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Article

LAI Variability as a Habitat Feature Determining Reptile Occurrence: A Case Study in Large Forest Complexes in Eastern Poland

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Abstract: Reptile habitats are described using various indices. The definitions of such indices are crucial, as they are applied to habitat modelling for numerous species on local to continental scales. We examined the Leaf Area Index (LAI) for its value as a tool for determining reptile habitat. During measurements carried out in spring and summer months between 2011 and 2013, LAI values were assessed and surveys were conducted on reptile fauna at 11 survey sites in the Solska Forest and Roztocze National Parks areas in Eastern Poland. In total, six Squamata reptiles occurring in Poland were found. We determined that LAI can be utilized as a reptile habitat index, with reptile species associated with LAI seasonal variability as well as LAI range. Moreover, we found that the higher the LAI median value, the greater the variety of reptile species. These findings are useful for development of spatial models of habitats based on LAI as they point to the importance of its seasonal variation.

Keywords: LAI; reptiles; habitat; habitat modelling; species occurrence modelling

1. Introduction

Reptile habitats are described using a variety of indices which can be classified as climatic, topographic and biological. Proper identification of habitat indices associated with a given species is of utmost importance as they are often utilized for the modelling of habitats on local to continental scales.

From among a number of animal habitat modelling methods, Leyequien [1] pointed out the important role of remote sensing and geostatistics. By means of these methods, Rodríguez *et al.* [2] found that the presence of reptiles was strongly associated with the energy available in the environment, which could be measured by potential evapotranspiration. Models of reptile habitat suitability were also obtained using a number of environmental variables in a hydrological model [3] and extensive analysis of LiDAR (light detection and ranging) data [4]. Another approach used biological remote sensing indices to model herpetofauna [5] and mammal [6] habitats. These studies show that NDVI (Normalized Difference Vegetation Index) time series can be used for the modelling of faunal habitats, but their results are less reliable compared to the models based on climatic indices. Climatic indices were compared with topographic indices by Guisan and Hofer [7] for the modelling of habitats of selected reptile species. In this comparison, like in the former examples, models based on climatic indices were found to better represent the real distribution of reptiles.

However, climatic indices have one essential drawback: they are assessed on the basis of point measurements at meteorological stations and then spatially interpolated. Therefore, climatic indices are more representative for large areas and may obscure local variability. For smaller spatial scales, alternative indices to assess habitat condition may be needed.

An example of a biological index that is very effective in measuring the extent of faunal habitats is the Dynamic Habitat Index [8]. This index is obtained from such remote sensing data sequences as fPAR (fractional Photosynthetically Active Radiation), NDVI or GPP (Gross Primary Productivity) and was utilized for the modelling of avian habitats [9] and for the evaluation of flora and fauna species richness in boreal forests at 1-km grid spacing [10]. The modelling of habitat extent is possible at an even more precise scale using satellite high-resolution data. This was demonstrated by Shen *et al.* [11], who successfully modelled avian ranges on the basis of NDVI and ATSAVI (Adjusted Transformed Soil-adjusted Vegetation Index); it should be noted that ground LAI (Leaf Area Index) measurements also constituted an important aspect of their survey.

A benefit of the above-mentioned biological indices is that they are associated with climatic and topographical indices, both of which directly influence vegetation. Moreover, indices of this sort can be measured on the ground and then used as input data for spatial models, based, for example, on remote sensing data.

In this research we focused on the analysis of reptile habitats as evaluated by LAI index. LAI's strength is the fact that it enables easy ground measurement reflecting local habitat conditions. LAI is also related to solar light interception by the plants [12]; when overstory trees are present, the degree of shading affects the development of lower stratum plants [13], which constitutes the habitat for reptiles surveyed in this research. An important feature of LAI is that this index can be evaluated not only on the basis of ground measurements but also by means of remote sensing, especially in forests [14–18]. So far, the association of LAI with reptile occurrence has not been extensively examined. Nevertheless, there are reports suggesting the existence of such a relationship. Greenberg [19] showed that forests damaged by wind were richer in reptile species compared to non-damaged forests in the eastern USA. Similar conclusions can be drawn from the research by Pike *et al.* [20], who studied the effect of the removal of trees on reptile biodiversity in southeastern Australia.

The specific aim of our research was to examine the utility of LAI as a habitat index for reptiles inhabiting the Solska Forest and Roztocze National Park, Poland. Our approach has a multispecies aspect as it not only takes into consideration the existence or non-existence of a given species but also examines the abundance of reptiles and the number of species in relation to the LAI index.

2. Data and Methods

2.1. Research Site

The study was conducted in two adjacent forest complexes in Poland: Puszcza Solska (the Solska Forest) and Roztocze National Park (Figure 1). The Solska Forest is a large forest complex in the southern part of Lublin Voivodeship and in the north-eastern part of Subcarpathian Voivodship, Poland. It lies in the Sandomierska Basin, on the Biłgorajska Plain, south of the Roztocze Mountain Range. The Solska Forest is a natural continuation of the Sandomierska Forest to the west. Southeastwards, the Solska Forest reaches the Polish-Ukrainian frontier, and in the vicinity of the city of Narol it merges with the Roztocze Forests. The Roztocze National Park is a northern continuation of the Solska Forest. It comprises the Upper Wieprz River valley and adjacent parts of Lubelska Upland and Sandomierska Basin.

The climate of the study area has been described on the basis of Uziak and Turski [21]. The average daily insolation in the province of Lublin amounts to 4.4 h, *i.e.*, 1600 h a year. During the year maximum insolation values are recorded in July and August and amount to 7–8 h on the average, whereas the lowest value of 1 h only is noted in December. The degree of cloudiness over the area of the Lublin province is fairly diverse. Mean yearly degree of cloudiness in the area of Zamość ranges between 6.3 and 6.4 (in a 0–10 scale). Two periods of cloudiness can be distinguished during the year: a cool period and a warm period (from March to October). The latter one is characterized by significantly lower but a more diverse degree of cloudiness. The least cloudy month is August and the most cloudy—December. Seasonally, most sunny hours are recorded in summer, accounting for 40% of the total annual insolation. The distribution of the average yearly air temperature in the area of the study area is not homogenous, but there is a general tendency toward decrease in temperatures from the west to the east. The central and eastern parts of the Lublin Voivodeship are thermally monotonous. Air temperature annual values over the studied area are typical for the general thermic conditions in Poland. The highest mean monthly air temperatures are recorded in July and amount to about 17.2 °C, whereas the lowest ones, of *ca.* −4.3 °C, are recorded in January. Frosty days in the study area are noted from November to March and only sporadically also in August and October. The vegetation period in the eastern and central part of the Lublin province lasts 211 and 214 days, respectively. The number of hot days (with the mean air temperature exceeding 25 °C) ranges between 28 and 37 on the average, and that of very hot days (over 30 °C) equals 4, on average. Annual mean total precipitation varies from 580 to 600 mm. Changes in the mentioned above climate characteristics in the last 40 years are provided in [22].

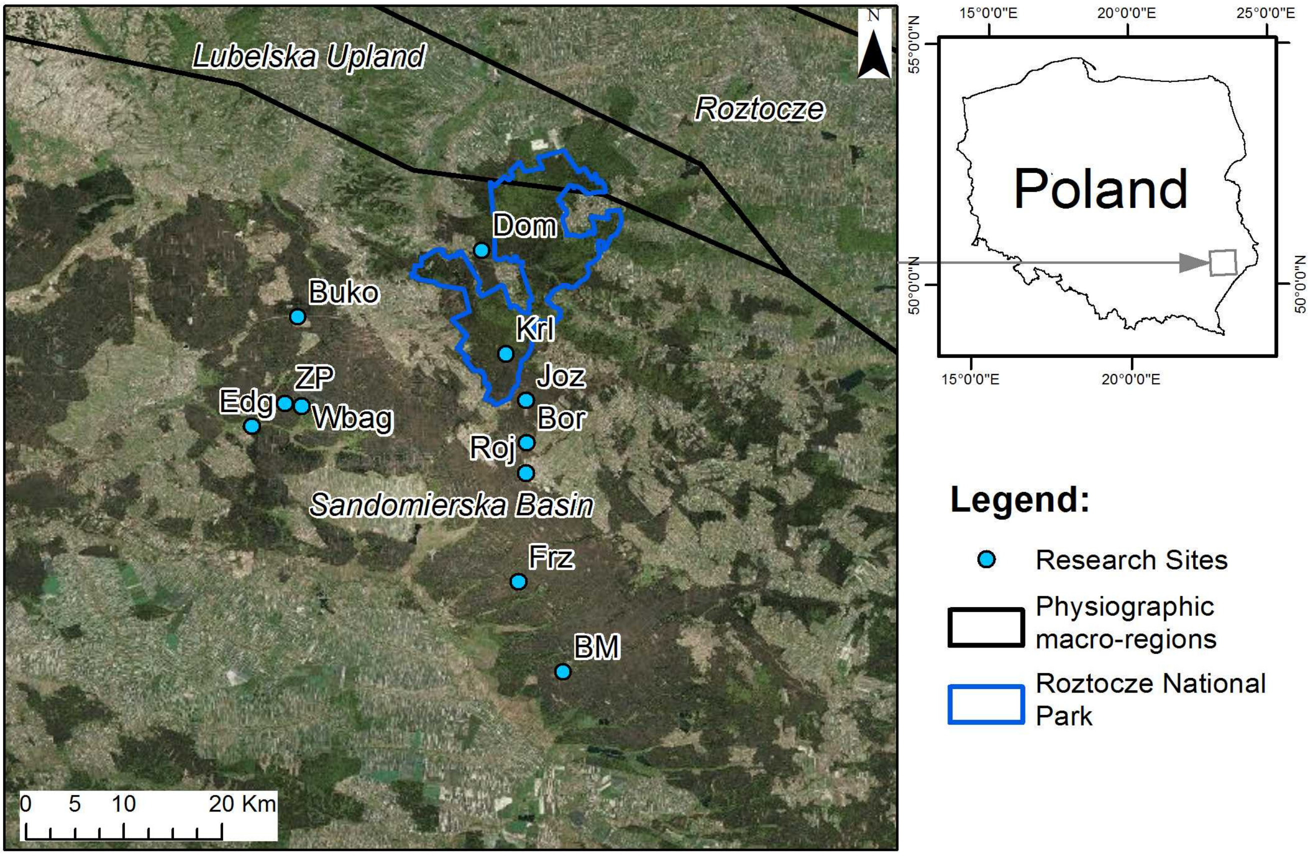

Figure 1. Location of the research sites. Full site names are provided in Table 1. Physiographic macro-regions of Poland are labeled in italics. Satellite true color image was used as the background: dark green = forest; light green = agriculture; grey = cities and villages.

Our measurements were carried out at 11 research sites (Figure 1, Table 1) situated in forest areas and in open areas adjacent to them. Each research site comprised an area of approximately 0.5 ha, and within this area LAI measurements and herpetological surveys were conducted (see Sections 2.2 and 2.3). The sites have been selected on the basis of reptile population surveillance in the area of the Solska Forest and its neighborhood since 2008 [23], and they represent various habitats comprising forests, open areas and mixtures of both. Six of our research sites (BM, Buko, Edg, Frz, Wbag and ZP) are located in the Solska Forest, on the Sandomierska Basin; four sites (Bor, Dom, Joz and Krl) are located in the Roztocze National Park area and its protection zone; and one site (Roj) is located on the Roztocze National Park and the Sandomierska Basin boundary, but outside the Solska Forest (Figure 1).

At present, nine reptiles representing two orders—turtles and squamata—are found in Poland. Squamata reptiles are subdivided into two suborders: lizards, represented by 2 genera and 4 species; and snakes, represented by 4 genera and 4 species. The European pond turtle *Emys orbicularis* is a separate order and, at this time, it is only representative in Poland [24]. In the present study the following reptiles were surveyed in the research area: smooth snake (*Coronella austriaca*), sand lizard (*Lacerta agilis*), common lizard (*Lacerta vivipara*), common viper (*Vipera berus*), grass snake (*Natrix natrix*) and blind worm (*Anguis fragilis*).

Table 1. Characteristics of research sites.

No.	Research Site	Habitat Characteristics	N. LAI
1	Józefów (Joz)	Xerothermic grassland found on carbonaceous rocks. Adjacent to it is dry and moderately moist coniferous forest.	5
2	Wielkie Bagno (Wbag)	Mixed coniferous forest and alder carr coniferous forest. Mixed coniferous forest soil is mainly represented by fine-grained sands located on alluvial sand-dune soil. Water-logged soils are typical for alder carr habitat.	4
3	Zaskrońcowa Polana (ZP)	Moderately moist coniferous forest on mineral deposits in podzolic soil and rusty soil of exceptionally thin layer of acid mor-humus. Groundwater level within the extent of tree root system.	6
4	Zwierzyniec Dom (Dom)	Private timber forests with species resembling moderately moist mixed coniferous forest. Forests strongly degraded by the remains of the owners' residential buildings.	8
5	Borowe Młyny II (BM)	Marshy coniferous forest on peaty earth soil formed in hollows in the terrain without flow. This area is located within the reach of acid stagnant groundwater.	6
6	Borowina (Bor)	Moderately moist coniferous forest located on mineral deposits on sod-podzolic soil. Habitat present on peat- and peat-earth soils.	3
7	Bukownica (Buko)	Ploughland, isolated by a railway crossing. Each year monocotyledon plants not exceeding 1.5 meters are planted.	3
8	Edwardów Nowy Most (Edg)	Dry soil coniferous forest located in immediate proximity of a brook. Adult tree stand on fine-grained sands.	3
9	Fryszarka (Frz)	Coniferous forests on moderately moist and moist soils. The area situated on podzolic type of soil, predominantly fine-grained sands. Peat or, in places, peaty earth soil is present in depressions.	4
10	Kruglik (Krl)	Mixed coniferous forest on specific podzolic soil formed on the basis of friable or slightly loamy sand.	3
11	Józefow rondo (Roj)	Mixed forest located partly on moderately moist brown soil and, partly, on podzolic soil. Large open areas in close proximity.	4

The column "N. LAI" shows the number of LAI measurements points at given research site.

2.2. LAI Measurements

LAI measurements were performed with the LAI 2000 instrument [12]. This device calculates LAI and other canopy features by measuring solar radiation with a "fish-eye" optical sensor (148 degrees field of view). Measurements made above and below the canopy serve for the identification of sky radiation penetrating the canopy. LAI is calculated using these measurements as an input for a model of light radiation transfer through plant canopies. An advantage of LAI 2000 measurements is that it is quick. Moreover, LAI 2000 does not require direct solar radiation, hence the measurements do not need to await sunny days or a change in the angle of solar radiation. Furthermore, measurements can be carried out in different cloudiness conditions; the best condition is when the sun is covered by clouds, but it is also possible to measure on sunny days if an appropriate protocol is applied. LAI 2000 can be utilized in various types of afforestation, from short grasses to the tree stand.

The same LAI measurement protocol was applied at each site. At the survey planning stage dominant areas within the sites were determined on the basis of uniform vegetation cover. The number of LAI measurement points for the survey sites is shown in Table 1. The Trimble Juno SB GPS receiver registered coordinates of measurement points. This allowed measurements to be taken in the same places over the entire period of the experiment. The accuracy of the GPS measurements of x and y coordinates was at the level of 20 m in the forests and about 2 m in open areas. At each point, LAI measurement consisted of one reference measurement relative to the non-canopy covered vegetation and nine measurements made below the vegetation. LAI measurements were carried out in invariable atmospheric conditions.

LAI measurements were made once a month from April until August in the years 2011–2013. The spring and summer months were chosen with a view to the activity of the surveyed reptiles. During the three years three measurement periods were missed: April 2011, July 2011 and May 2012. Moreover, six last measurements were missed at ZP site due to the timber harvest carried out in the area of this site.

2.3. Herpetofauna Surveys

During our herpetological surveys, we attempted to obtain as much data as possible, but without negatively affecting the class of reptiles which, in Poland, are among the least numerous of vertebrate classes. Therefore, we renounced the application of such invasive methods as radiotelemetry or the use of thermosensitive radiotransmitters. Neither did we apply any invasive methods used for the marking and subsequent identification of animals. Field studies took place from April through to October. The investigators dedicated about one person-hour to each site per visit during the annual and daily activity times of reptiles.

Herpetological surveys were conducted by visual estimation surveys conducted along parallel transects [25]. The number of transects depended strictly on the location of the site. In spring, the surveys were conducted usually between 1100 and 1500 h, but as spring progressed, reptiles started to bask earlier, so we initiated our surveillance at 0800 h. The best hours for summer surveillance of reptiles are between 0800 and 1100 h and, again, between 1700 and 1900 h. Except for in wintertime, during which reptiles hibernate, it is not possible to unequivocally determine the optimal weather conditions for the surveillance of reptiles. In spring, it should by sunny or only partly cloudy with the air temperature between 10 °C and 20 °C. In late spring, overcast or slightly cloudy weather may by appropriate as it makes reptiles stay in basking places relatively longer than on sunny days. The most suitable conditions for surveillance arise on sunny days following rainfalls or on the first sunny day following several cloudy days.

2.4. Data Analysis

Within the framework of this research, we assessed the distribution of LAI index values in the area of the surveyed sites. The following parameters were analyzed: (1) temporal variability of LAI distribution at the sites where the presence of reptiles was determined; (2) changes of LAI distribution depending on the recognition of various animal species; (3) changes of LAI distribution as a function of the number of registered reptile species. Analysis of variance was employed to evaluate differences between LAI distributions depending on various factors; for this reason, statistical F-value as well as the level of statistical significance test (p-value) were indicated on the plots.

All analyses were carried out on the assumption that reptiles are present at the given LAI value only if they had been sighted during herpetological transect surveys. Consequently, the presence of reptiles at research sites was not extrapolated to the entire research period but rather referred exclusively to the measurement dates when the animals were actually sighted.

3. Results and Discussion

3.1. LAI Measurements

In total, 532 LAI measurements were made, with single measurement points being omitted whenever the area turned out to be inaccessible because of high groundwater levels. This was the case only for measurement points in marsh areas in April and should not affect the results significantly.

LAI values varied monthly (Figure 2). The median values for every single month illustrate the typical tendency of LAI reported in earlier studies [26,27]. The level of significance obtained in the F test shows strong seasonal LAI variability in the surveyed area.

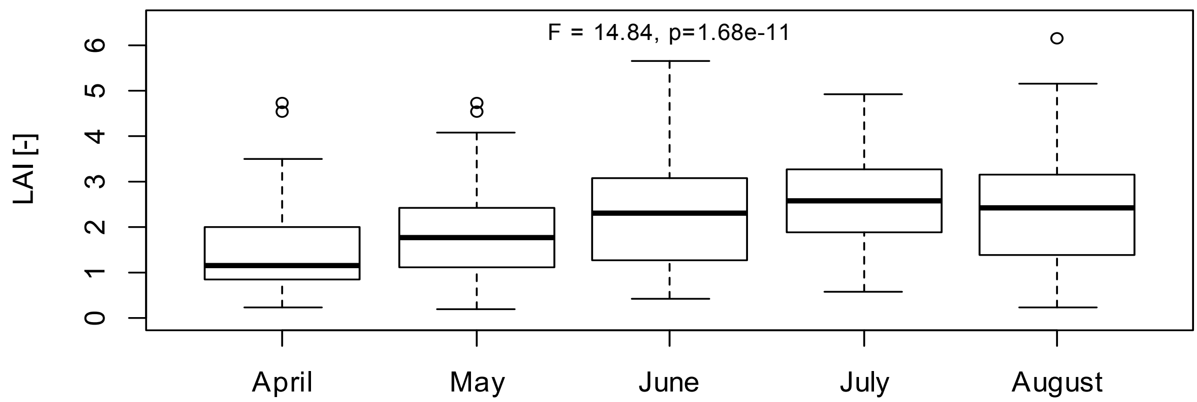

Figure 2. Monthly distribution of LAI values in the period 2011–2013 for all research sites.

LAI values also varied by study site (Figure 3). LAI median values were higher in forests compared to the mixed forest-open sites. The highest LAI median values were obtained for the Dom site in the area, with a managed forest site habitat similar to that of a moderately moist soil mixed coniferous forest.

3.2. Herpetofauna Survey

Six reptile species were observed at study sites (Table 2). The sand lizard and common lizard were the dominant species surveyed in Solska Forest (Figure 4). Among snakes, the grass snake was the most frequently observed species. Other snakes (common viper and smooth snake) were observed in lower numbers, limiting our analysis of their patterns. Reptiles were most abundant at the Joz site, with the BM having only slightly lower abundance. These two sites, however, have completely different habitats (Table 1), suggesting the number of observations relies on other factors. Similarly, the least abundant sites (Buko, ZP and Krl) are located in various habitats.

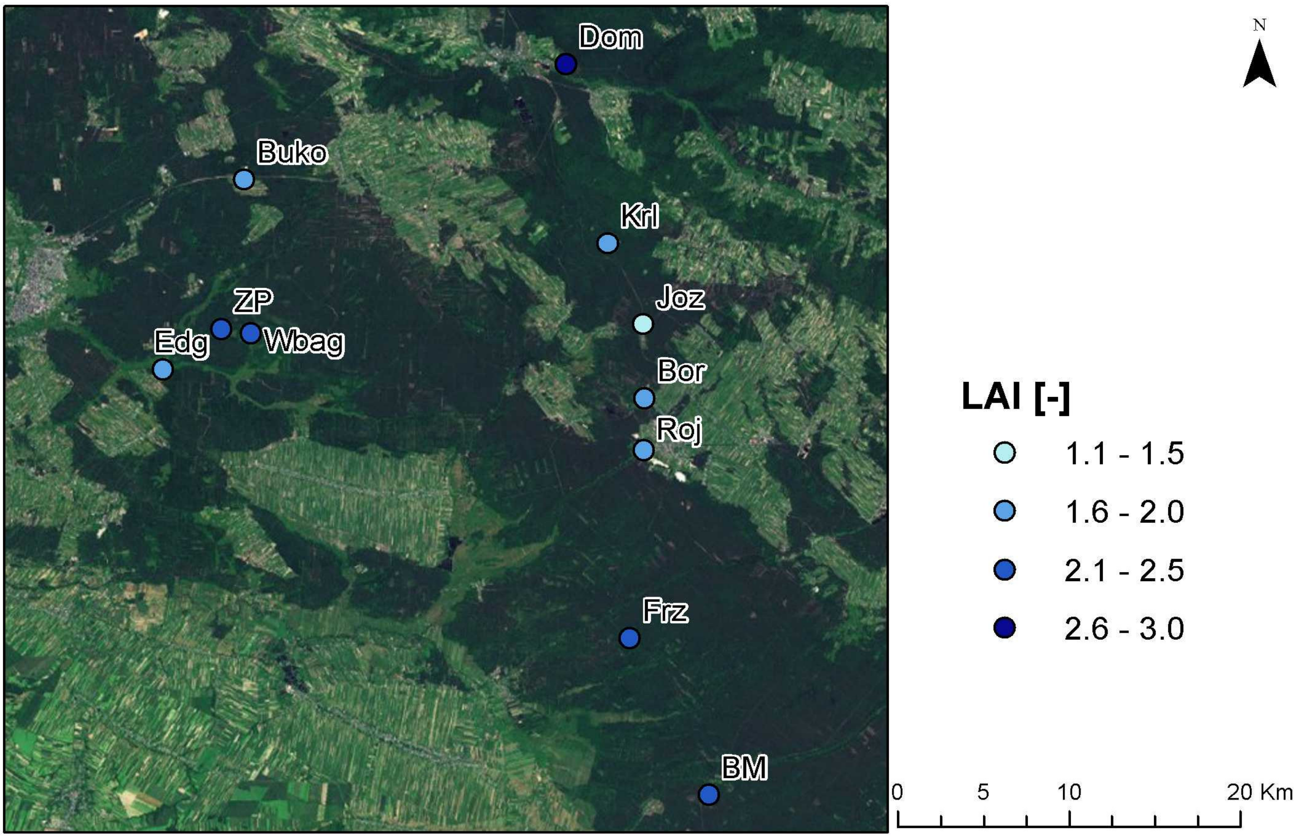

Figure 3. Median LAI value for study sites for the whole research period in Poland. Full site names are provided in Table 1. Satellite true color image was used as the background: dark green = forest; light green = agriculture; grey = cities and villages.

Table 2. Number of observed reptile individuals at all research sites during the 2011–2013 period in Poland.

Research Site	Smooth Snake	Sand Lizard	Common Lizard	Common Viper	Grass Snake	Blind Worm	Total
BM	3	99	11	3	4	0	120
Bor	1	72	21	1	0	6	101
Buko	0	50	0	0	0	0	50
Dom	0	56	19	0	1	1	77
Edg	0	37	6	0	13	3	59
Frz	0	64	13	1	0	12	90
Joz	4	121	8	1	0	2	136
Krl	0	55	0	2	0	0	57
Roj	2	80	12	0	0	3	97
Wbag	1	16	37	0	3	5	62
ZP	0	42	4	0	9	2	57
Total	11	692	131	8	30	34	906

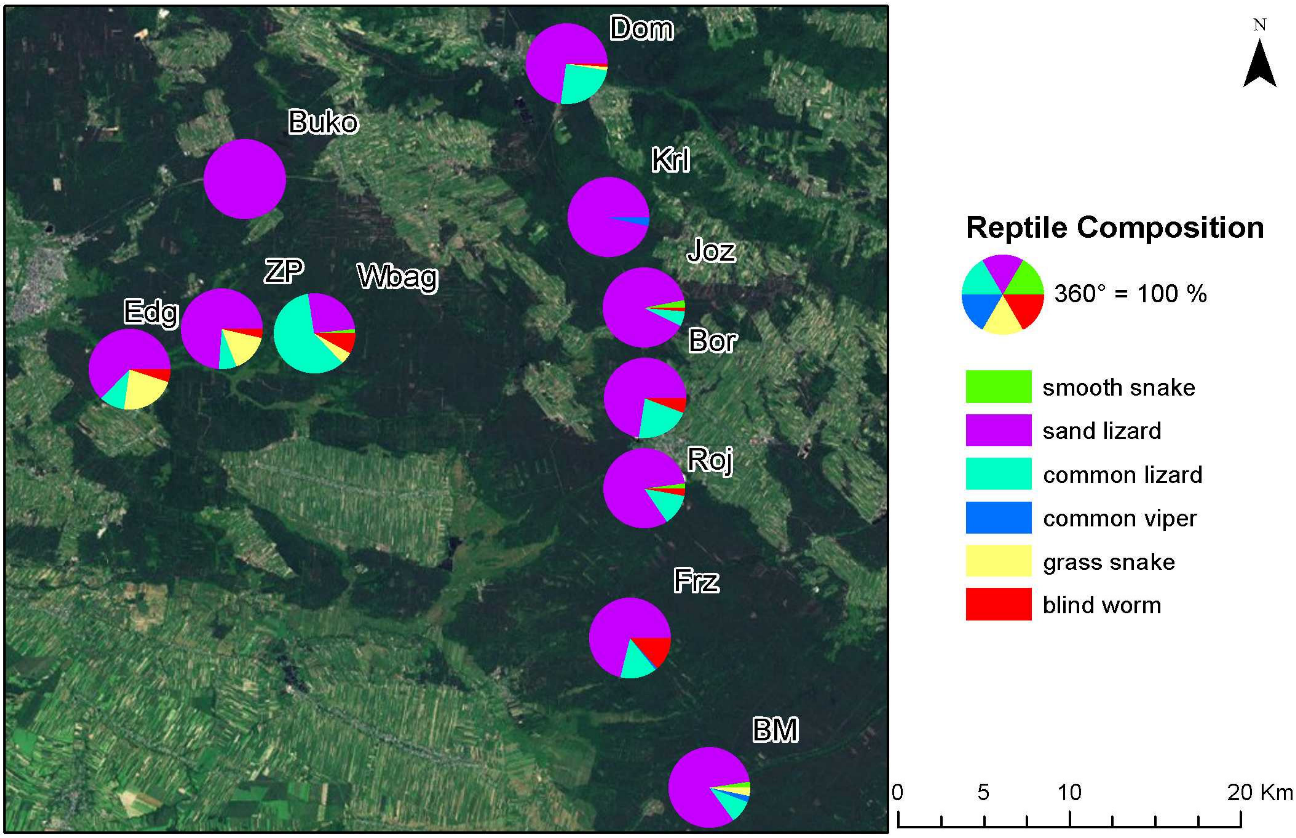

Figure 4. Reptile species composition (%) at study sites. Full name of the abbreviations are provided in Table 1. Satellite true color image was used as the background: dark green = forest; light green = agriculture; grey = cities and villages.

3.3. Implications of LAI as a Habitat Index for Reptiles

The relationships between the distribution of LAI values and number of reptile observations in the area of the Solska Forest show a few patterns (Figure 5). For the lowest range of sightings (1–3) LAI distribution is relatively narrow with the median value at 1.8. This is due to the fact that only a limited amount of surveillance was conducted in the early spring, *i.e.*, when LAI values were small (Figure 2). For other ranges of reptile sightings (from 4–6 to 19–21) LAI distribution ranges are similar, except for the 16–18 range where the number of species detected (N = 16) was smaller compared to the others (average N = 67). These distributions represent optimal LAI values in reptile habitats without, however, distinguishing between actual reptile species. The distributions are relatively large and cover LAI values varying between 0.17 and 5.17. The last two ranges of reptile sightings (22–24 and 25–27) are narrower than the previous ones and their median LAI values are lower. This high number of sightings was recorded during spring at Joz and BM sites, and refers to sand lizards as the reptile species most frequently observed during our research (Table 2).

LAI distributions were significantly different depending on the number of reptile species sighted at the research site (Figure 6). The higher the number of the species, the higher the LAI median. This shows that low LAI values, typical for pine monocultures and xerothermic grasslands, were not preferential for multiple reptile populations. It is also worthwhile noting that LAI distribution for three surveyed species in a research site was narrower (Figure 6). This may indicate that more restrictive habitat conditions, with the participation of vegetation characterized by 0.8–4.3 LAI values, are associated with greater species richness. Nevertheless, the extent of the LAI distribution for three species may also result from the lower number of measurements ($N = 33$), compared to other factors.

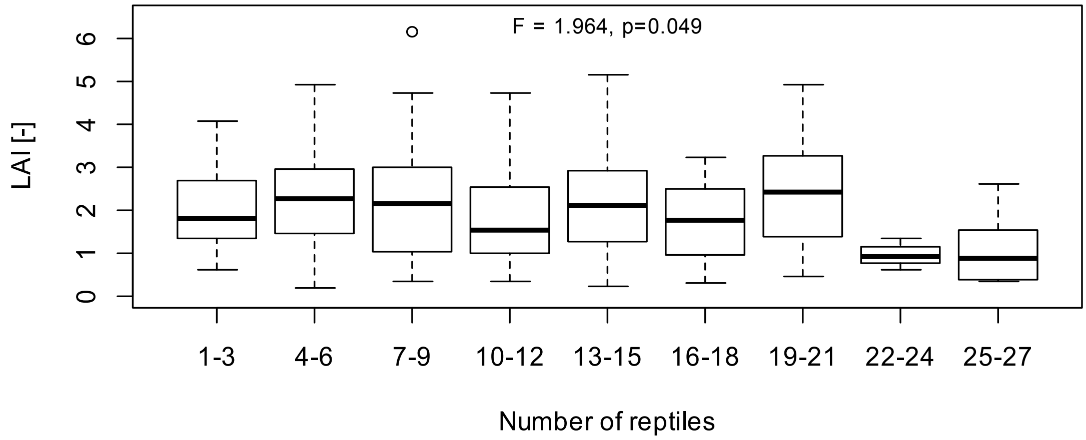

Figure 5. Number of observed reptiles as a function of LAI values.

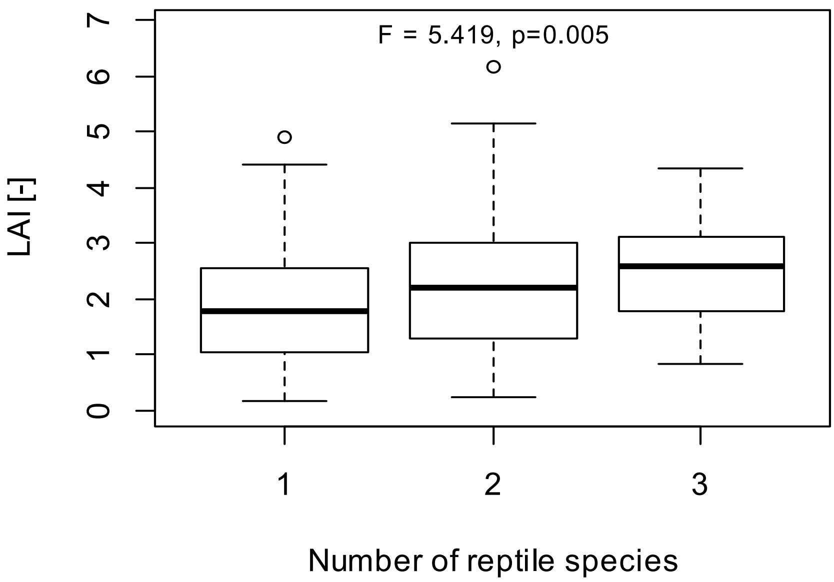

Figure 6. Number of reptile species observed at each research site as a function of LAI values.

The number of reptile species sighted at research sites also can be illustrated with regard to LAI distributions for the occurrence and non-occurrence of specific reptile species (Figure 7). Smooth snakes, sand lizards and common lizards, despite differences in the extent of their relative LAI distributions, do not show significant differences for the "observed" and "not observed" factors. This suggests these species are present at a large range of LAI, but this fact by itself is not necessarily the main factor determining the presence of these animals. The opposite is true for the common viper, grass snake and blind worm; in the case of these species, a significant difference was noted between the "observed" and "not observed" factors. For these three reptile species there is an apparent association with higher LAI values, the evidence of which is the higher LAI median value for the "observed" factor compared to the "not observed" one.

These three species may be dominant contributors to the increase in the median LAI value for the greater number of total observed reptile species (Figure 6). Nonetheless, the distributions shown in Figure 7 can also be interpreted in a different way. Other research has shown that the investigated reptile species are associated with the presence of diverse vegetation [28–30] which, in turn, results in a large spectrum of LAI among habitats, as shown in Figure 7. Our results show sand lizard observations over a broader range of LAI values (Figure 7). Moreover, earlier studies have shown that the surveyed reptiles are associated with habitats with diverse landscapes [31] and that when in environments dominated by monocultures, they search for such places [32]. It has also been found that some particular vegetation mosaics have a favorable impact on the diversity and abundance of reptiles [33].

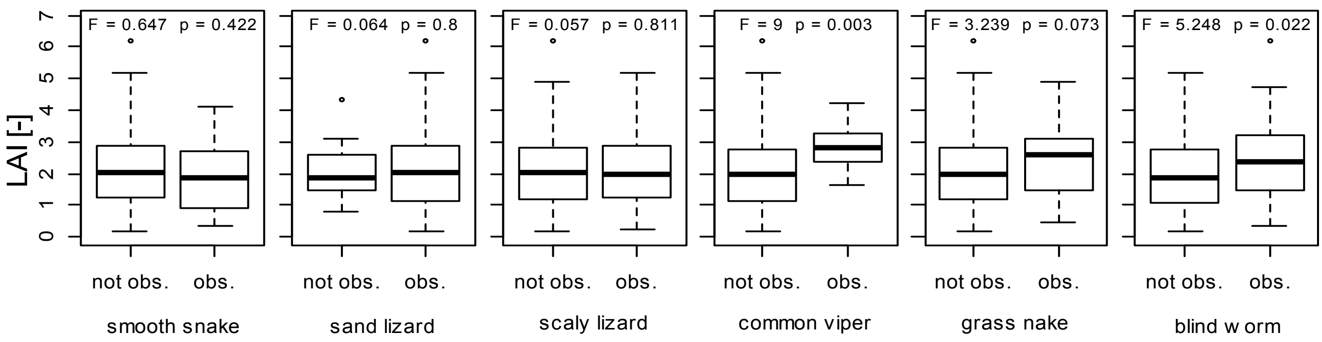

Figure 7. LAI distributions per reptile species observed (obs.) or not observed (not. obs) in the surveys at our Poland study sites.

The analysis of the variability of LAI distributions over months and for various species reveals another aspect of our results (Figure 8). No significant seasonal changes in LAI distributions were found in smooth snake areas or in the areas of the three other species for which a significant difference was stated between the "observed" and "not observed" factor (*i.e.*, common viper, grass snake, blind worm, Figure 7). This suggests that they use habitats or complexes of habitats that guarantee similar, steady LAI levels from April until August. Apparently, these habitats are of the dry and coniferous forest type (Frz, BM, Wbag) as well as open land used by man, systematically reaped or mown (*Leucobryo-Pinetum* community; peripheral subatlantical coniferous forest with an admixture of meadow species and *Piceo-Vaccinienion* community). Frequently mown xerothermic grasses, farm meadows or kitchen gardens, which are present at Roj, Krl and Dom sites, are good examples of such open land habitats. Seasonal variability of LAI distributions can be seen at sites with sand and common lizards. The latter species were frequently sighted at sites with open, unmown areas (Joz, ZP, Bor, Buko) and with lush herbaceous vegetation (*Artemisietea*—rudimentary xerophylous and xerothermic grassland and *Leucobryo-Pinetum* community). This supports the fact that despite the above-mentioned lack of significant difference between the "observed" and "not observed" factors, these two species have an association with sites with variable LAI distributions in the period April-August. Therefore, one specific LAI value during the whole year may be inappropriate to characterize the habitat of these lizards.

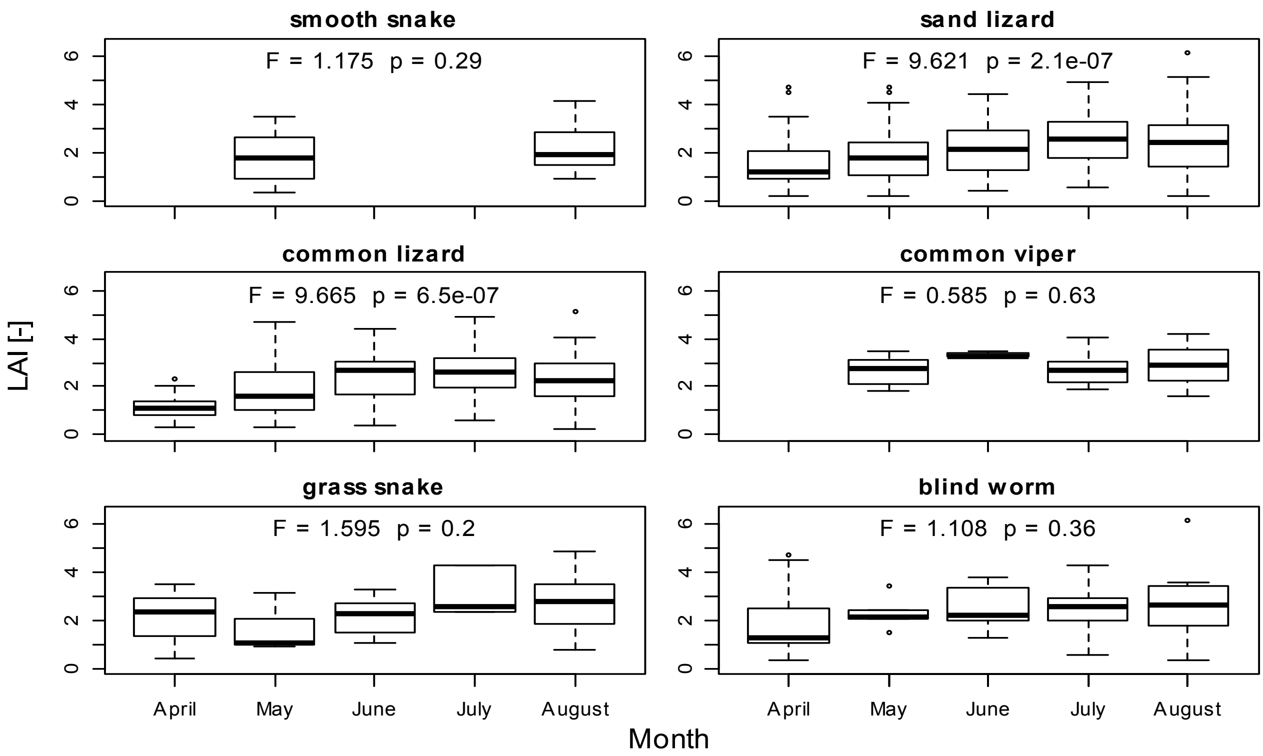

Figure 8. LAI monthly variability depending on sighted reptile species.

Significant differences in LAI distributions in each month (see Figure 8) are important for the creation of models simulating species occurrence areas. In these models, a generalized variable for the period of a year or a number of years is frequently used as an independent variable [2,5,7]. This type of annual analysis provides good results when some response metrics are analyzed; however, our reptile study seems to indicate an opportunity for further improvement by taking into account seasonal variability of the studied indicators. From our analyses, reptiles appear to need variable habitats in terms of LAI (Figure 7) and this fact, in turn, suggests that for the modelling of habitat extent, information about the LAI's variability within the studied area or the analysis of its vicinity is required.

4. Conclusions

The Leaf Area Index (LAI) determines the abundance of leaves at the given measurement site, which influences the amount of solar radiation reaching it and may thereby influence the presence of various species of reptiles. In our study we examined the variability of the LAI in reptile habitats in the area of the Solska Forest and Roztocze National Park, Poland. By means of an LAI-2000 device, we measured the distributions of LAI values over the period of 2011 to 2013 at 11 sites and conducted herpetological surveillance. We found six reptile species in the investigated area.

Our results demonstrate that the relationship between the occurrence of reptiles and LAI values distributions depend on the reptile species. From among the species investigated in our study, the common viper, grass snake and blind worm were the only ones that were observed in habitats with higher median yearly LAI values. However, the sand lizard and the common lizard occurred in habitats where LAI values were seasonally variable. The smooth snake, the grass snake, the common viper and blind worm, on the other hand, were found in habitats with broad LAI distributions and similar LAI medians.

Importantly, our studies have also found a relationship between LAI and reptile biodiversity and abundance of individuals. It appeared that the optimal distribution of LAI values for reptile habitats ranged from 0.17 to 5.17, which was considered broad. The narrower LAI ranges were linked with a lower number of sighted reptiles. The distribution of LAI values also was associated with the biodiversity of reptiles; a greater number of species was detected at sites with higher median LAI values. However, with increasing biodiversity, LAI distribution became narrower. This could have resulted from a smaller number of reptile observations in habitats with lower LAI values.

The aim of this research was to examine the utility of the LAI as a habitat index for reptiles inhabiting our study area in Poland. Based on our results, we can conclude that the LAI is a suitable habitat index for the observed reptiles' biodiversity. Moreover, LAI distributions within an area can provide information about the presence or absence of the common viper and grass snake and, to some extent, about reptile abundance. However, due to broad LAI distributions, it cannot be used as a threshold variable to determine reptile abundance or the presence or absence of individual species. It is also worth noting that LAI distributions are seasonally variable for the common lizard and sand lizard. These findings stress the necessity of taking into account LAI seasonal variability and distributions for studies on the relationship between this index and reptile occurrence, e.g., whilst developing spatial models of reptile habitats. Our results can also be used as a guide for reptile protection, such as for planning new protection areas or managing existing areas in scope of LAI.

For future research, it would be interesting to create a more detailed habitat model depicting the occurrence of reptiles in the area of the Solska Forest and Roztocze National Park. Such a model could include LAI values obtained from remote sensing data and serving as an independent variable. In the studies to come, it would be very important to stress that for successful modelling of reptile occurrences, seasonal variability and spatial diversification of habitat attributes warrant consideration, such as the LAI.

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Author Contributions

Tomasz Berezowski and Jakub Kośmider conceived and designed the experiments, analyzed the data and wrote the paper; they also performed the experiments with help of Magdalena Greczuk; Jarosław Chormański contributed materials/analysis tools and supervised the work including the manuscript revision.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Leyequien, E.; Verrelst, J.; Slot, M.; Schaepman-Strub, G.; Heitkönig, I.; Skidmore, A. Capturing the fugitive: Applying remote sensing to terrestrial animal distribution and diversity. *Int. J. Appl. Earth Obs. Geoinf.* **2007**, *9*, 1–20.
2. Rodríguez, M.Á.; Belmontes, J.A.; Hawkins, B.A. Energy, water and large-scale patterns of reptile and amphibian species richness in Europe. *Acta Oecol.* **2005**, *28*, 65–70.
3. Mitchell, N.; Hipsey, M.R.; Arnall, S.; McGrath, G.; Tareque, H.B.; Kuchling, G.; Vogwill, R.; Sivapalan, M.; Porter, W.P.; Kearney, M.R. Linking eco-energetics and eco-hydrology to select sites for the assisted colonization of Australia's rarest reptile. *Biology* **2013**, *2*, 1–25.
4. Sillero, N.; Gonçalves-Seco, L. Spatial structure analysis of a reptile community with airborne LiDAR data. *Int. J. Geogr. Inform. Sci.* **2014**, *28*, 1709–1722.
5. Skidmore, A.K.; Toxopeus, A.G.; de Bie, K.; Corsi, F.; Venus, V.; Omolo, D.P.; Marquez, J.; Giménezb, R.R. Herpetological species mapping for the Meditteranean. In *ISPRS Commission VII Mid Term Symposium on Remote Sensing from Pixel to Processes;* ISPRS: Enschede, The Netherlands, 2006.
6. Said, M.Y.; Skidmore, A.K.; de Leeuw, J.; Aligula, H.M.; Kumar, L.; Prins, H.H.T. Analysis of the relationship between ungulate species richness in East Africa and climatic and remotely sensed productivity indices. In *Multiscale Perspectives of Species Richness in East Africa*; University of Wageningen: Wageningen, The Netherlands, 2003; pp.17–38.
7. Guisan, A.; Hofer, U. Predicting reptile distributions at the mesoscale: Relation to climate and topography. *J. Biogeogr.* **2003**, *30*, 1233–1243.
8. Coops, N.C.; Wulder, M.A.; Duro, D.C.; Han, T.; Berry, S. The development of a Canadian dynamic habitat index using multi-temporal satellite estimates of canopy light absorbance. *Ecol. Indicators* **2008**, *8*, 754–766.
9. Coops, N.C.; Wulder, M.A.; Iwanicka, D. Demonstration of a satellite-based index to monitor habitat at continental-scales. *Ecol. Indicators* **2009**, *9*, 948–958.
10. Powers, R.P.; Coops, N.C.; Morgan, J.L.; Wulder, M.A.; Nelson, T.A.; Drever, C.R.; Cumming, S.G. A remote sensing approach to biodiversity assessment and regionalization of the Canadian boreal forest. *Prog. Phys. Geogr.* **2013**, *37*, 36–62.
11. Shen, L.; He, Y.; Guo, X. Suitability of the normalized difference vegetation index and the adjusted transformed soil-adjusted vegetation index for spatially characterizing loggerhead shrike habitats in north American mixed prairie. *J. Appl. Remote Sens.* **2012**, *7*, 073574.
12. Welles, J.M.; Norman, J.M. Instrument for indirect measurement of canopy architecture. *Agron. J.* **1991**, *83*, 818–825.
13. Dąbrowski, P.; Pawluśkiewicz, B.; Kalaji, H.M.; Baczewska, A.H. The effect of light availability on leaf area index, biomass production and plant species composition of park grasslands in Warsaw. *Plant Soil Environ.* **2013**, *59*, 543–548.
14. Beets, P.N.; Reutebuch, S.; Kimberley, M.O.; Oliver, G.R.; Pearce, S.H.; McGaughey, R.J. Leaf area index, biomass carbon and growth rate of radiata pine genetic types and relationships with LiDAR. *Forests* **2011**, *2*, 637–659.

15. Portillo-Quintero, C.; Sanchez-Azofeifa, A.; Culvenor, D. Using VEGNET *in-situ* monitoring LiDAR (IML) to capture dynamics of plant area index, structure and phenology in aspen parkland forests in Alberta, Canada. *Forests* **2014**, *5*, 1053–1068.
16. Szporak-Wasilewska, S.; Krettek, O.; Berezowski, T.; Ejdys, B.; Sławik, Ł.; Borowski, M.; Chormański, J. Leaf Area Index of forests using ALS, Landsat and ground measurements in Magura National Park (SE Poland). *EARSeL eProc.* **2014**, *13*, 103–111.
17. Dąbrowska-Zielińska, K.; Gruszczyńska, M.; Lewiński, S.; Hościło, A.; Bojanowski, J. Application of remote and *in situ* information to the management of wetlands in Poland. *J. Environ. Manag.* **2009**, *90*, 2261–2269.
18. Berezowski, T.; Chormański, J. Wetland leaf area index modelling with field and satellite hyperspectral data. *EARSeL eProceedings* **2014**, *13*, 30–35.
19. Greenberg, C.H. Response of reptile and amphibian communities to canopy gaps created by wind disturbance in the southern Appalachians. *For. Ecol. Manag.* **2001**, *148*, 135–144.
20. Pike, D.A.; Webb, J.K.; Shine, R. Removing forest canopy cover restores a reptile assemblage. *Ecol. Appl.* **2011**, *21*, 274–280.
21. Uziak, S.; Turski, R. *Natural Environment of Lubelszczyzna;* Lubelskie Towarzystwo Naukowe: Lublin, Poland, 2008. In Polish.
22. Skowera, B.; Kopcińska, J.; Kopeć, B. Changes in thermal and precipitation conditions in Poland in 1971–2010. *Ann. Wars. Univ. Life Sci. Land Reclam.* **2014**, *46*, 153–162.
23. Kośmider, J. Ecological and Geographical Distribution of Smooth Snake Coronella Austrica and Charecteristic Features of Its Habitat in the Area of Solska Forest and Roztocze National Park. Master's Thesis, Warsaw University of Life Sciences, Warsaw, Poland, 2010.
24. Juszczyk, W. *Domestic Amphibians and Reptiles*; Państwowe Wydawnictwo Naukowe: Warsaw, Poland, 1974. In Polish.
25. Heyer, W.R.; Donnelly, M.A.; McDiarmid, R.W.; Hayek, L.A.C.; Foster, M.S. *Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians*; Smithsonian Institution Press: Washington, DC, USA, 1994.
26. Fang, H.; Liang, S.; Townshend, J.R.; Dickinson, R.E. Spatially and temporally continuous LAI data sets based on an integrated filtering method: Examples from North America. *Remote Sens. Environ.* **2008**, *112*, 75–93.
27. Szporak, S. Remote sensing methods in assessment of evapotranspiration in the Biebrza River Lower Basin. Ph.D. Thesis, Warsaw University of Life Sciences, Warsaw, Poland, 2011.
28. Spellerberg, I.F.; Phelps, T.E. Biology, general ecology and behaviour of the snake, *Coronella austriaca* Laurenti. *Biol. J. Linnean Soc.* **1977**, *9*, 133–164.
29. House, S.M.; Spellerberg, I.F. Ecology and conservation of the sand lizard (*Lacerta agilis* L.) habitat in Southern England. *J. Appl. Ecol.* **1983**, *20*, 417–437.
30. Dent, S.; Spellerberg, I.F. Habitats of the lizards *Lacerta agilis* and *Lacerta vivipara* on forest ride verges in Britain. *Biol. Conserv.* **1987**, *42*, 273–286.
31. Reading, C.J.; Buckland, S.T.; McGowan, G.M.; Jayasinghe, G.; Gorzula, S.; Balharry, D. The distribution and status of the adder (*Vipera berus* L.) in Scotland determined from questionnaire surveys. *J. Biogeogr.* **1996**, *23*, 657–667.

32. Wisler, C.; Hofer, U.; Arlettaz, R. Snakes and monocultures: Habitat selection and movements of female grass snakes (*Natrix natrix* L.) in an agricultural landscape. *J. Herpetol.* **2008**, *42*, 337–346.
33. Stumpel, A.H. Reptile habitat preference in heathland: Implications for heathland management. *Herpetol. J.* **2012**, *22*, 179–182.