic species), agricultural intensification, monocropping, risk for biodiversity; conflict with food crops; reclamation of abandoned land in places
		forest biomass monocultures of energy trees; lowering of forest rotation age; changes in appearance of natural mixed forest; possible conflict with multifunctional use of forest
		organic waste improvement in waste management; infrastructure for collecting and pre-processing
	electricity or heat generation	growth of industrial areas – new facilities for producing biogas and liquid biofuel, new (local scale) biogas power plants
	production of fuel for transport	
Wind	new objects - single wind turbines and wind power farms	wind turbines – highly conspicuous objects; aesthetic concerns; implication for cultural elements (monuments, historic architecture); conflict with birds and bats; conflict with tourist use and forestry
Water – small scale	new objects or modernisation	ecosystem change; risk for fish; increased tourist value
Water - large scale	new objects	massive ecosystem change; dam; power generation facilities, transmission lines; loss of residential and agricultural land; conflict with cultural heritage; resettlement; increased tourist value; new ecological functions (e.g. bird habitat)
Sun	new elements – solar thermal collectors or photovoltaic modules; photovoltaic power plants	changed appearance of buildings – solar panels on roofs and walls or in vicinity of buildings; aesthetic concerns; infrastructure elements, loss of agricultural areas, possible location on underused land
Geothermal	new objects	infrastructure elements; swimming pools and spas; increased tourist value

Current major change processes in landscapes of central Poland

Landscape changes in central Poland during the past few decades have been mimicking trends observed and studied in other parts of Europe (Klijn & Vos 2000, Antrop 2004). The area has been subject to the following main directions of change: (i) the intensification and increase of scale of agricultural production; (ii) the extensification of land use and abandonment of agricultural land; (iii) development of tourism and specific tourist and recreational forms of land use; (iv) expansion of the built-up areas, the growth of infrastructures and the road network. These changes accelerated after 1989, when Poland began its political and economic post-socialist transition and took a path towards accession to the European Union.

Before 1989, the agricultural landscape of Poland consisted of small individual and huge state-owned farms. After 1991, state-owned farms were divided and sold or leased, which resulted in a growing number of large holdings. Nonetheless, until now the share of small family farms in the study remains high with 59% of farms being smaller than 5 ha (GUS 2010a).

Economic transformation during the 1990s challenged the profitability of farms and deepened the split between intensive and extensive use of the land. On one hand, an increase in intensity of land use, involving modern practices and techniques aiming at higher production, yields and labour productivity, has occurred in places, on the other, large patches of abandoned farmland are gradually becoming overgrown (Krysiak 2008). Generally, likewise in other European countries (Antrop 2004), rural landscapes in Poland are following two opposite directions of transformation: intensification and extensification, which leads to the spatial concentration of activities and to polarization of landscapes.

Intensification and scale enlargement in agriculture

The intensification and increase of scale of agricultural production occurs mainly in favourable areas: on flat or gently undulating glacial plains with fertile soils that developed from till. Even better soils occur on till with a coating of eolian silt, where the permeable layer of silt enhances soil moisture.

Typical changes in the landscape resulting from the agricultural intensification include farmland consolidation and an increase in size of fields, thereby the traditional fine-grained rural landscape structure is gradually being replaced by a coarse one. However, in spite of these recent changes, a considerable amount of fine-grained landscape structures of small family farms still exists.

Intensification of farmland is accompanied by the removal of small landscape elements with particular ecological value, such as hedges, clumps of bushes, solitary trees, grass and herb field margins, wetlands and ponds. Large fields are planted with single crops; thereby diversity in cultivated plants diminishes. An insignificant share of forest is also a characteristic feature of intensively cultivated areas.

Extensification of land use and land abandonment

The extensification trend affects lands with less favourable biophysical qualities, such as unfertile soils or higher relief. These features are typical for flat and undulating glaciofluvial plains and eolian cover sands with dunes. The main reason for the extensification of land use and land abandonment is the low profitability of agriculture: unfavourable biophysical conditions result in lower productivity of land, which in turn requires larger inputs and increases the cost of production. Additionally, the small size of farms and limited access to some remote fields hinders mechanisation, which is a direct cause of extensification and land dereliction. In consequence, the share of abandoned agricultural land is increasing and subsequently the region experiences economic marginalisation and decline.

The process of extensification brings mixed results. Low-productive small-scale agriculture, although being an intrinsic element of Polish rural landscape, perpetuates abandonment of agricultural land, that eventually leads to the disappearance of traditional agricultural practices and cultural rural landscapes. To survive, traditional agriculture has to find economically viable reasons for its existence. To some extent, new functions of rural space: touristic and recreational ones could alleviate the problem (see: third trend of landscape change).

The extensification of land use has had some positive ecological effects as naturally regenerating grasses,

herbs, shrubs and trees encroach on abandoned farmlands. Regular afforestation is rare. The final result is “greening” or “re-wilding” of the landscape.

Specific tourist and recreational forms of land use

In the countryside, tourist infrastructure is virtually absent from intensively cultivated farmland (Krysiak 2008), because of its a rather monotonous landscape without forests, that also contains disturbing by-products of agriculture, for example odours.

Regions of traditional small-scale agriculture attract more tourists. In particular, areas affected by the extensification of land use and land abandonment, with higher relief, poor soils and numerous hedges and woodlots, adopt touristic and recreational functions. A scarcity of rivers in central Poland makes the existing river valleys particularly appealing for tourism and recreational use.

A variety of types of tourist settlements and recreational land uses in central Poland can be identified: large, former state-owned holiday facilities; allotment plots; summer or second houses; and farm buildings adopted for recreational purposes (Krysiak 2009).

Since the 1990s, former state-owned holiday facilities were closed, privatised or sold in parts. However, a number of them have fallen into ruin and become a negative element of landscape.

The role of allotment plots has shifted over the years. Originally, allotment gardening was popular within urban or suburban areas, but more recently it moved further into the country. The location of newer allotment plots is related to the distribution of abandoned farmland, as farmers willingly sell derelict, unproductive fields and meadows for use as recreational areas. Typically, new allotments are mixed with patches of abandoned farmland.

Currently allotments display an astonishing variety of sizes and physiognomy. Some of them, especially private ones, arranged on abandoned agricultural lands, are quite large (up to 1 ha and bigger). The allotment architecture varies from rusty house trailers to wooden huts like mountain sheds. Besides this, there are swings, wells, and place for a bonfire or barbecue party. Many allotments lack any facilities and only fences mark their existence.

In the suburbs of Łódź, however, allotment architecture more often takes the form of solid summer houses, or second homes. Close to urban area, large density of allotments eventually impairs natural (e.g. open space, wild vegetation) and cultural (e.g. tradition, tranquillity) values on which recreational function was originally built. In suburban areas, some second homes have become permanently occupied, thereby the recreational function of former agricultural land has eventually transformed this land into a residential area.

Urban expansion

Urbanisation is a multifaceted process, including expansion of built-up areas: residential, commercial and industrial; growth of infrastructures, development of the road network, and the spread of urban culture, including building styles, to rural areas. Urbanisation means intensification of land use that creates heterogeneous and fragmented landscapes and has high environmental impacts.

In central Poland suburban landscapes are characterised by residential housing encroaching upon rural areas. These are usually single houses standing in garden plots. Sometimes they form complexes in the countryside, situated some distance from or next to existing villages. Single houses or small groups of houses are quite often mingled with abandoned farmland or allotment plots.

Sometimes, new houses appear inside existing villages, filling empty lots or replacing old dwellings. New residential buildings chiefly introduce indistinct (universal) urban design, which has a double effect. On the one hand, new buildings contribute to the decline of traditional rural architecture, on the other, older architecture in the suburban area of Łódź represents, in general, a poor standard, having been built with some obsolete and harmful building materials, such as asbestos-cement roofing. Therefore modern houses bring some positive impacts into neglected rural regions.

Another important effect of urbanisation consists in improvements in the transport infrastructure. Central Poland,

due to its central position, is cut by two main motorways: A1 and A2 (now under construction). Fragmentation of and damage to ecological corridors is a typical effect of motorways on landscape. The upgrading of local roads, forced by motorway construction, seems equally important, as that facilitates accessibility of remote parts of the suburban zone and encourages further urbanisation.

Marks of the international climate change-related policy in landscape

The mainstream landscape change processes in central Poland, described in the previous section, have been known for quite some time, being widespread in Europe (Antrop 2004). Some of them show peculiarities related to local natural or cultural conditions, but they are on the whole driven by economic and social factors, with Europeanization, i.e. "the process of influence deriving from European decisions and impacting member states' policies and political and administrative structures" (Héritier et al., 2001), in the background. Also landscape changes that reflect efforts to curb CO₂ emissions and limit global warming can be counted as an influence of Europeanization and the EU climate-energy package.

In central Poland, landscape changes that can be associated with the energy-climate package are rare and include new landscape elements related to the introduction of renewable energy sources into energy generation. The most prominent new landscape elements are: (i) a wind power plant at Góra Kamieńsk, (ii) solar thermal collectors in Łódź, (iii) geothermal water utilisation system in Uniejów. The wind farm at Góra Kamieńsk, with a capacity of about 30 MW, consists of 15 wind turbines. They are located on the top of an artificial hill, which is a reclaimed overburden pile of a nearby lignite opencast mine. Solar thermal collectors with an active surface area of ca. 7300 m² have been already installed on roofs of about 60 blocks of flats by the "Radogoszcz-Zachód" housing cooperative in Łódź. A geothermal water system in Uniejów is used for heating of both houses and a local football field, as well as for balneology, sport and recreation (3 swimming pools).

There are also smaller, less visible, new landscape elements related to the climate-energy package. These are, however, often implemented unintentionally, without purposeful association with the international policy, but only to economise or to give profit, for example: biogas power stations using sewage waste or dump biogas, single wind turbines or solar thermal collectors, and small hydro-power stations.

According to Energy Regulatory Office data (URE 2011), as of 31st March 2011, in the Łódź Province there were: 2 sewage treatment and 4 dump biogas power stations, 72 wind power-stations, 36 hydro-electric power stations with a capacity of less than 0.3 MW, 2 hydro-electric power stations with a capacity of 1-5 MW, as well as 3 cases of implementation of co-firing. Their total productive capacity was equal to 105 MW, which is 3.8% of the country capacity.

Projection of changes in the landscape of central Poland

Until now international change-related policy has had weak impact on landscape change in central Poland. Recent mainstream landscape change processes include agriculture intensification and extensification, plus an increase in tourist and recreational forms of land use and urbanisation. These processes are likely to outweigh new drivers of landscape change in the near future.

The most probable impact of climate change policy on landscape changes in central Poland will consist of the development of small and medium-scale objects relating to renewable energy sources. These might include wind turbines and wind farms, as well as biogas power stations using agricultural waste. The number of small-scale initiatives, like solar thermal collectors or photovoltaic panels, energy efficient houses, will be growing slowly, unless support from the authorities is significantly improved. Due to a scarcity of rivers, hydroelectric power generation has little potential for future development. Bioenergy production will result in the expansion of energy crops, that could change the perception of rural landscape from an agricultural or recreational area into an energy landscape.

At a local level, the influence of international climate change-related policy on landscape is adjusted to local context and biophysical conditions. In the case of central Poland it is modified by unfavourable conditions for solar energy generation, by moderate conditions for wind and geothermal energy use, and by large deposits of

lignite and tradition (and experience) in lignite extraction and lignite-fired power plant operation. According to The Energy Policy of Poland till 2030 (2009) in the near future, the energy sector in Poland will still be dominated by coal. As a consequence of this, the rural landscape near Rogóźno and Złoczew may be endangered by lignite extraction by open-pit mining.

Projecting the future of landscapes of central Poland is fraught with uncertainty, but stronger involvement in research on landscape response to climate change is generally needed with a view to feed into spatial planning and land management.

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