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LAND USE CHANGES AND THEIR CATCHMENT-SCALE ENVIRONMENTAL IMPACT IN THE POLISH WESTERN CARPATHIANS DURING TRANSITION FROM CENTRALLY PLANNED TO FREE-MARKET ECONOMICS

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Abstract

Land use and land cover changes (LULC) and their impact on potential soil erosion, road density as transfer routes of material and water to channels as well as channel level changes were studied in three catchments (~20 km^2 each) in the central part of the Polish Western Carpathians in 1975-2015. It was hypothesised that short-term LULC changes during transition from a centrally planned to a free-market economy are sufficient to modify selected elements of the environment and that these changes can be identified in a measurable way. The analysis of aerial photographs and socio-economic data indicates that during the investigated period, the forest area increased by 20-27%, with a continuous decrease of cultivated land by 89-93% in the three catchments. LULC changes were accompanied by continuous population density growth by 29-50% and a decrease of the population dependent only on agriculture to less than 5%. Analyses confirmed the hypothesis that the environment was significantly modified due to the LULC changes. Abandonment of cultivated land, forest succession and a decrease in used road density, have resulted in lower efficiency of slope wash and sediment transport within the 4th-order catchments. This has led to an interruption of aggradation and initiated channel deepening by approximately 1 cm·year^{-1} after the introduction of a free-market economy in 1989.

Key words

LULC • human impact • socio-economic transformation • catchment • Carpathians

Introduction

Over recent decades, many mountain regions of Europe have been subjected to land use and land cover (LULC) changes associated with socio-economic transformation of rural areas (MacDonald et al. 2000; Bender et al. 2005; Rudel et al. 2005; Meyfroidt & Lambin 2011). Several reasons for this phenomena are indicated, such as relatively low agricultural production profitability (Gellrich et al. 2007; Müller et al. 2013; Pazúr et al. 2014) related to high cultivation cost due to small size of individual farms and agricultural land fragmentation (Pointereau et al. 2008; Keenleyside & Tucker 2010). Agricultural land abandonment has become a serious socio-economic problem that is accelerated by the retirement of the older generation of farmers, who are not able to cultivate the fields in a difficult mountain environment, as well as the significant migration of young people to lowlands and urban centers (Griffiths et al. 2013; Pašakarnis et al. 2013; Munteanu et al. 2014). Low soil fertility and unfavourable climatic conditions are also important factors which have caused abandonment cultivation on steeper slopes and higher elevations (Gellrich et al. 2007; Pointereau et al. 2008; Baumann et al. 2011). The European Union tries, to some extent, to mitigate land abandonment with use of the Common Agricultural Policy (CAP), the aim of which is to support environmentally beneficial farming practices and rural communities in less productive farming areas (Keenleyside & Tucker 2010).

LULC changes associated with agricultural land abandonment also have a variety of environmental consequences. Succession of vegetation can change landscape fragmentation (Bennett & Saunders 2010) and reduce soil erosion on slopes (Asselman et al. 2003; Zorn & Komac 2009; Latocha et al. 2016). Both processes increase forest stands as well as biomass and the carbon sequestration in soils (Guo & Gifford 2002; Lasanta-Martínez et al. 2005; Gellrich et al. 2007). Abandonment of agricultural fields usually reduces their connection with unpaved roads. This limits the potential sediment sources, transfer routes, flow velocities, storage and consequently flow connectivity and concentration times of water and material within catchments (Wemple et al. 2001; Tarolli et al. 2013; Latocha 2014). Complex changes in slope-channel transport frequently facilitate conversion of braided rivers to incised, single-thread channels (Kondolf et al. 2002; Liébault & Piégay 2002).

The spatial pattern of LULC changes differs markedly between mountain regions and within administrative units as a consequence of diverse historic, geographic, political and socio-economic factors (Pointereau et al. 2008). After the collapse of the communist system in Central and Eastern Europe, countries carried out land reforms to restructure the farming sector, individualise land use and privatise farmland (Kuemmerle et al. 2009; Baumann et al. 2011; Griffiths et al. 2013). Such transition from the centrally planned to a free-market economy after 1989 caused the decreased profitability of agriculture (Kozak 2010; Munteanu et al. 2014; Bucała-Hrabia 2017a, b) and led to the bankruptcy of many agricultural enterprises (Banski 2011; Müller et al. 2013). In effect, dense vegetation succession on abandoned agricultural land was observed in Czechia (Bičík et al. 2001; Kupková & Bičík 2016), Slovakia (Bezak & Mitchley 2014; Šebo & Nováček 2014), Romania (Munteanu et al. 2014) and East Germany (Baessler & Klotz 2006).

In contrast to other Central and Eastern European countries, land fragmentation and individual farming still dominated in the ownership system following World War II (WW II) in the Polish Western Carpathians (Kuemmerle et al. 2008; Soja 2008; Munteanu et al. 2014; Bański 2017). Most of this area also experienced a gradual decline in agricultural land use during that time which accelerated after the collapse of the centrally planned economy in 1989 (Kuemmerle et al. 2008; Ostafin 2009; Kozak 2010; Bucała-Hrabia 2017a). Such LULC dynamics can be characterised as a period of relative stability followed by rapid changes with potentially long-lasting effects in the society and environment (Dearing et al. 2010; Lambin & Meyfroidt 2010; Hostert et al. 2011; Price et al. 2017). Several studies have shown spatio-temporal variability of this phenomenon during the transformation period at scales of the entire Polish Carpathians (Kozak 2005, 2010; Ciołkosz et al. 2011; Kolecka et al. 2017), their subregions

(Kozak 2003; Kaim 2009; Ostafin 2009) and administrative units (Dec et al. 2009; Kolecka et al. 2015, 2016). However, environmental consequences of recent LULC changes are still not sufficiently understood, particularly at the catchment scale (Bucała 2014; Bucała--Hrabia 2017a, b).

The objective of this study was an analysis of LULC changes and their environmental effects at the catchment scale in the central part of the Polish Western Carpathians during transformation from a centrally planned to a free-market economy between 1975 and 2015. More specifically, the study aimed to understand trends and dynamics of LULC and their impact on potential soil erosion, material and water transfer to channels as well as channel bed changes. The investigated period covers three broad stages of socio-economic development: (1) 1975(77)-1986(87) – a period of centrally planned economics in the late phase of the communist system; (2) 1986(87)-2003(04) – an early phase of transformation to free-market economics; and (3) 2003(04)-2015 – a late phase of free-market economics and European Union membership. It was hypothesised that short-term LULC changes after 1989 are sufficient to modify selected elements of the environment and that these changes can be identified in a measurable way.

Study area

The Polish Western Carpathians (16,700 km^2) cover, besides the small region of the high Tatra Mountains, areas of mid- and low-mountains (the Beskid Mountains), as well as foothills and valley bottoms (Starkel 1972; Fig. 1). The foothills are traditionally the cultivation areas, with a small proportion of forest (20-30%) and 10-30% of steep slopes above 15°. The structure of cropland is dominated by cereals and root crops, such as potatoes and beetroots. The Beskid Mountains region with cultivation and animal husbandry primarily comprise forest (30-70%) and 50-80% steep slopes above 15° (Starkel 1990).

Detailed investigations were performed in three catchments of the central part of the Polish Western Carpathians: the upper Uszwica (22.7 km^2) in the Wiśnickie Foothills

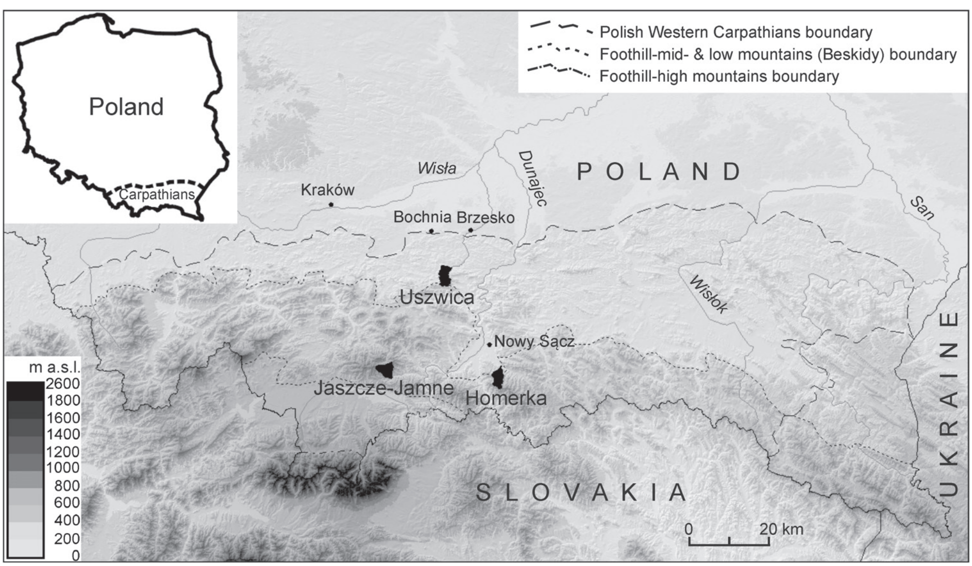

Figure 1. Study area on the background of the Polish Carpathians

Source: Authors' elaboration based on Starkel 1972.

as well as in the Homerka (19.3 km^2) and the Jaszcze-Jamne (20.3 km^2) located in the mid-mountains region of the Beskid Sądecki and the Gorce Mountains, respectively. The Jaszcze-Jamne comprises two subcatchments and forms one catchment with a similar total area to the remaining Uszwica and Homerka catchments. The catchments are representative in terms of geology, relief, soils, land use structure and history of human occupation for the central part of foothill and mid-mountain areas of the Polish Western Carpathians (Gerlach & Niemirowski 1968; Starkel 1972; Niedziałkowska 1981; Skiba et al. 1998; Soja 2002; Łajczak et al. 2014). The studied area has not experienced population displacement and then rapid LULC changes after WW II, in contrast to areas located east of the Homerka catchment (Affek 2016; Wolski 2016).

Catchments are underlined by flysch sediments (alternate sandstone and shale layers) of Silesia nappe in foothills and Magura nappe in the mid-mountains (Starkel 1972). The Uszwica catchment is characterised by wide hills rising to 300-500 m a.s.l. and relatively wide valleys dissected up to 100-300 m (Fig. 2). Gentle relief with domination of convex-concave slopes is reflected in an only 21% contribution of the steep slopes above 15°. Slopes are covered by thick weathered mantles and loess-like deposits in places. Rounded ridges (1000-1250 m a.s.l.) built of resistant sandstone, deep and narrow V-shaped valleys dissected up to 300-600 m are the main relief forms of the mid-mountain area in the Homerka and Jaszcze-Jamne catchments (Gerlach & Niemirowski 1968; Niedziałkowska 1981). Only the lower part of the Homerka catchment, with ridges up to 600 m a.s.l. consisting of marls, calcareous sandstones, and variegated shales with a minor contribution of resistant sandstones geomorphologically belongs to the foothills. Slopes are straight or convex. About 71% of the slopes have an inclination of more than 15° in these catchments.

The entire Uszwica catchment is located in a temperate warm zone with a mean annual temperature from 8 to 6°C up to 600-650 m a.s.l. (Hess 1965). The mean annual precipitation reaches about 751 mm (Gnojnik Institute of Meteorology and Water Management station – Instytut Meteorologii i Gospodarki Wodnej – IMGW at 310 m a.s.l. approximately 10 km east of the Uszwica catchment). The Homerka catchment covers a temperate warm zone as well as a temperate cool zone (4 to 6°C) above 650 m a.s.l. The catchment receives about 950 mm of precipitation annually (Frycowa Institute of Geography and Spatial Organization Polish Academy of Sciences station at 415 m a.s.l. in 1971-2010). The lower and middle part of the Jaszcze-Jamne catchment is located in a temperate cool zone between 650 and 1100 m a.s.l., while the upper part occupies a cool zone (2 to 4°C). Mean annual precipitation observed in the catchment reaches 837 mm (Ochotnica Górna IMGW station at 610 m a.s.l. in 1971-2010).

All three catchments are drained by 4th-order streams with similar annual discharge of about 0.3 $m^3 \cdot s^{-1}$ (Strahler 1952; Niemirowski 1974; Bucała et al. 2015; Authors' measurements). High precipitation, considerable slope inclinations and the dense dissection combined with low permeability of flysch bedrock limits infiltration and favours high runoff. These factors facilitate irregularities of water discharge, with two flood seasons related to spring snowmelt and heavy summer rainfalls (Dynowska 1971; Ziemońska 1973).

The silt loess-like formation supports the formation of Luvisols in the lower part of the Uszwica catchment. These soils are deep (up to 280 cm) and mainly silt loam (Skiba et al. 1998; IUSS Working Group WRB 2014; Szymański et al. 2017). In the upper part of the Uszwica catchment, shallower Cambisols are developed. In the Homerka and Jaszcze-Jamne catchments, Cambisols are dominant (Adamczyk & Komornicki 1969; Adamczyk & Słupik 1981; IUSS Working Group WRB 2014). They are deep (up to 170 cm), mainly silt clay loam with rock fragments of approximately 40-60% in the Foothill part but shallower (up to 120 cm), mainly sandy clay loam with

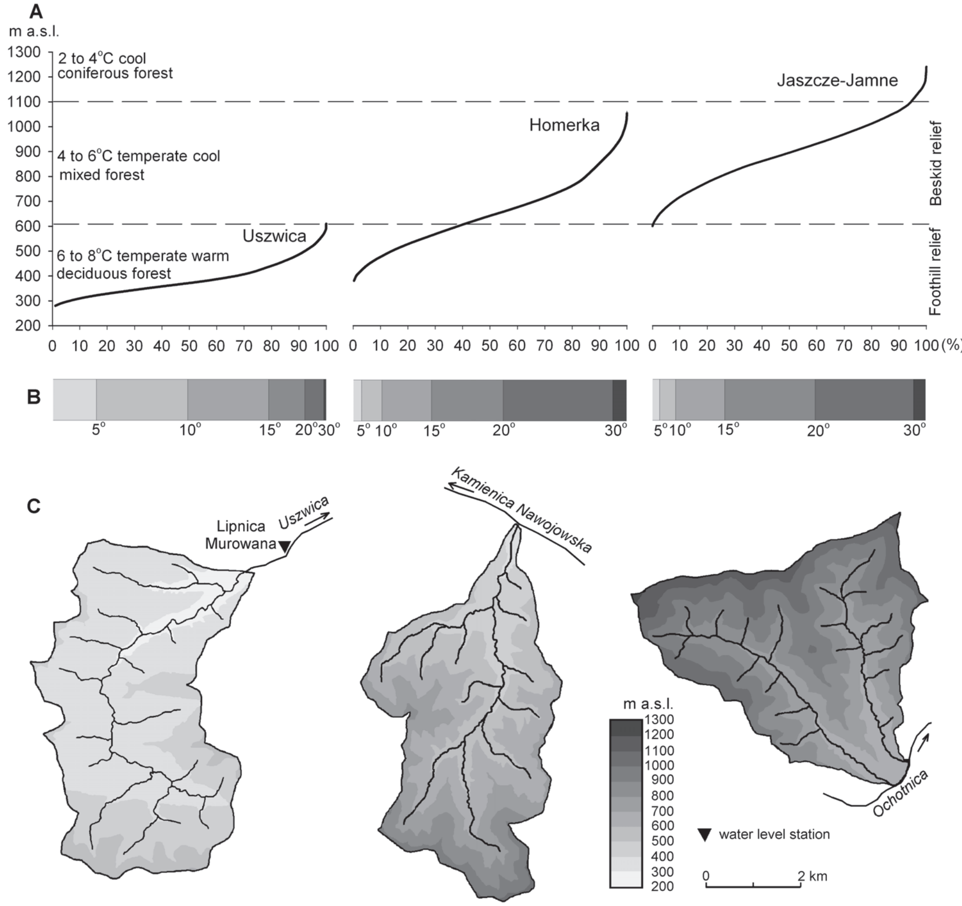

Figure 2. Study area: (A) hypsometric curves of the three catchments on the background of geomorphological units and climate-vegetation zones, (B) contributions of slope inclinations, (C) elevations in the Uszwica, Homerka and Jaszcze-Jamne catchments

Source: Authors' elaboration based on Hess (1965), Starkel (1972).

higher rock fragments of about 70-80% in the Beskid part. Only within the highest ridges built of sandstones, have sandy loam Podzols developed in the Jaszcze-Jamne catchment (Bucała et al. 2015). The valley bottoms of all catchments are covered by alluvial sandy clay soils. They are waterlogged in places in the foothill catchment.

Vertical zonation of climate is reflected in natural vegetation changes with the increase of elevation. The foothill zone is occupied mainly by deciduous forests with hornbeams, oak, lime and beech. The lower mountain zone is represented by mixed forests, such as beech, fir and spruce (Staszkiewicz 1981; Grodzińska & Szarek-Łukaszewska 1997). Coniferous forest with spruce occurs at elevations above 1100 m a.s.l. only in the highest part of the Jaszcze-Jamne catchment (Medwecka-Kornaś & Kornaś 1968). Long term, the irregular course of human activity transformed the natural vegetation that occupies mainly areas not suitable for agricultural use or settlement (Łajczak et al. 2014).

Catchments differ in terms of population and transport accessibility to the nearest urban areas. The Uszwica catchment was inhabited by 2,649 people living in the villages of Rajbrot and Lipnica Górna in 2015 (Central Statistical Office of Poland (Główny Urząd Statystyczny – GUS 1978-2015)). The catchment is well connected by roads to the nearby district town of Brzesko with a population of 17,026 in 2015, and Bochnia with a population of 30,107 in 2015, both at a distance of 25 km. The Homerka catchment is inhabited by 1,549 people living in four villages: Frycowa, Homrzyska, Bącza-Kunina and Złotne, while the Jaszcze-Jamne catchment, inhabited by 484 people in 2015 comprises hamlets of the Ochotnica Górna village. At a distance of 10 km from the Homerka catchment, Nowy Sącz city had a population of 83,903 in 2015. This is the main industrial, service and cultural centre of the Beskid Sądecki region. The Jaszcze-Jamne catchment is more isolated from urban centers at a distance of approximately 40 km from Nowy Sącz.

Material and methods

The changes in LULC in the three catchments were derived from panchromatic aerial photographs at scales of 1:8,000-16,000 for the years 1975-1977, at a scale of 1:25,000 for the years 1986-1987 and at scales of 9,000-25,000 for the years 1996-1997, as well as orthophotomaps at a scale of 1:13,000 for the years 2003-2004 and natural colour orthophotomaps at a scale of 1:5,000 for the years 2009 and 2015 from the Main Centre of Geodetic and Cartographic Documentation in Poland (Centralny Ośrodek Dokumentacji Geodezyjnej i Kartograficznej – CODGiK). Geometric corrections were performed to rectify aerial photographs using the Transverse Mercator projection system in a GIS ILWIS 3.3 environment (International Institute for Aerospace Survey and Earth Science 1997). Manual vectorisation was conducted in detailed zoom to scale at ~1:2,000. The vector data were converted to raster with 1 m spatial resolution.

In order to standardise the values of the maps from different time periods, six consistent LULC categories were defined: forests, grasslands (meadows and pastures), cultivated lands (cereals and root crops), groups of trees and shrubs, tree belts along roads and buildings. The analysis was supported by the Authors' field surveys in all three catchments between 2013 and 2016. A Digital Elevation Model (DEM) at 1 m spatial resolution (CODGiK), served to generate hypsometric curves, derivative maps of a proportion of the LULC in relation to slope inclination, as well as its changes in the 100 m classes of elevation across different time periods.

Socio-economic information such as population data for 1978, 1988, 1997, 2003, 2009, 2015 and sources of inhabitants' income (dependent only on agriculture – understood as a person whose income is directly dependent on agriculture, off-farm activities, public transfers (pensions) and unemployment) for 1978, 1988, 2002 in the three studied catchments were collected from the Central Statistical Office of Poland (1978-2015). All data were collected at village level except for 2002, for which data were collected at commune level. The information was supplemented by Authors' questionnaire surveys related to inhabitants' income conducted in 2013-2016. The survey covered 60% of the population in the Uszwica and Homerka catchments and 80% of the population in the Jaszcze-Jamne catchment.

Due to the scarcity of field measurements of soil loss in the studied catchments, potential soil erosion was calculated on the basis of measurements conducted on experimental slopes (plots) in the Polish Western Carpathians. The average of three years of soil erosion measurements under the natural forest covering a wide range of slope inclinations (0-28°) in the Jaszcze catchment (Gerlach 1976) was used for calculation of soil loss under forest in the three studied catchments. The average of thirty years of soil erosion measurements under grassland as well as cultivated land with cereals and potatoes in the Research Station of the Institute of Geography & Spatial

Organization Polish Academy of Sciences (IG&SO PAS) in Szymbark (Gil 2009) was applied to calculation of soil loss under grassland and cultivated land in the Jaszcze-Jamne and Homerka catchments. These catchments have the same soil type (Cambisol), similar annual rainfall (~850 mm), dominant slope inclination under cultivation (11-12°) and agricultural terrace length (10-30 m) as in the case of the experimental slope (plots) in the IG&SO PAS Research Station in Szymbark (Beskid Mts). The average of two years of soil erosion measurements under grassland as well as cultivated land with cereals and potatoes in the Research Station of the Institute of Geography & Spatial Management Jagiellonian University (IG&SM JU) in Łazy (Święchowicz 2012a, b) was applied to soil loss under grassland and cultivated land in the Uszwica catchment. This catchment has the same dominant soil type (Luvisol), similar annual rainfall (~750 mm), dominant slope inclination under cultivation (8°) and agricultural terrace length (up to 22 m) as in the case of the experimental slope (plots) in the Research Station IG&SM JU in Łazy (Carpathian Foothills) located 10 km north of the Uszwica catchment. Soil erosion rates under forest and grassland were used directly in the three studied catchments, while soil erosion under cultivated land was calculated as an average of soil erosion under cereals and potatoes. This reflects the typical crop rotation system in the Polish Western Carpathians (Gerlach 1976; Gil 2009).

The road network complements the river network in transport of eroded material and water during rainfall (Reid & Dunne 1984; Froehlich & Walling 1997; Latocha 2014; Kroczak et al. 2016). Therefore, road network density is an important indicator of possible transfer routes downslope, to channels and outside the catchment. A permanent river network and road network were digitized from aerial photographs for 1975(1977). Data were supported in the case of forest areas and type of pavement by interpretation of topographic maps at a scale of 1:10,000 for 1980(81) (Soja & Prokop 1996). Changes in road network in terms of used, unused (abandoned), connected to streams (crossing streams and/or ending close to the channel) as well as paved and unpaved were calculated using ortophotomaps for 2015 and verified in the three catchments during a field survey in 2016.

The impact of both LULC and road network changes on channel bed position was assessed by analysis of daily absolute minimum and maximum water levels in the Uszwica river in 2009-2017 (http://lsop.imgw.pl/brzesko/). The method was successfully applied in the Polish Carpathians (Soja 1977; Klimek 1987; Wiejaczka & Kijowska-Strugała 2015; Kijowska-Strugała & Bucała-Hrabia 2019). The use of water levels for estimation of river bed changes is less accurate than geodetic measurements; however, it provides reliable information on the direction of change (bed incision or raising) and its intensity (Wiejaczka & Kijowska-Strugała 2015). Regular water level records are rare in the 4th-order rivers, and therefore changes of river bed position were additionally measured in relation to the bridgeheads and concrete structures (gabions). The dates of their construction were collected from the Regional Water Management Authority (Regionalny Zarząd Gospodarki Wodnej – RZGW) and Poviat Road Management in Nowy Sącz (Powiatowy Zarząd Dróg w Nowym Sączu – PZD) for all catchments. Selected measurement places were not affected by river regulation or gravel mining in recent decades.

Results and Discussion

LULC changes during transition from centrally planned to free-market economics

Centrally planned economics in the late phase of the communist system in 1975(77)-1986(87)

Between 1975 and 1987, in the late phase of the communist centrally planned economy, the apparently prominent feature was the highest contribution of cultivated land in the LULC structure (Fig. 3; Tab. 1). It was accompanied by the high location of cultivated

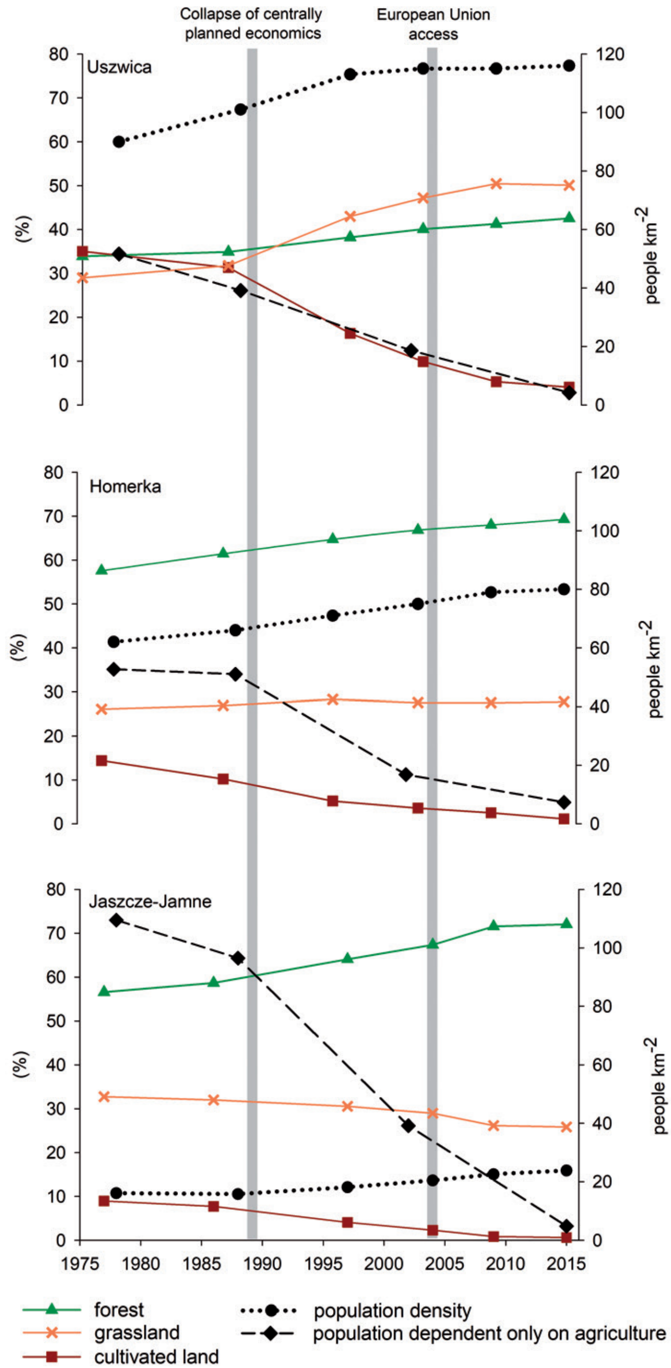

Figure 3. LULC, population density and population dependent only on agriculture changes in the three catchments for 1975(77)-2015

Source: Authors' elaboration based on data from Table 1.

Table 1. LULC changes (%), population density (people km^{-2}) and population dependent only on agriculture (%) in the Uszwica, Homerka and Jaszcze-Jamne catchments for 1975(77)–2015

Uszwica	1975	1987	1997	2003	2009	2015
Forest	33.90	34.88	38.22	40.08	41.27	42.52
Cultivated land	35.01	31.30	16.30	9.90	5.31	4.04
Grassland	28.97	31.76	42.97	47.16	50.42	50.07
Building	0.59	0.61	0.85	0.93	0.95	0.99
Group of trees and bushes	1.20	1.12	1.16	1.34	1.49	1.75
Tree belt along road	0.33	0.33	0.50	0.59	0.56	0.63
Population density *	90	101	113	115	115	116
Population dependent only on agriculture **	51.60	39.10	-	18.60	-	4.20
Homerka	1977	1987	1996	2003	2009	2015
Forest	57.56	61.43	64.71	66.83	68.00	69.23
Cultivated land	14.40	10.22	5.19	3.57	2.50	1.10
Grassland	26.10	26.92	28.31	27.55	27.54	27.75
Building	0.21	0.24	0.35	0.37	0.38	0.42
Group of trees and bushes	1.29	0.97	0.92	1.11	0.97	0.88
Tree belt along road	0.44	0.22	0.52	0.57	0.61	0.62
Population density *	62	66	71	75	79	80
Population dependent only on agriculture **	35.1	34.0	-	11.2	-	4.9
Jaszcze-jamne	1977	1986	1997	2004	2009	2015
Forest	56.58	58.66	64.06	67.35	71.52	72.03
Cultivated land	8.94	7.71	4.08	2.32	0.87	0.64
Grassland	32.71	31.97	30.53	28.96	26.16	25.83
Building	0.19	0.21	0.25	0.28	0.33	0.34
Group of trees and bushes	1.20	1.07	0.72	0.66	0.81	0.85
Tree belt along road	0.38	0.38	0.37	0.43	0.31	0.31
Population density *	16	16	18	20	23	24
Population dependent only on agriculture **	73.0	64.3	-	26.1	-	3.2

* - data for 1978, 1988, 1997, 2003, 2009, 2015 (Central Statistical Office)

** - data for 1978, 1988, 2002 (Central Statistical Office), 2013-2016 (Authors' questionnaire surveys)

Source: Authors' elaboration based on Central Statistical Office and questionnaire surveys.

land, covering the entire Uszwica catchment and reaching 800-900 m a.s.l. and 1000-1100 m a.s.l. in the Homerka and Jaszcze-Jamne catchments, respectively (Fig. 4). Cultivated land occurred even on the steepest slopes > 15° (Fig. 5). The forest dominated (contribution > 50%) above 500 m a.s.l. in the upper part of the Uszwica catchment, as well as above 600 m a.s.l. and 800 m a.s.l. in the middle and upper parts of the Homerka and Jaszcze-Jamne catchments, respectively. Slopes > 15° in the Uszwica and Homerka

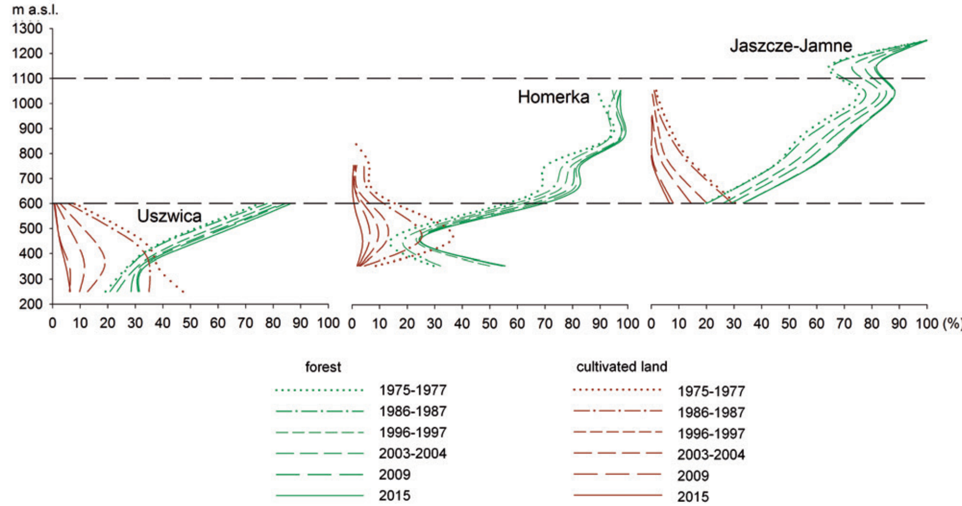

Figure 4. Changes in the proportion of forest cover and cultivated land with elevation of each 100 m altitude class in the three catchments for 1975(77)-2015

catchments, and > 10° in the Jaszcze-Jamne catchment, were mostly covered with forest (contribution > 50%).

The population density was smallest with simultaneously the highest contribution of people depending only on agriculture, which exceeded 50% of the total population in the Uszwica and Jaszcze-Jamne (Fig. 3; Tab. 1). The exception was the Homerka catchment, where most of the inhabitants worked outside the agricultural sector, mainly in Nowy Sącz (Bucała-Hrabia 2017a; Authors' questionnaire surveys 2013-2016).

Until 1987, the LULC structure was not changed substantially. However, there became apparent trends of a gradual increase in forest area by 2.9-6.7% and a decrease in the cultivated land area by 10.6-29.0% in the three catchments (Tab. 1). At the same time, the upper boundary of cultivated land was lowered by 100 m in the Homerka catchment (Fig. 4). Increasing population density was accompanied by significant changes in income sources. The number of people dependent only on agriculture has decreased (Fig. 3; Tab. 1), while public transfers have significantly increased from 13.2 to 19.3% in the Uszwica catchment, from 13.1 to 17.4% in the Homerka catchment and from 3.2 to 12.2% in the Jaszcze-Jamne catchment (Central Statistical Office 1978-2015).

The gradual cessation of cultivation and the decreased number of people dependent only on agriculture resulted from development of income sources outside of the agricultural sector (industry, building construction) and from the change in policy of the communist government in relation to the farmers (Bucała-Hrabia 2017a, b). In 1972, compulsory deliveries were abolished. For the first time, farmers and their families were provided with free health care and they were also granted the right to a pension (Bański 2010; Machałek 2013).

An early phase of transformation to free-market economics in 1986(87)-2003(04)

The highest dynamic of LULC change was observed in this period, particularly up to 1997. The increase in forest cover ranged from 8.8-14.9%, while the decrease in cultivated land area reached 65.1-69.9% (Fig. 3; Tab. 1). The increase in forest area was the largest on the steepest slopes > 15°. The fastest

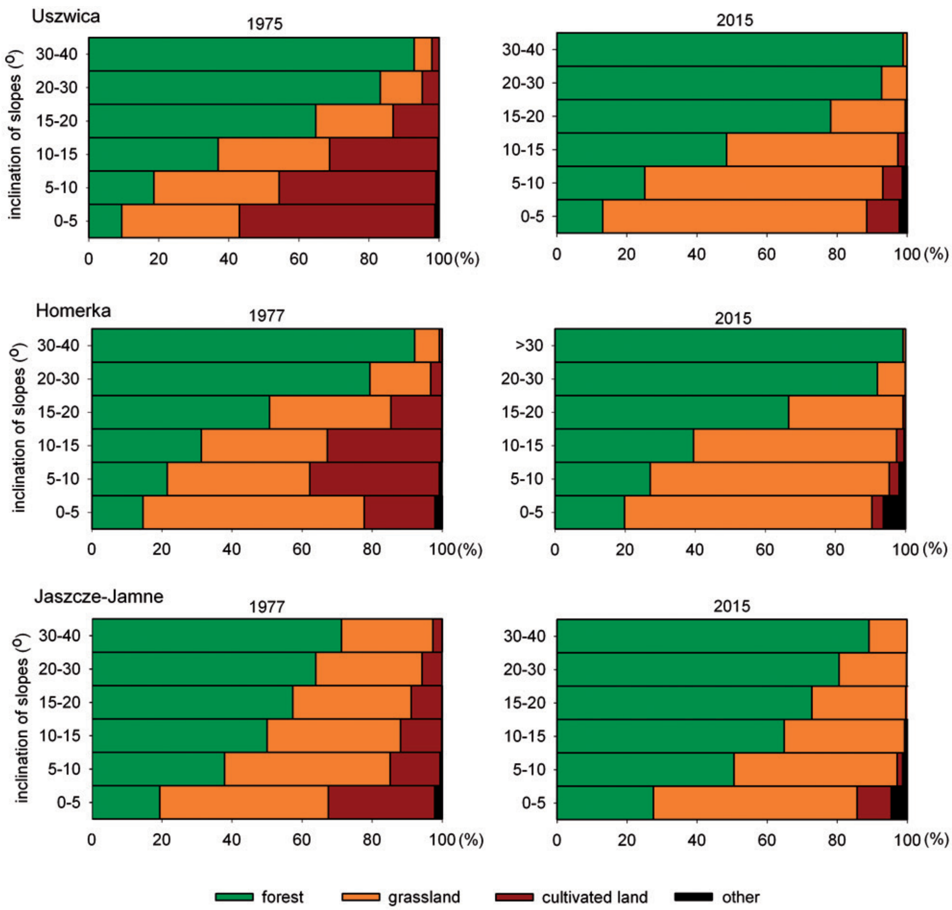

Figure 5. LULC changes in slope inclinations in the three catchments in 1975(77)-2015

decline in cultivated land area occurred in the lower parts of the catchments and on the steepest slopes > 15°. The upper boundary of cultivated land was lowered by 100 m, to below 1000 m a.s.l. in the Jaszcze-Jamne catchment (Fig. 4).

A faster decline in cultivation land compared to forest expansion results from the different succession rate of secondary vegetation. An abandoned cultivated field is overgrown with dense grass usually within two years in the mid-mountains (Kostuch 2003). The transformation of grassland into forest is slower and usually takes up to 15 years for tree germination, and conversion of shrubs into high trees (Tasser et al. 2007).

Changes in LULC were accompanied by a rapid population density increase by 14% in Uszwica and Homerka catchments and by 25% in the Jaszcze-Jamne catchment in 1986(87)-2003(04). This was the largest increase in the entire investigated period (1975-2015) (Tab. 1). At the same time, the number of people dependent only on agriculture has decreased to below 20-30% in all catchments (Fig. 3; Tab. 1). For the first time in history since WW II, a group of unemployed who are able to work has appeared, constituting 13-23% of the population (Central Statistical Office 1978-2015).

Rapid cultivated land abandonment was related to a fast decline in the profitability of agricultural production after the collapse of the centrally planned economy. It was a result of depriving the farmers of special budgetary subsidies for farms in the mountains and the promulgating of a 1988 statute on individual economic entities, which supported the development of activities other than agriculture (Górz 2002, 2003).

A late phase of free-market economics and European Union membership 2003(04)-2015

The period is characterised by slower changes of LULC with forest expansion by 3.6-6.9% and reduction of cultivated land by 59.2-72.4% (Fig. 3; Tab. 1). The upper boundary of cultivated land was again lowered by 100 m to below 900 m a.s.l. in the Jaszcze-Jamne catchment. The forest dominated (contribution > 50%) in the upper part of the Uszwica catchment, above 400 m a.s.l. as well as in the middle and upper parts of the Homerka and Jaszcze-Jamne catchments over 500 m a.s.l. and 700 m a.s.l., respectively. It is on average lower by 100 m compared to the period before the economic transformation. The cultivated land disappeared from steep slopes > 20° in all catchments. Only single cultivated fields remained on the slopes > 15°. Forest succession and cultivated land abandonment caused the gradual shift of the forest-agriculture boundary close to its natural location 600-800 m a.s.l., that is limited by climatic parameters (i.e. +6°C annual average isotherm (Adamczyk et al. 1980; Starkel & Obrębska-Starklowa 2005)) and are in accordance with the concept of rational land use in various types of Polish Carpathian reliefs (Starkel 1975; Starkel et al. 2007). The position of the forest-agriculture boundary may differ locally from given elevations as a result of soil fertility and related agricultural land use pattern. In such cases, the course of the boundary is less dependent on annual temperature, but its position does not fall below the course of the +6°C annual average isotherm.

The increase in population density slowed to 1-20%. The contribution of population depending only on agriculture fell to less than 5% (Tab. 1). The main sources of income for inhabitants were off-farm activities (e.g. construction, services, agrotourism (Bucała-Hrabia 2017a, b)). About 52% of the Homerka catchment inhabitants worked in Nowy Sącz, while about 29% of the Uszwica catchment inhabitants were employed in the neighbouring Bochnia and Brzesko towns. The peripheral location of the Jaszcze-Jamne catchment meant that its inhabitants found work outside of urban centers, mainly in the Ochotnica Dolna community. In addition, a further increase of public transfers was observed to 21-24% in the Uszwica and Homerka catchments and to 38% in the Jaszcze-Jamne catchment (Authors' questionnaire surveys 2013-2016).

Between 2004 and 2015, reduced area of LULC change resulted mainly from already abandonment of most of the cultivated land and the rising role of forest succession (Kolecka et al. 2017). CAP as a new form of agricultural support also facilitated stabilization of LULC. The subsidies for mowing the grasslands were used by twice as many people in the mid-mountain catchments (12%) in comparison with the foothill catchment (6%) in 2016 (Authors' questionnaire surveys 2013-2016). However, the scale and effects of CAP are not as significant compared to the Polish part of the Sudety Mountains, abandoned long ago and currently undergoing recovery (Latocha 2016).

General trends in LULC change 1975(77)-2015

The conducted analysis revealed continuous increase of forest area by 20-27%, continuous decrease of cultivated land by 89-93% in 1975(77)-2015 (Fig. 3; Tab. 1). Grasslands area underwent complex changes associated with a decrease due to forest succession or increase in effect of cultivated land abandonment. These three LULC types covered approximately 98% of each catchment.

A small contribution of trees and bushes as well as tree belts along roads was observed in all catchments in each of the studied periods. Building area showed a continuous increase, although the surface did not exceed 1% in each catchment. LULC changes were accompanied by continuous population density growth by 29% in the Uszwica and Homerka catchments and by 50% in the Jaszcze-Jamne catchment between 1975 and 2015. In contrast, the population dependent only on agriculture decreased from 52% in the Uszwica catchment, 35% in the Homerka catchment and 73% in the Jaszcze-Jamne catchment to less than 5% in all catchments in the same period. General LULC changes, with highest dynamics in 1986(87)-2003(04), confirm trends observed during transition from a centrally planned to a free-market economy at scales of the entire Polish Carpathians (Kozak 2010; Ciołkosz et al. 2011; Kolecka et al. 2017), geographical subregions (Kozak 2003; Ostafin 2009), administrative units (Kolecka et al. 2015, 2016) and catchments (Kijowska-Strugała 2015; Bucała 2014; Bucała-Hrabia 2017ab).

LULC stability in 1975(77)-2015

The majority area of the three catchments was not subject to any LULC change during the 1975(77)-2015 period (Fig. 6; Tab. 2). The stable land use area mainly comprises a large complex of forest at highest elevations and less accessible steepest slopes, and core areas of large grasslands located along valley bottoms. Cultivated lands were the least stable form of land use throughout the considered period. Therefore, catchments with highest contribution of forest and lowest contribution of cultivated land shows highest LULC stability (i.e. 59.4%, 69.5% and 70.7% in the Uszwica, Homerka and Jaszcze-Jamne catchments, respectively).

In each of the periods after the early phase of the introduction of a free-market economy (after 1996), there was a gradual increase of the stable land use in the three catchments. This was an effect of the cultivated land abandonment (conversion cultivated land to grassland) and forest succession on agricultural land (grassland and cultivated land). The increase of the stability of land use was also correlated with a decrease of the population dependent only on agriculture. This was noted despite the population growth in the each of the studied catchments.

Results of analyses indicate that spatio-temporal changes of LULC revealed a similar pattern in the three catchments during the socio-economic transformation period. The upper part of the catchments is dominated by stable forest. The valley bottoms, wider in the foothills and narrower in the mid-mountains, are dominated by stable grasslands. Between these two areas with relatively stable land use, changes associated with the abandonment of cultivated land and forest succession prevail. Their characteristic features are non-linear changes with dominance of cultivated land abandonment in the lower parts of the valleys and on their gentler slopes as well as dominance of forest succession in the upper parts of the valleys and steeper slopes (Fig. 7). A similar pattern of LULC changes has been observed in the Alpine region (Netting 1972; Netting 1981; Taillefumier & Piégay 2003) and Polish Carpathians (Kozak 2003, 2010).

Environmental consequences of LULC change in 1975(77)-2015

Potential soil erosion

Studies on experimental plots have demonstrated that the slope wash increases from 0.0068 $t \cdot ha^{-1} \cdot year^{-1}$ under the natural forest in the Jaszcze catchment (Gerlach 1976) to 0.048 $t \cdot ha^{-1} \cdot year^{-1}$ under grasslands, 0.396 $t \cdot ha^{-1} \cdot year^{-1}$ under cereals and 25.666 $t \cdot ha^{-1} \cdot year^{-1}$ under potato cultivation in the Beskid Mts. (Gil 2009). Similar results were obtained for the Łazy IG&SM JU Research Station in the Carpathian Foothills (i.e. 0.259 $t \cdot ha^{-1} \cdot year^{-1}$ under grasslands, 0.609 $t \cdot ha^{-1} \cdot year^{-1}$ under cereals and 21.953 $t \cdot ha^{-1} \cdot year^{-1}$ under potato cultivation (Święchowicz 2012a, b)). Based on the

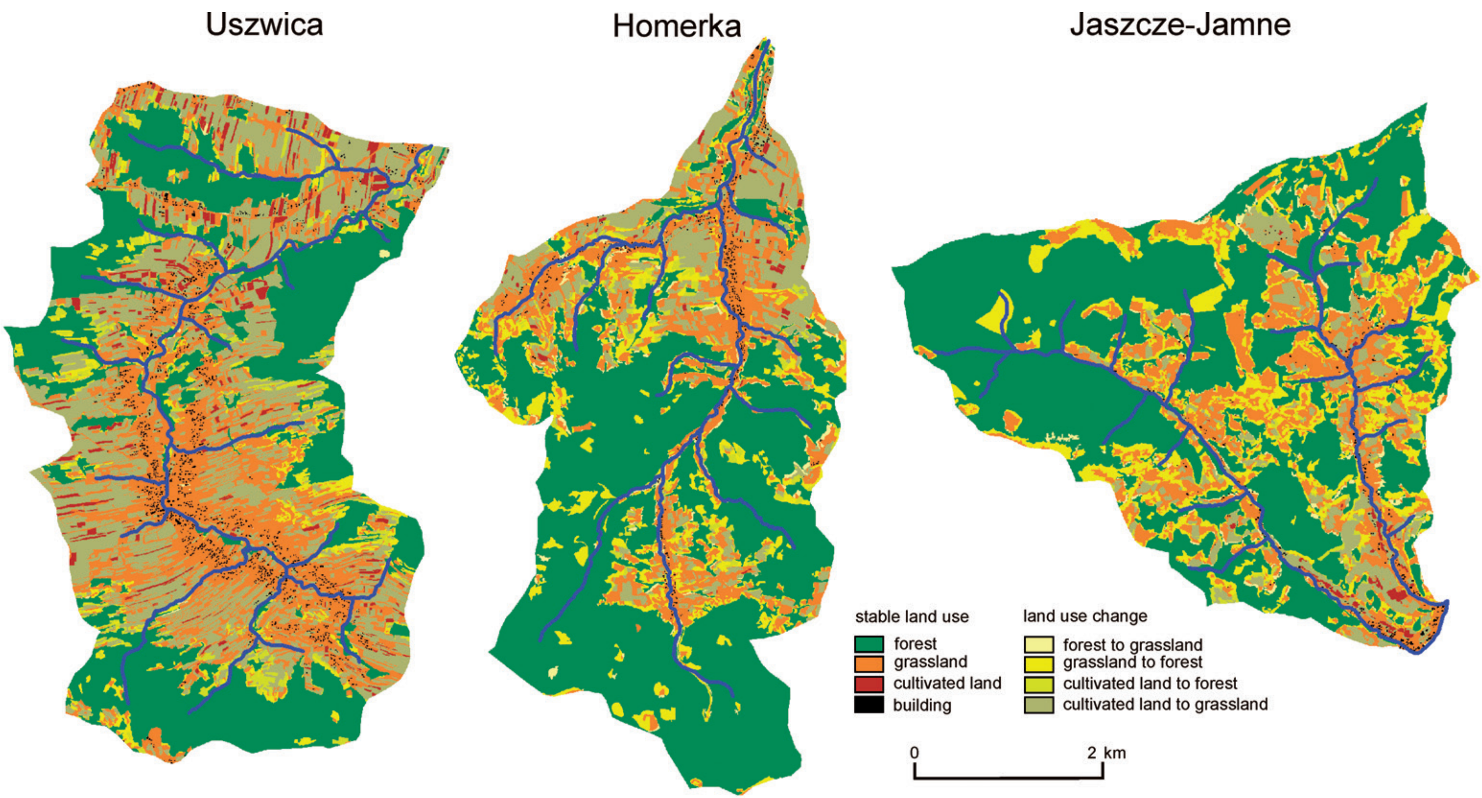

Figure 6. Map of stable land with predominant types of LULC changes in the three catchments in 1975(77)-2015

Table 2. Stable land with predominant types of LULC changes (%) in the Uszwica, Homerka, Jaszcze-Jamne catchments for 1975(77)-2015

Uszwica catchment	1975-1987	1987-1997	1997-2003	2003-2009	2009-2015	1975-2015
Without changes	90.55	73.17	82.03	87.35	87.67	59.35
Forest to grassland	0.17	0.29	0.15	0.05	0.21	0.26
Grassland to forest	0.84	2.31	1.70	1.13	1.35	4.85
Cultivated land to forest	0.24	1.05	0.17	0.03	0.01	3.52
Cultivated land to grassland	4.68	16.94	9.55	6.43	4.21	27.28
Homerka catchment	1977-1987	1987-1996	1996-2003	2003-2009	2009-2015	1977-2015
Without changes	76.06	79.14	90.02	92.40	92.52	69.45
Forest to grassland	3.21	2.87	0.35	0.59	0.55	1.85
Grassland to forest	6.08	5.44	2.41	1.60	1.67	10.68
Cultivated land to forest	0.93	0.55	0.04	0.03	0.03	2.15
Cultivated land to grassland	6.93	6.87	3.27	1.99	2.13	11.20
Jaszcze-jamne catchment	1977-1986	1986-1997	1997-2004	2004-2009	2009-2015	1977-2015
Without changes	80.95	75.76	87.17	90.29	97.55	70.67
Forest to grassland	4.35	4.51	2.26	0.95	0.00	2.32
Grassland to forest	6.12	9.25	5.19	4.68	0.48	15.60
Cultivated land to forest	0.46	0.83	0.22	0.07	0.32	1.23
Cultivated land to grassland	2.97	4.75	2.29	1.58	0.00	6.94

mentioned field measurements under different land use types and land use structure in each of the studied catchments, the average potential soil erosion was calculated at 4.03 $t \cdot ha^{-1} \cdot year^{-1}$ in the Uszwica catchment, 1.90 $t \cdot ha^{-1} \cdot year^{-1}$ in the Homerka catchment and 1.19 $t \cdot ha^{-1} \cdot year^{-1}$ in the Jaszcze-Jamne catchment for 1975(77). The highest soil erosion intensity in the Uszwica catchment is related to greater susceptibility to erosion of soils developed on loess-like deposits and highest agricultural land contribution. Results correspond to an average soil loss estimated at 1.48 $t \cdot ha^{-1} \cdot year^{-1}$ (denudation rate 0.072 mm) for foothills and mid-mountains of the Polish Carpathians in 1969-2000 (Gil 2009). Calculated potential soil erosion rates for 2015 were lower by 85%, 93% and 92% in the Uszwica, Homerka and Jaszcze-Jamne catchments, respectively.

Confirmed lack of statistically significant changes in precipitation trends, as well as small impact of land management practices on soil erosion in the Polish Carpathians in the 19th and 20th centuries (Wypych & Ustrnul 2016; Kijowska-Strugała et al. 2018), indicate that changes of soil erosion are closely related to changes of LULC structure in the catchments. This is clearly visible in the case of cultivated land area that was reduced from 89% in the Uszwica catchment to 92% in the Homerka and 93% Jaszcze-Jamne catchments between 1975(77) and 2015. A predominant role of LULC structure on soil erosion is confirmed also by long-term analysis using the Revised Universal Soil Loss Equation (RUSLE) model for the Homerka catchment (Kijowska-Strugała et al. 2018). The estimated soil erosion was reduced by 77% from 18.13 $t \cdot ha^{-1} \cdot year^{-1}$ in 1846 when cultivated land contribution reached 30.3% to 4.11 $t \cdot ha^{-1} \cdot year^{-1}$ in 2009 when contribution of cultivated land decreased to only 2.5% of the catchment. The most significant

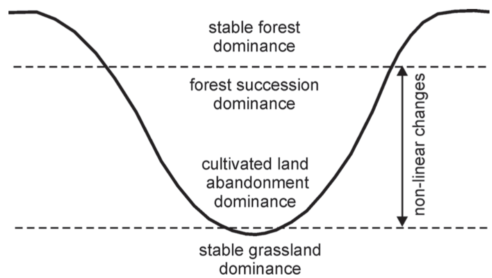

Figure 7. Model of LULC changes for the 4th-order catchments in the central part of the Polish Western Carpathians during transformation from centrally planned to free market economics in 1975(77)-2015

decrease in soil erosion occurred on slopes where former cultivated land was abandoned and turned into grasslands and forests (Kijowska-Strugała et al. 2018).

However, the comparison of soil erosion rates calculated using the RUSLE model with the slope wash measurements in the same Bystrzanka catchment (experimental slope in Szymbark IG&SO PAS Research Station) indicates that the RUSLE model overestimates soil losses by 2.9 times (Gil 2009; Demczuk & Gil 2009). Application of a 2.9 reduction factor to results obtained using RUSLE in the Homerka catchment caused reduction soil erosion rates to only 1.40 $t \cdot ha^{-1} \cdot year^{-1}$ in 2009 (Kijowska-Strugała et al. 2018). This value is closer to soil erosion rates (0.13 $t \cdot ha^{-1} \cdot year^{-1}$ when cultivated land decreased to 1.10%) calculated on the basis of land use structure method for the Homerka catchment for 2015 in this paper.

Roads network

Rising population and hungry for land in the Polish Western Carpathians caused agricultural land fragmentation and connection of small parcels with a dense road network (Bucała et al. 2014; Kroczak et al. 2016). While permanent river network density varies from 2.2 in the Uszwica catchment to 3.0 in the Homerka and 3.7 $km \cdot km^{-2}$ in the Jaszcze-Jamne catchments, the road network varied from 13.0 to 10.9 and 7.0 $km \cdot km^{-2}$ in the same catchments respectively in 1975(77) (Fig. 8). Therefore, in the foothills, the lowest density of the river network was compensated by the highest density of roads.

Analysis of aerial photographs showed that all cart roads connected cultivated fields and grasslands (meadows and pastures) at the end of the 1970s. Therefore, it was assumed that almost all roads were used at that time. Topographic maps indicated that over 95% of them were unpaved in all investigated catchments at the end of the 1970s. Unpaved roads crossing streams and/or ending close to the channel are a source and transfer route of eroded material and water from cultivated fields to rivers. According to Froehlich (1982) and Froehlich and Słupik (1986), used and unpaved roads in the Homerka catchment contribute up to 90% of the suspended material transported by rivers and during flood events, and the road network delivers 60% of rainfall water to channels. The suspended sediment load concentration measured on the unpaved roads was also several times higher than in the Homerka stream. This relationship was confirmed in the Bystrzanka catchment (13.0 km^2) located in the Beskid Mts. during heavy rainfall events (Kijowska-Strugała 2015). In particular, the roads that have a connection with streams are an important source of suspended sediment transported from slopes to rivers (Froehlich 1982; Reid & Dunne 1984; Froehlich & Walling 1997). This type of road accounted for 30% of total roads in the Uszwica catchment, 50% in the Homerka catchment and 61% of the Jaszcze-Jamne catchment in the 1970s.

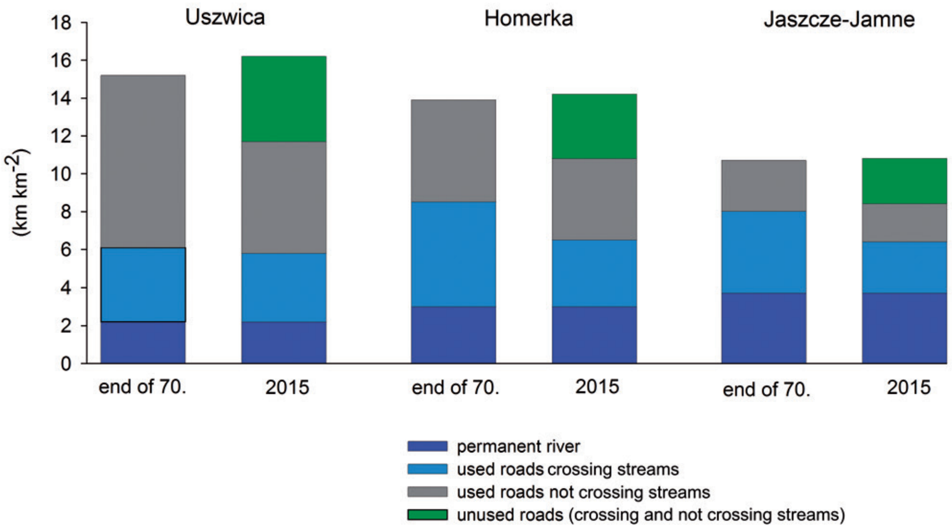

Figure 8. Permanent rivers and road density in the three catchments during 1975(77)-2015

Between 1975(77) and 2015, LULC and population changes caused significant modification of the spatial pattern of the roads network and its surface. Abandonment of the agricultural land started cessation of the access roads to the fields, mainly on cultivated slopes but also in forest. Simultaneous increase of the population and settlement development led to construction of the new roads and their pavements, mainly in the valley bottoms. Such processes initiated a change of the LULC structure of roads, and thus their role in the transfer of water and sediment within the catchment. The density of roads slightly increased by 8%, 4% and 1% in the Uszwica, Homerka and Jaszcze-Jamne catchments, respectively. However, the density of used roads decreased by 27%, 28% and 33% in the same catchments. Significant was also the decrease of the roads used density that have a connection with streams by 8% in the Uszwica catchment and almost by 37% in the Homerka and Jaszcze-Jamne catchments (Fig. 8).

During heavily rainfalls, the transfer of water is additionally intensified by pavement roads and buildings. Those impermeable surfaces increased their contribution by about 100% (assuming a 5 m width of the main pavement road) in all three catchments in 1975(77)-2015. They usually cover bottoms of valleys and slopes with a smaller inclination (i.e. areas more valuable for rainwater infiltration and retention). Paved roads facilitate water transfer because their runoff coefficient (0.95) is higher than any other LULC type (Radwan-Dębski 1995). In contrast, paved roads are an insignificant source of sediment that produce less than 1% of sediment in comparison to unpaved roads (Reid & Dunne 1984).

Present-day roads' density in the studied catchments, however, remains still much higher than the density of the permanent river network or density of roads in most mountains of the world, estimated at 2 km·km^{-2} (Wemple et al. 2001; Takken et al. 2008). The unused roads overgrown with dense vegetation are well visible in the landscape of the three catchments. According to Reid and Dunne (1984), abandoned roads produce 130 times less sediment than intensively used roads. Observations in catchments confirmed that during heavy rainfalls, unused roads produce and transport less sediment, but they still play an important role in water transfer downslope. Such different roles of abandoned unpaved and used unpaved roads in material and water transfer were visible several times during heavily rainfall in the Homerka and Jaszcze-Jamne catchments (Fig. 9).

located 5 km upstream of the gauging station (Fig. 9). A similar rate of the Homerka channel downcutting was observed, 4 km above its outlet to Kamienica Nawojowska river, along suspended gabions (i.e. 1.2 cm·year^{-1} in 1999-2016). Measurements near suspended

Figure 9. (A) Suspended sediment on the roads during heavy rainfalls: A1 – unused unpaved road, used unpaved road, paved road in the Jaszcze-Jamne catchment during continuous rainfall of 82 mm 24 h^{-1} in 15.05.2014, A2 – unpaved used road in the Homerka catchment during local downpour of 30 mm 2 h^{-1} in 28.07.2016, (B) River beds' position in relation to suspended bridgeheads and concrete structures: B1 – suspended bridgehead in the Uszwica stream, B2 – suspended gabion in the Homerka stream

River bed level changes

Measurements indicate that the 4th-order channel incision dominates in each of the three investigated catchments in recent decades. In the Uszwica river, the decreasing daily absolute minimum water levels recorded at Lipnica Murowana reveal about 1 cm·year^{-1} downcutting in 2009-2017 (Fig. 10). Results correspond with the estimated river bed incision rate at approximately 0.9 cm·year in 1989-2016 near suspended bridgeheads bridgeheads in the Jamne channel also indicated a bed incision of 1 cm·year^{-1} in the period 1969-2008 (Bucała 2014; Bucała et al. 2015). Repeated measurements confirmed further the Jamne channel downcutting with the same rate in 2008-2014. The incision trend of the Jamne stream also corresponds with changes of the Ochotnica channel at Tylmanowa (Kijowska-Strugała & Bucała-Hrabia 2019). This 5th-order river drains the area of 107.6 km^2 of the Gorce Mountains, including the Jaszcze-Jamne

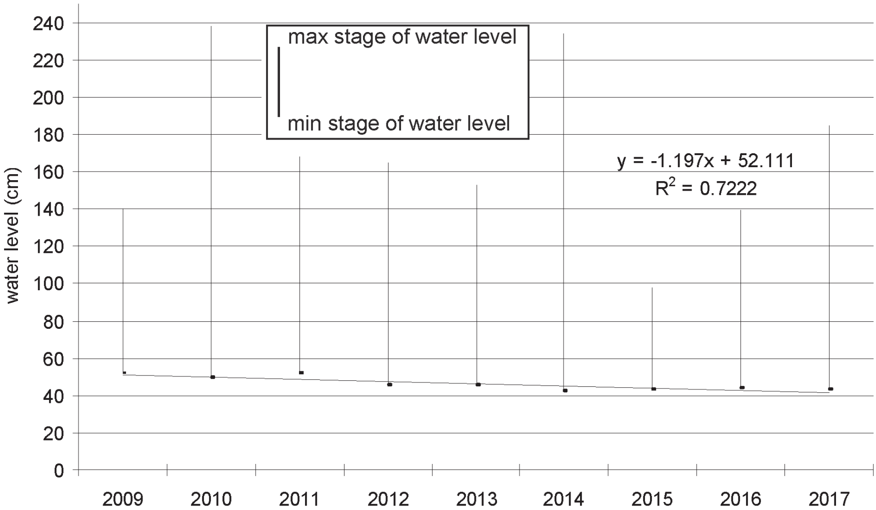

Figure 10. Daily absolute minimum and maximum water stage in the Uszwica river for 2009-2017

Source: Authors' elaboration based on data from http://lsop.imgw.pl/brzesko/.

catchment. Analysis of daily absolute minimum water levels indicates that the Ochotnica channel had an aggradation with an average rate of 3.9 cm·year^{-1} in 1972-1996 (the period with high contribution of the cultivated land), while incision with an average rate of 3.2 cm·year^{-1} in 1997-2011 (the period of rapid decrease of cultivated land). Simultaneously, the same study revealed no statistically significant changes of flood frequency between 1972 and 2011.

Observations at subcatchment scale, however, indicate that despite the rapid cultivated land and road abandonment after 1989, the past land use structure still has a noticeable impact on contemporary suspended sediment concentration in streams. This was clearly visible during the two floods registered on 11.7.2013 (local downpour of 21.2 mm 4 h^{-1}) and 15.5.2014 (continuous rainfall of 82 mm 24 h^{-1}) in the Jaszcze-Jamne catchment (Fig. 6 and Fig. 9). Jamne stream draining subcatchment with high contribution of cultivated land in the past compared to Jaszcze stream, had both higher concentration of suspended sediment by 130% and higher fine particles contribution eroded from cultivated land in the past.

The presented impact of LULC change on downcutting of upper courses of the rivers complement observations from the middle and lower courses of the Polish Carpathian rivers that incision was mainly related to channel regulation and gravel mining in the second half of the 20th century (Wyżga 2001; Wyżga et al. 2016). However, the impact of LULC change on flood regime is more complex than in the case of eroded material transport at catchment scale. Increase of forest cover can reduce flood peaks, while expansion of impermeable surfaces (houses, roads) can increase flood peaks at the same time (Rogger et al. 2017). Therefore, the expected reduction in the frequency of floods due to channel incision is not always observed (Łajczak 2007; Kijowska-Strugała & Bucała-Hrabia 2019), because probably culmination water levels tend to increase in effect of higher concentration and greater velocity of flood-waves (Łajczak 2007; Wiejaczka & Kijowska-Strugała 2015; Kijowska-Strugała & Bucała-Hrabia 2019).

Conclusions

LULC structure in the three catchments reflected diversity of environmental conditions with overlapped effects of human activity in different socio-economic systems. A common feature of catchments was a lower contribution of forests and a higher contribution of agricultural land as well as a higher population density in the foothill catchment compared to both catchments in the mid-mountains. Despite the different environmental (climate, relief, soil), and socio-economic (population density, sources of income, distance to urban centers) conditions of the catchments and their inhabitants, the general spatio-temporal trends of LULC change over time were similar.

In a centrally planned economy, anthropogenic pressure on the environment limits the role of environmental factors, which was reflected in the increase of the forest-agriculture boundary above its climate-conditioned (locally modified by land use pattern) elevation and the cultivation of marginal land with steep slopes. The largest decrease of cultivated land and increase of forest occurred just after the collapse of communism in 1989 but before Poland's accession to the European Union in 2004. At the same time, it was the period with the largest increase of population density and the largest decrease of population dependent only on agriculture. The most significant land use changes occurred on the slopes between the valley bottoms occupied by stable grasslands and the upper parts of the catchment overgrown by stable forest. Forest succession and cultivated land abandonment caused the gradual decrease of the forest-agriculture boundary close to its natural, climatically conditioned location as well as the modification of the LULC structure that is closer to the concept of sustainable development of the mountain areas. Therefore, the free-market economy has increased the impact of environmental factors on the shaping of the LULC structure as well as its stability.

Conducted analyses confirmed the hypothesis that the environment was significantly modified by LULC changes. Alterations in cultivated land area most quickly and clearly reflected the transformation of the socio-economic system. This type of land use can be used as an indicator of short-term (decadal) changes in anthropogenic pressure. Abandonment of cultivated land, forest succession and a decrease in used road density, have resulted in lower efficiency of slope wash and sediment transport within 4th-order catchments. This has led to an interruption of aggradation and initiated channel deepening by approximately 1 cm·year^{-1} during the socio-economic transformation after 1989. The water transfer in the slope-channel system is complex and does not always lead to reduction in the frequency of floods due to channel incision.

Editors' note:
Unless otherwise stated, the sources of tables and figures are the authors', on the basis of their own research.

References

ADAMCZYK B., KOMORNICKI T., 1969. *Charakterystyka gleboznawcza dolin potoków Jaszcze i Jamne.* Studia Naturae, Ser. A, 3, pp. 102-153.

ADAMCZYK B., GERLACH T., OBRĘBSKA-STARKLOWA B., STARKEL L., 1980. *Zonal and azonal aspects of the agriculture-forest limit in the Polish Carpathians*. Geographia Polonica, vol. 43, pp. 71-84.

ADAMCZYK B., SŁUPIK J., 1981. *Gleby* [in:] L. Starkel (ed.), Warunki naturalne zlewni Homerki i jej otoczenia, Dokumentacja Geograficzna, no. 3, pp. 51-72.

AFFEK A., 2016. *Past Carpathian landscape recorded in the microtopography.* Geographia Polonica, vol. 89, no. 3, pp. 415-424.

ASSELMAN N.E.M., MIDDELKOOP H., VAN DIJK P.M., 2003. *The impact of changes in climate and* *land use on soil erosion, transport and deposition of suspended sediment in the River Rhine.* Hydrological Processes, vol. 17, no. 16, pp. 3225-3244.

Baessler C., Klotz S., 2006. *Effects of changes in agricultural land-use on landscape structure and cultivated weed vegetation over the last 50 years*. Agriculture, Ecosystems & Environment, vol. 115, no. 1-4, pp. 43-50.

Bański J., 2010. *Rozwój gospodarki rolnej w Polsce* [in:] J. Bański (ed.), Atlas Rolnictwa Polski, Warszawa, pp. 25-37.

Bański J., 2011. *Changes in agricultural land ownership in Poland in the period of the market economy.* Agricultural Economics, vol. 57, no. 2, pp. 93-101.

Bański J., 2017. *The consequences of changes of ownership for agricultural land use in Central European countries following the collapse of the Eastern Bloc.* Land Use Policy, vol. 66, pp. 120-130.

Baumann M., Kuemmerle T., Elbakidze M., Ozdogan M., Radeloff V.C., Keuler N.S., Prishchepov A.V., Kruhlov I., Hostert P., 2011. *Patterns and drivers of post-socialist farmland abandonment in Western Ukraine.* Land Use Policy, vol. 28, no. 3, pp. 552-562.

Bender O., Boehmer H.J., Jens D. Schumacher K.P., 2005. *Using GIS to analyse long-term cultural landscape change in Southern Germany*. Landscape and urban planning, vol.70, pp. 111-125.

Bennett A.F., Saunders D.A., 2010. *Habitat fragmentation and landscape change* [in:] N. Sodhi, P. Ehrlich (eds.), Conservation biology for all, Oxford, UK: University Press, pp. 88-106.

Bezák P., Mitchley J., 2014. *Drivers of change in mountain farming in Slovakia: From socialist collectivisation to the common agricultural policy*. Regional Environmental Change, vol. 14, no. 4, pp. 1343-1356.

Bičlík I., Jeleček L., Štěpánek V., 2001. *Land-use changes and their social driving forces in Czechia in the 19th and 20th centuries.* Land Use Policy, vol. 18, no. 1, pp. 65-73.

Bucała A., 2014. *The impact of human activities on land use and land cover changes and environmental processes in the Gorce Mountains (Western Polish Carpathians) in the past 50 years.* Journal of Environmental Management, vol. 138, pp. 4-14.

Bucała A., Margielewski W., Starkel L., Buczek K., Zernitskaya V., 2014. *The reflection of human activity in the sediments of Iwankowskie Lake from Subatlantic Phase (Polish Outer Carpathians).* Geochronometria vol. 41, no. 4, pp. 377-391.

Bucała A., Budek A., Kozak M., 2015. *The impact of land use and land cover changes on soil properties and plant communities in the Gorce Mountains (Western Polish Carpathians), during the past 50 years.* Zeitschrift für Geomorphologie, vol. 59, no. 2, pp. 41-74.

Bucała-Hrabia A., 2017a. *From communism to a free-market economy – a reflection on economic changes in land use in the vicinity of the city of Beskid Sądecki (Western Polish Carpathians).* Geographia Polonica, vol. 90, no. 1, pp. 65-79.

Bucała-Hrabia A., 2017b. *Long-term impact of socio-economic changes on agricultural land use in the Polish Carpathians*. Land Use Policy, vol. 64, pp. 391-404.

Ciołkosz A., Guzik Cz., Luc M., Trzepacz P., 2011. *Zmiany użytkowania ziemi w Karpatach Polskich w okresie 1988-2006*. Kraków: Instytut Geografii i Gospodarki Przestrzennej UJ, pp. 145.

Central Statistical Office of Poland, 1978-2015.

Dec M., Kaszta Ż., Korzeniowska K., Podsada A., Sobczyszyn-Żmudź S., Wójtowicz A., Zimna E., Ostapowicz K., 2009. *Zmiany użytkowania ziemi w trzech gminach Karpackich (Niedźwiedź, Szczawnica i Trzciana) w drugiej połowie XX wieku.* Archiwum Fotogrametrii, Kartografii i Teledetekcji, vol. 20, pp. 81-98.

Dearing J., Braimoh A., Reenberg A., Turner B., van der Leeuw S., 2010. *Complex land systems: The need for long time perspectives to assess their future.* Ecology and Society, vol. 15, no. 4. [online].

Demczuk P., Gil E., 2009. *The application of the USLE model in the automatic mapping of soil erosion in the Bystrzanka catchment (Flysh Carpathian).* Quaestiones Geographicae, vol. 28A, no. 2, pp. 15-25.

Dynowska I., 1971. *Typy reżimów rzecznych w Polsce*. Zeszyty Naukowe Uniwersytetu Jagiellońskiego. Prace Instytutu Geograficznego UJ, Kraków: Nakładem Uniwersytetu Jagiellońskiego.

Froehlich W., 1982. *Mechanism of fluvial transport and delivering of the mantle to the channel* *of flysch mountain catchment*. Prace Geograficzne, vol. 143, Warszawa: Instytut Geografii i Przestrzennego Zagospodarowania PAN.

Froehlich W., Słupik J., 1986. *Rola dróg w kształtowaniu spływu i erozji w karpackich zlewniach fliszowych*. Przegląd Geograficzny, vol. 58, no. 1-2, pp. 67-85.

Froehlich W., Walling D.E., 1997. *The role of unmetalled roads as a sediment source in the fluvial systems of the Polish Flysch Carpathians, human impacts on erosion and sedimentation* [in:] Walling D.E., Probst J.L., (eds.), Human impact on erosion and sedimentation, IAHS Publication, no. 245, Wallingford: IAHS Press., pp. 159-169.

Gerlach T., Niemirowski M., 1968. *Charakterystyka geomorfologiczna dolin Jaszcze i Jamne* [in:] A. Medwecka-Kornaś, (ed.), Doliny potoków Jaszcze i Jamne w Gorcach, Studia Naturae, ser. A, vol. 2, pp. 11-22.

Gerlach T., 1976. *Współczesny rozwój stoków w polskich Karpatach fliszowych*. Prace Geograficzne, vol. 122, Warszawa: Instytut Geografii i Przestrzennego Zagospodarowania PAN.

Gellrich M., Baur P., Koch B., Zimmermann N.E., 2007. *Agricultural land abandonment and natural forest re-growth in the Swiss mountains: A spatially explicit economic analysis.* Agriculture, Ecosystems & Environment, vol. 118, no. 1-4, pp. 93-108.

Gil E., 2009. *Extreme values of soil downwash on cultivated slopes in the Polish Flysch Carpathians* [in:] W. Bochenek, M. Kijowska (eds.), Funkcjonowanie środowiska przyrodniczego w okresie przemian gospodarczych w Polsce, Biblioteka Monitoringu Środowiska, Szymbark, pp. 191-218.

Górz B., 2002. *Współczesne przemiany na obszarach wiejskich Podhala.* Przegląd Geograficzny, vol. 74, no. 3. pp. 451-468.

Górz B., 2003. *Społeczeństwo i gospodarka Podhala w okresie transformacji*. Kraków: Wydawnictwo Naukowe Akademii Pedagogicznej.

Griffiths P., Müller D., Kuemmerle T., Hostert P., 2013.*Agricultural land change in the Carpathian ecoregion after the breakdown of socialism and expansion of the European Union*. Environmental Research Letters, vol. 8, no. 4, pp. 1-12.

Grodzińska K., Szarek-Łukaszewska G., 1997. *Polish mountain forests: Past, present and future.* Environmental Pollution, vol. 98, no. 3, pp. 369-374.

Guo L.B., Gifford R.M., 2002. *Soil carbon stocks and land use change: A meta analysis*. Global Change Biology, vol. 8, no. 4, pp. 345-360.

Hess M., 1965. *Piętra klimatyczne w polskich Karpatach Zachodnich.* Zeszyty Naukowe UJ, Prace Geograficzne, vol. 11, Kraków: Nakładem Uniwersytetu Jagiellońskiego.

Hostert P., Kuemmerle T., Prishchepov A., Sieber A., Lambin E.F., Radeloff V.C., 2011. *Rapid land use change after socio-economic disturbances: The collapse of the Soviet Union versus Chernobyl*. Environmental Research Letters, vol. 6, no. 4, 1-8.

IUSS Working Group WRB, 2014. *World reference base for soil resources 2014*. World Soil Resources Reports No. 106. FAO, Rome.

Kaim D., 2009. *Zmiany pokrycia terenu na pograniczu polsko-słowackim na przykładzie Małych Pienin.* Przegląd Geograficzny, vol. 81, no. 1, pp. 93-105.

Keenleyside C., Tucker G., 2010. *Farmland abandonment in the EU: An assessment of trends and prospects.* Report prepared for WWF. London: Institute for European Environmental Policy.

Kijowska-Strugała M., 2015. *Transport zawiesiny w warunkach zmieniającej się antropopresji w zlewni Bystrzanki (Karpaty Fliszowe).* Prace Geograficzne, vol. 147, Warszawa: Instytut Geografii i Przestrzennego Zagospodarowania PAN.

Kijowska-Strugała M., Bucała-Hrabia A., Demczuk P., 2018. *Long-term impact of land use changes on soil erosion in an agricultural catchment (the Western Polish Carpathians).* Land Degradation & Development, pp. 1-14. DOI: 10.1002/ldr.2936

Kijowska-Strugała M., Bucała-Hrabia A., 2019. *Flood types in a montain catchment: the Ochotnica river, Poland.* Acta Geographica Slovenica-Geografski Zbornik, vol 59, no. 1, pp. 23-36 (in press).

Klimek K., 1987. *Man's impact on fluvial processes in the Polish Western Carpathians.* Geografiska Annaler, vol. 69A, no. 1, pp. 123-131.

Kolecka N., Kozak J., Kaim D., Dobosz M., Ginzler C., Psomas A., 2015. *Mapping secondary forest succession on abandoned agricultural* *land with LiDAR point clouds and terrestrial photography*. Remote Sensing, vol. 7, no. 7, pp. 8300-8322.

Kolecka N., Dobosz M., Ostafin K., 2016. *Forest cover change and secondary forest succession since 1977 in Budzów commune, the Polish Carpathians*. Prace Geograficzne, vol. 146, Kraków: Wydawnictwo Uniwersytetu Jagiellońskiego, pp. 51-65.

Kolecka N., Kozak J., Kaim D., Dobosz M., Ostafin K., Ostapowicz K., Wężyk P., Price B., 2017. *Understanding farmland abandonment in the Polish Carpathians.* Applied Geography, vol. 88, pp. 62-72.

Kondolf G.M., Piégay H., Landon N., 2002. *Channel response to increased and decreased bedload supply from land use change: contrasts between two catchments*. Geomorphology, vol. 45, pp. 35-51.

Kostuch R., 2003. *Sukcesja roślinna na odłogowanych gruntach ornych.* Woda-Środowisko-Obszary Wiejskie, vol. 2, no. 8, pp. 57-79.

Kozak J., 2003. *Forest cover change in the Western Carpathians in the past 180 years, A case study in the Orawa region in Poland.* Mountain Research and Development, vol. 23, no. 4, pp. 369-375.

Kozak J., 2005. *Zmiany powierzchni lasów w Karpatach Polskich na tle innych gór świata*. Kraków: Wydawnictwo Uniwersytetu Jagiellońskiego.

Kozak J., 2010*. Forest cover changes and their drivers in the Polish Carpathian Mountains since 1800* [in:] H. Nagendra, J. Southworth (eds.), Reforesting Landscapes, Dordrecht: Springer, pp. 253-273.

Kroczak R., Bryndal T., Bucała A., Fidelus A., 2016. *The development, temporal evolution and environmental influence of an unpaved road network on mountain terrain: an example from the Carpathian Mts. (Poland).* Environmental Earth Sciences, vol. 75, no. 3, pp. 1-14.

Kuemmerle T., Hostert P., Radeloff V.C., van der Linden S., Perzanowski K., Kruhlov I., 2008. *Cross-border comparison of post-socialist farmland abandonment in the Carpathians.* Ecosystems, vol. 11, no. 4, pp. 614-628.

Kuemmerle T., Müller D., Griffiths P., Rusu M., 2009. *Land use change in Southern Romania after the collapse of socialism.* Regional Environmental Change, vol. 9, no. 1, pp. 1-12.

Kupková L., Bičík I., 2016. *Landscape transition after the collapse of communism in Czechia*. Journal of Maps, vol. 12, pp. 526-531.

Lambin E.F., Meyfroidt P., 2010. *Land use transitions: Socio-ecological feedback versus socio-economic change*. Land Use Policy, vol. 27, no. 2, pp. 108-18.

Lasanta-Martínez T., Vicente-Serrano S.M., Cuadrat-Prats J.M., 2005. *Mountain Mediterranean landscape evolution caused by the abandonment of traditional primary activities: a study of the Spanish Central Pyrenees.* Applied Geography, vol. 25, no. 1, pp. 47-65.

Latocha A., 2014. *Geomorphic connectivity within abandoned small catchments (Stołowe Mts, SW Poland).* Geomorphology, vol. 212, pp. 4-15.

Latocha A., 2016. *Programy rolnośrodowiskowe a zmiany krajobrazu w Sudetach (na przykładzie powiatu kłodzkiego)* [in:] A. Richling, Ł. Zbucki (eds.), Dynamika zmian w krajobrazie, Problemy Ekologii Krajobrazu*,* 43, pp. 43-52.

Latocha A., Szymanowski M., Jeziorska J., Stec M., Roszczewska M., 2016. *Effects of land abandonment and climate change on soil erosion – An example from depopulated agricultural lands in the Sudetes Mts., SW Poland*. Catena, vol. 145, pp. 128-141.

Liébault F., Piégay H., 2002. *Causes of 20th century channel narrowing on mountain and piemont rivers of southeastern France.* Earth Surface Processes and Landforms, vol. 27, no. 4, pp. 425-444.

Łajczak A., 2007. *River training vs. flood risk in the upper Vistula basin.* Poland. Geographia Polonica, vol. 80, no. 2, pp. 79-96.

Łajczak A., Margielewski W., Rączkowska Z., Świechowicz Z., 2014. *Contemporary geomorphic processes in the Polish Carpathians under changing human impact*. Episodes, vol. 37, no. 1, pp. 21-32.

MacDonald D., Crabtree J.R., Wiesinger G., Dax T., Stamou N., Fleury P., Gutierrez Lazpita J., Gibon A., 2000. *Agricultural abandonment in mountain areas of Europe: Environmental consequences and policy response*. Journal of Environmental Management, vol. 59, no. 1, pp. 47-69.

Machałek M., 2013. *Przemiany polskiej wsi w latach 1918-1989*. Klio. Czasopismo poświęcone dziejom Polski i powszechnym, vol. 26, no. 3, pp. 55-80.

Medwecka-Kornaś A., Kornaś J., 1968. *Zbiorowiska roślinne dolin Jaszcze i Jamne.* Studia Naturae, Ser. A, vol. 2, pp. 49-91

Meyfroidt P., Lambin E.F., 2011. *Global forest transition: Prospects for an end to deforestation.* Annual Review of Environment and Resources, vol. 36, pp. 343-371.

Munteanu C, Kuemmerle T., Boltiziar M., Butsic V., Gimmi U., Halada L., Kaim D., Király G., Konkoly-Gyuró E., Kozak J., Lieskovský J., Mojses M., Müller D., Ostafin K., Ostapowicza K., Shandra O., Štych P., Walker S., Radeloff V.C., 2014. *Forest and agricultural land change in the Carpathian region – a meta-analysis of long-term patterns and drivers of change*. Land Use Policy, vol. 38, pp. 685-697.

Müller D., Leitão P.J., Sikor T., 2013. *Comparing the determinants of cropland abandonment in Albania and Romania using boosted regression trees*. Agricultural Systems, vol. 117, pp. 66-77.

Netting R. McC., 1972. *Of men and meadows: Strategies of alpine land use*. Anthropological Quarterly, vol. 45, no. 3, pp. 132-144.

Netting R. McC., 1981. *Balancing on an Alp: ecological change and continuity in a Swiss mountain community.* Cambridge: Cambridge University Press.

Niedziałkowska E., 1981. *Rzeźba terenu* [in:] L. Starkel (ed.), Warunki naturalne zlewni Homerki i jej otoczenia, Dokumentacja Geograficzna, vol. 3, pp.13-21.

Niemirowski M., 1974. *Dynamika współczesnych koryt potoków górskich (na przykładzie potoków Jaszcze i Jamne w Gorcach).* Zeszyty Naukowe UJ, Prace Geograficzne, vol. 34, Kraków: Nakładem Uniwersytetu Jagiellońskiego.

Ostafin K., 2009. *Zmiany granicy rolno-leśnej w środkowej częś Beskidu Średniego od połowy XIX wieku do 2005 roku*. Kraków: Wydawnictwo Uniwersytetu Jagiellońskiego.

Pašakarnis G., Morley D., Malienė V., 2013. *Rural development and challenges establishing sustainable land use in Eastern European countries*. Land Use Policy, vol. 30, no. 1, pp. 703-710.

Pazúr R., Lieskovský J., Feranec J., Oťaheľ J., 2014. *Spatial determinants of abandonment of large-scale arable lands and managed grasslands in Slovakia during the periods of post-socialist transition and European Union accession.* Applied Geography, vol. 54, pp. 118-128.

Pointereau P., Coulon F., Girard P., Lambotte M., Stuczynski T., Sánchez Ortega V., Del Rio A., 2008. *Analysis of the driving forces behind farmland abandonment and the extent and location of agricultural areas that are actually abandoned or are in risk to be abandoned*. JRC Scientific and Technical Reports, Institute for Environment and Sustainability, European Commission. Joint Research Centre.

Price B., Kaim D., Szwagrzyk M., Ostapowicz K., Kolecka N., Schmatz D.R., Wypych A., Kozak J., 2017. *Legacies, socio-economic and biophysical processes and drivers: The case of future forest cover expansion in the Polish Carpathians and Swiss Alps.* Regional Environmental Change, vol. 17, no. 8, pp. 2279-2291.

Radwan-Dębski R., 1995. *Szacunek opadu efektywnego na podstawie stopnia uszczelnienia terenu*. Gospodarka Wodna, vol. 12, pp. 315-318.

Reid L.M., Dunne T., 1984. *Sediment production from forest road surfaces*. Water Resources Research, vol. 20, no. 11, pp. 1753-1761.

Rogger M., Agnoletti M., Alaoui A., Bathurst J.C., Bodner G., Borga M., Chaplot V., Gallart F., Glatzel G., Hall J., Holden J., Holko L., Horn R., Kiss A., Kohnová S., Leitinger G., Lennartz B., Parajka J., Perdigão R., Peth S., Plavcová L., Quinton J.N., Robinson M., Salinas J.L., Santoro A., Szolgay J., Tron S., van den Akker J.J.H., Viglione A., Blöschl G., 2017. *Land-use change impacts on floods at the catchment scale: Challenges and opportunities for future research.* Water Resources Research, vol. 53, no. 7, pp. 5209-5219.

Rudel T., Coomes O., Moran E., Achard F., Angelsen A., Xu J., Lambin E., 2005. *Forest transitions: Towards a global understanding of land use change*. Global Environmental Change, vol. 15, no. 1, pp. 23-31.

Skiba S., Drewnik M., Klimek M., Szmuc R., 1998. *Soil cover in the marginal zone of the Carpathian foothills between the Raba and Uszwica Rivers.* Prace Geograficzne, vol. 103, Kraków: Instytut Geografii UJ, pp. 126-135.

Soja M., 2008. *Cykle rozwoju ludności Karpat polskich w XIX i XX wieku*. Kraków: Instytut Geografii i Gospodarki Przestrzennej UJ.

Soja R., 1977. *Deepening of channel in the light of the cross profile analysis (Carpathian river* *as example).* Studia Geomorphologica Carpatho-Balcanica, vol. 11, pp. 128-138.

Soja R., 2002. *Hydrologiczne aspekty antropopresji w polskich Karpatach*. Prace Geograficzne, vol. 186, Warszawa: Instytut Geografii i Przestrzennego Zagospodarowania.

Soja R., Prokop P., 1996. *Drogi jako element antropogenicznego przekształcenia środowiska.* Zintegrowany monitoring środowiska przyrodniczego. Funkcjonowanie i monitoring geoekosystemów. Szymbark 14-16 września 1995, pp. 72-74.

Starkel L., 1972. *Zachodnie Karpaty Zewnętrzne (fliszowe)* [in:] M. Klimaszewski (ed.), Geomorfologia Polski, vol. 1, Warszawa: Państwowe Wydawnictwo Naukowe, pp. 52-115.

Starkel L., 1975. *Rola typów rzeźby w użytkowaniu ziemi obszarów górskich na przykładzie polskich Karpat*. Zeszyty Problemowe Postępów Nauk Rolniczych, vol. 162, pp. 523-525.

Starkel L., 1990. *Ewolucja środowiska przyrodniczego Karpat w okresie działalności człowieka.* Problemy Zagospodarowania Ziem Górskich, vol. 29, pp. 34-46.

Starkel L., Obrębska-Starklowa B., 2005. *Geomorfologiczne uwarunkowania położenia granicy rolno-leśnej w polskich Karpatach.* Problemy Zagospodarowania Ziem Górskich, vol. 51, pp. 11-16.

Starkel L., Pietrzak M., Łajczak M., 2007. *Wpływ zmian użytkowania ziemi i wzrostu częstotliwości ekstremalnych opadów na obieg wody i erozję oraz ochronę zasobów przyrodniczych Karpat.* Problemy Zagospodarowania Ziem Górskich, vol. 54, pp. 19-31.

Staszkiewicz J., 1981. *Zbiorowiska roślinne* [in:] L. Starkel (ed.), Warunki naturalne zlewni Homerki i jej otoczenia, Dokumentacja Geograficzna, vol. 3, pp. 43-50.

Strahler A.N., 1952. *Hypsometric (area-altitude) analysis of erosional topography.* Bulletin of the Geological Society of America, vol. 63, no. 11, pp. 1117-1142

Szymański W., Skiba M., Błachowski A., 2017. *Influence of redox processes on clay mineral transformation in Retisols in the Carpathian Foothills in Poland. Is a ferrolysis process present?* Journal of Soils and Sediments, vol. 17, no. 2, pp. 453-470.

Šebo D., Nováček J., 2014. *Case study areas Pruské, Bohunice, Vršatské Podhradie and Krivoklát: Land cover changes 1949-2009.* Land Use/Cover Changes in Selected Regions in the World, vol. 9, pp. 57-62.

Święchowicz J., 2012a. *Rainfall thresholds for erosion processes in agricultural catchments*. Kraków: Instytut Geografii i Gospodarki Przestrzennej UJ.

Święchowicz J., 2012b. *Water erosion on agricultural foothill slopes (Carpathian Foothills, Poland).* Zeitschrift für Geomorphologie, Supplementary Issues, vol. 56, no 3, pp. 21-35.

Taillefumier F., Piégay H., 2003. *Contemporary land use changes in prealpine Mediterranean mountains: A multivariate GIS-based approach applied to two municipalities in the Southern French Prealps*. Catena, vol. 51, pp. 267-296.

Takken I., Croke J., Lane P., 2008. *Thresholds for channel initiation at road drain outlets.* Catena, vol. 75, no. 3, pp. 257-267

Tarolli P., Calligaro S., Cazorzi F., Fontana G.D., 2013. *Recognition of surface flow processes influenced by roads and trails in mountain areas using high resolution topography.* European Journal of Remote Sensing, vol. 46, pp. 176-197.

Tasser E., Walde J., Tappeiner U., Teutsch A., Noggler W., 2007. *Land-use changes and natural reforestation in the Eastern Central Alps.* Agriculture, Ecosystems & Environment, vol. 118, no. 1, pp. 115-129.

Wemple C.B., Swanson F.J., Jones J.A., 2001. *Forest roads and geomorphic process interactions, Cascade Range, Oregon*. Earth Surface Processes and Landform, vol. 26, pp. 191-204.

Wiejaczka Ł. Kijowska-Strugała M., 2015. *Dynamics of the channel beds level in mountain rivers in the light of the minimum water stages analysis.* Carpathian Journal of Earth and Environmental Sciences, vol. 10, no. 4, pp. 105-112.

Wolski J., 2016. *The landscape of abandoned villages in the Western Bieszczady: the problem of definition and classification*. Geographia Polonica, vol. 89, no. 3, pp. 371-387.

Wypych A., Ustrnul Z., 2016. *Zmiany i zmienność warunków klimatycznych w Karpatach Polskich w latach 1851-2010 oraz potencjalne scenariusze zmian 2021-2060* [in:] J. Kozak, D. Kaim (eds.), Forecom. Podręcznik użytkownika, Kraków: Instytut Geografii i Gospodarki Przestrzennej UJ, pp. 21-28.

Wyżga B., 2001. *Impact of the channelization-induced incision of the Skawa and Wisłoka Rivers, Southern Poland, on the conditions of overbank deposition*. River Research and Applications, vol. 17, no. 1, pp. 85-100.

Wyżga B., Zawiejska J., Radecki-Pawlik A., 2016. *Impact of channel incision on the hydraulics of flood flows: examples from Polish Carpathian rivers.* Geomorphology, vol. 272, pp. 10-20.

Ziemońska K., 1973. *Stosunki wodne w polskich Karpatach Zachodnich*. Prace Geograficzne, vol. 103, Warszawa: Instytut Geografii PAN.

Zorn M., Komac B., 2009. *Response of soil erosion to land use change with particular reference to the last 200 years (Julian Alps, Western Slovenia)*. Revista de geomorfologie, vol. 11, pp. 39-47.

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