Rural land use design based on an evaluation of insect ecological sensitivity

Abstract

Insects are crucial components of many ecosystems, where they perform many essential functions. They aerate the soil, pollinate blossoms, and control insect and plant pests. The ecological importance of insects cannot be underestimated: they form the core part of the food pyramid and affect our agricultural ecosystems and human health. All organisms are co-evolved and are dependent on one another. Human activities, which are a part of the ecosystem, cause adverse effects on the living environments of insects. Opening forests and natural areas to agricultural activities hurt the insect ecosystem. Land, which is the foundation of all human activities, is also the home of insects. Insects have been in competition with humans for the products of our labor ever since the cultivation of soil began. In this research, we evaluated the impact of land use (by humans) on insect ecology.
In one village of Burundi, where the most practiced activity is agriculture, we evaluated the effects of cropland, settlement, forestry system, and humid areas on insect ecology. We coined "insect ecological sensibility" and considered it in our study area. The entire village area is used as agricultural land and settlement. Artificial forestry, and pastures, especially the absence of protected areas and ecological corridors, are the main points that negatively affect insect ecology.
Key words: insect ecological sensitivity, insect ecology, burundi, rural land use, GIS and insects.

Introduction

Animal and plants have co-evolved and interwoven strong relations between themselves and their ecology. The biotic and abiotic relationships make life in any area. Humans, one of the animal kingdom's members in these complex relationships and whose health depends on the life of biodiversity, influence the ecosystem's life (Chivan and Bernstein 2010, Yonglong *et al.* 2015, Morand and Lajaunie 2019).

Insects are a critical part of biodiversity in numbers and biodiversity services. More than 80% of identified animals and more than 50% of all identified beings are insects (Schowalt 2020). Insects are keystone species in many ecosystems. More than 80% of all existing insects are waiting to be identified. Seeing the threats that insects face, some species maywhich insects are facing, it seems that there are species which may disappear before being identified (Gullan and Cranston 2014, Schowalt 2016).

The World is in growing need to feed the increasing population. On the other side, humanity competes for economic growth. The only resource to answer increasing food and financial needs in rural areas is the land (Garnett 2013, Marcos-Martinez 2017). Rural areas are considered as a big reservoir of biodiversity. Biodiversity tends to decrease with various effects. Slowly forests are cut and replaced by farms and field crops. The natural landscape is substituted with an artificial landscape (agriculture), which only promotes some plant species. Changes in land use, which greatly affect biodiversity in rural areas, are occurring rapidly. Agriculture and settlement are the most eminent land use (Kleijn 2009, Haines-Young 2009).

Burundi's political strategies since the year 2005 are encouraging the extension of rural farming. This type of farming uses virgin lands that host native species. In their plan to open new fields to agriculture there is no ecological consideration. Many indiginous trees are disappearing and are not coming back. Considering the interdependence between species, the disappearance of trees also causes the disappearance of the insect species that depend on them. Burundi's climate has two seasons; a rainy and dry season. During the dry season, local people are encouraged to farm on swamps and marshes. Marshes and wetlands are among the most significant water banks after lakes and oceans. People drain water from swamps and wetlands to open them up for agriculture. With the opening of these areas to agriculture, thousands of species living in the ecosystem that has formed are disappearing. Marshes and swamps play a significant role in fighting against climate change. This means that to destroy the marshes and swamps means to open a window to climate change (Zhaoqing and Zhou 2013, Romanowski 2013, Weller 1994). The increasing Burundian population increases pressure on land in different ways. The new generation needs a place for farming and settlement. Some virgin land is open to agriculture. The increase in population necessitates the opening of new agricultural areas. The fact that each family has many children causes the lands to be divided by inheritance laws. The fragmentation of land causes increased erosion and loss of biodiversity.

The only considerations in rural land use are socio-economic. Ecologic sensibility is given less, even no, consideration. The ecology means the life of the plots. If ecology is not considered, the land will gradually lose its economic performance. Rural planning improves the quality of life and economic well-being of communities living in relatively unpopulated areas rich in natural resources. Regarding land use and management, in the context of the rural regions, it seems that there are less scientific works about rural planning. Many reasons for that; many investments are made in urban areas. Businessmen/women from the towns come to exploit rural farms and return to the towns. These factors put rural ecosystems in danger. The district of Mukike is one of the highest altitudes in Burundi (more than 2000m a.s.l), and it houses the highest mountain of Burundi (Mount Heha: 2700 m a.s.l). The district is made of a succession of many hills separated by streams and rivers. Mukike has a long mountain range (Congo-Nile ridge, along which (along its feet) take source many streams). The village of Gisorwe, where the main economic activity is agriculture, is located in the west part and feet of the Congo-Nile ridge.

Insects have various benefits as well as harms. There are pests to crops, timber, and store products among the ecosystem disservices are vectors of many diseases (some pandemics). Despite those disservices, insects are keystone species in all ecosystems. They recycle nutrients, are pollinators, seed dispersers, maintain soil structure and fertility, control populations of many other organisms, and are a food source for many other taxas (Gullan and Cranston 2014, Schowalt 2020). Land use should take care of insect population stability. That is why we formulated here "insect ecological sensitivity". Ecological sensitivity stands for the impact of human interventions on the natural environment. Ecological sensitivity is determined by the reactions of the ecosystem to environmental changes caused by external and internal factors (Rossi *et al.* 2008, Liang and Li 2012, Zhang *et al.* 2012).

Insect ecological sensitivity will consider the main factors influencing insect ecology (biotic and abiotic). In this study we will determine the insect ecological sensitivity in the village of Gisorwe.

Materials and methods

Study area

The district of Mukike is one of the Bujumbura (rural) province's districts. It is located in middle-west of Burundi. The area of Mukike is 147.44 Km^2. Burundi by its wide range of altitudes (741 m to 2664 m a.s.l.) has all tropical microclimates. The district of Mukike is located at a distance of 45 Km from Bujumbura the economic capital of Burundi. The main economic activity is agriculture. The study area is the village of Gisorwe (one of Mukike district's villages) located between 3°30'50''-3°32'08'' South Latitude and 29°32'51''-29°31'02'' East Longitude in the West feet of the Congo-Nile ridge. It has a total of 419.93 hectares (Figure 1).

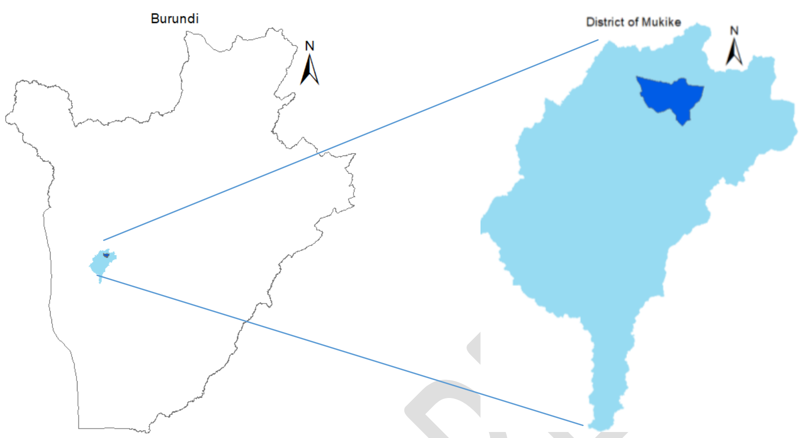


Figure 1: Location of the study area (Village of Gisorwe) on the Burundi map.

Data source

Raw GIS data about Burundi were obtained from Institut Géographique du Burundi (IGEBU).
Demographic data were obtained from the Office of the district of Mukike.

Materials

The factors influencing insect ecological sensitivity were identified by reviewing pre-existing literature. Field surveys were also conducted in the study area. Gullan and Cranston (2014) and Schowalt (2016) show which factors cause insect ecological and environmental problems. These factors vary from agroecological zone to another, region to region, and country to country. Field visits were conducted from February to August 2020. Farmers, academicians, and agriculture officers were interviewed and information was collected about the area through open-ended questions. GIS database were given by Institut Géographique du Burundi (IGEBU).

Ecological sensitivity is the reaction level of the environmental change caused by internal and external factors. Insect ecological sensitivity is an ecological sensitivity in which the domain in insect ecology. Human activities dramatically affect insect ecology, so some disappear (Schowalt 2020). In this analysis, we evaluated land use activities and pattern their effects on insect environmental conditions.

Research Methods

Identification of insect ecological sensitivity (GIS-based insect ecological sensitivity analysis)

As our study aims to determine the sensibility of insect ecology, our primary criteria are deduced from the main factors of insect ecology. In **"Rural land use design based on an evaluation of insect ecological sensitivity,"** the significant finding is the threat of human land use to the life of insects. Our criteria focus on the following factors: altitude, agriculture, light pollution, roads, settlements and artificial forest exploitation. In our GIS-based analysis, we measured the area occupied by each factor. We confront each area and respective threats (on insect) gravity. We establish maps showing different factors' area. This GIS method was reinforced by insect samples collected from each factor area. ANOVA analysis was used to compare the insect samples numbers.

Agriculture (cropland) factor: Agriculture is significant in insect habitat loss. Before installing crop fields, natural habitat is destroyed. A broad amalgam of pesticides is used during field exploitation to protect crops. These pesticides kill pests and natural enemies.

Settlement factor: Rural or urban settlements occupy fields that insects occupy. Even if we have some insects (which are enemies in most cases), these ones are completely different from the indiginous ones. Settlement is always associated with insect habitat destruction.

Road factor: As an essential ecologic factor, roads destroy natural habitat by the place it occupies and its buffer (segmentation of habitat).

Light pollution factor: Night lights destroy insect ecology by disrupting insect phenology. Insects like moths mate at night are attracted by the light and are not mating. On the other side, insects that could rest at night are attracted by night lamps, they stay flying long time and experience a lot of early deaths.

Pastures and artificial forest exploitation factor: Insects need a quiet habitat without human intervention. Carpenter bees need dried logs to make galleries (for laying eggs). Moths and butterflies need stable places for pupae, diapause, etc. Herbivores and other insects need stable and optimal conditions to perform their ecosystem role at different trophic levels.

Results and discussion

Elevation. The village of Gisorwe is between 2171.18 m and 2587.34 m of sea level, then an altitude difference of 416.16 m (Fig. 2.1). We tested if the altitude influences the insect population in the village. Temperatures change with elevation, hence the change in environmental factors (Rahbek *et al.* 2019). Multiple studies have shown that the effect of elevation on species diversity varies between locations and taxonomical groups (McCain 2009). In our study area we collected a sample of insects at four different spots at different altitudes (there was a difference of 100 m of altitude between 2 consecutive points). Every sample was collected at an area of 10x10m and all samples were taken in plots with similar soil cover (pastures). The sample of insects that we collected shows no difference in species (Table 1). Our systematics analysis limits at the Order level. The main Orders considered were Coleoptera, Hymenoptera, Diptera and Lepidoptera. ANOVA analysis ($p=.9352 > .005$) shows no difference between samples collected at different altitudes of the village. This proves that the difference in altitude in the village of Gisorwe is not enough to cause differences in insect diversity. The village of Gisorwe belongs to the same eco-elevation spectrum. No previous entomological studies were performed in these villages.

Table 1: Number of sample species collected in four spots.

Site	Order	Species	Site	Order	Species	Site	Order	Species	Site	Order	Species
1	Hymenoptera	20	2	Hymenoptera	17	3	Hymenoptera	11	4	Hymenoptera	20
1	Coleoptera	25	2	Coleoptera	32	3	Coleoptera	33	4	Coleoptera	24
1	Lepdoptera	10	2	Lepdoptera	12	3	Lepdoptera	9	4	Lepdoptera	12
1	Diptera	15	2	Diptera	19	3	Diptera	16	4	Diptera	16

P=.9352 (>.05).

Light pollution. Of 71 households in our study area, only ten households have (solar energy) electricity lighting overnights. Light pollution threatens biodiversity through changed night habits of insects, amphibians, fish, birds, bats and other animals: disruption of foraging patterns, increased predation risk, disruption of biological clocks, increased mortality on roads, and disruption of dispersal movements through artificially lighted landscapes, etc. (Beier P 2006, Gauthreaux Jr. and Belser 2006, Moore et al. 2006). Insects are one class of animals mostly affected by photopollution (Eisenbeis 2006). Artificial lights disrupt the day-night equilibrium of insects (Frank 2006, Lloyd 2006)). Insects are first of all attracted to artificial light sources. The first effect is that they die of exhaustion (Smith 2009, Sanders and Gaston 2018). Most insects' affected biological activities are flight, vision, defense against predators, oviposition, courtship/mating, feeding/foraging (van Langevelde 2017, Li et al. 2019, Manriquez et al. 2019). Light pollution can therefore harm insects by reducing total biomass and population size and changing the relative composition of populations, all of which can affect further up the food chain. Furthermore, light pollution is considered an important driver behind some ecologic erosion (van Langevelde 2017). In our study area, mostly moths were attracted to lamps in the night. The night light pollution caused by a number of 10 households is far from causing severe harm to the insect population in the village.

Road factor. The village counts three soil roads that length 3269.07 m (Fig. 2.4). Worldwide one potentially significant but under appreciated threat to insects is road mortality. Studies have clearly shown that insects are killed by roads traffic in different ways (Baxter-Gilbert *et al.* 2015, Amanada *et al.* 2018). Given the extent of the global road network worldwide, billions of insects are likely killed on roads each year. These deaths are specially observed in cities and towns and on busy highways (Andersson *et al.* 2017). The more active the traffic, the higher the insect mortality. Only one road (2076,15 m) has medium traffic of 10 (maximum 20) cars per day in our study area. The other two (536,36 m and 656,56 m) are community roads that can pass for months without a car or a motorcycle. Except for some insects and larvae, which can die on the soil, flying insects can easily cross these roads without being hit by cars or humans. Roads are not a threat to insect ecology in the village of Gisorwe.

Agriculture (cropland) factor. Agriculture is considered worldwide factor number two in the threats against insects (Eggleton 2020). Agricultural pesticides can reduce insects population and diversity, which are important species for the ecosystem (Gibbs *et al*. 2009). Many pesticides are toxic to beneficial insects, birds, mammals, amphibians, or fish. These have led to the population decline of many species living on farmland (Boatman *et al.* 2007). In farmland habitats, population declines have occurred in about half of plants, a third of insects, and four-fifths of bird species (Robinson and Sutherland 2002). In our study area, agriculture occupies 45.17% (cropland and tea plantations) (Table 3). Both croplands and tea plantations are not good insect biotopes. Before the installation of fields, natural habitat is destroyed. This means that some insects may also disappear. It follows the installation of new crops, sometimes monoculture; some insects will lack food. As the natural habitat has been destroyed, the natural ecosystem equilibrium is lost and some insects will become pests. Pesticides are the mostly used way to control pests; this justifies the use of pesticides in conventional agriculture. We recorded the use of two main insecticides; dimethoate and chlorpyrifos. The mostly used fungicide is dithane. All farmers are using pesticides in their fields. In tea plantations we recorded the use of chemical fertilizers, and weeds are regularly hoed or cut. This makes tea plantations an unstable habitat for insects.

Pastures and artificial forest exploitations. Green spaces like pastures and forests would normally be the natural habitat of insects and another biodiversity. The more the environment is stable, the more insect populations are stable. Insects should be well conserved via efforts to preserve their habitats (Wolda *et al.* 1992). But, when humans exploit the forests and pastures, insect habitat is destroyed. In the village of Gisorwe, pastures are permanently grazed, and grasses are often cut to be brought into stables or for composting. Many types of grass are cut before they reach their flowering or maturity stages, depriving many insects of their food and habitat (as some insects feed on flowers). As they are made to be exploited, artificial forests lose their natural forest nature. In our study area, the main tree species found are Eucalyptus maidenii, Eucalyptus saligna, and Acacia maerensii (Table 2, Fig. 2.6), which are exploited for use in construction or transformed into charcoal. Woods and charcoal are sent to towns. Besides business, rural families collect firewood in these artificial forests. These practices are hazardous to insect ecology (Samways et al. 2020). Insects like carpenter bees (*Xylocopa sp.*) and other insects which use dried or decomposing logs are endangered species because they don't find logs or dried woods in nature (Raju and Lao 2006, He and Zhu 2020). *Eucalyptus sp*., *Cupressus sp.* and *Acacia maerensii* are exotic species, this means that indiginous tree species were lost with some insect species (Payn *et al.* 2015, Perry *et al.* 2016). Some indiginous trees which are remaining should be unable to support indiginous insects. Furthermore, the surexploitation in firewood and grasses for stables can't allow the stability of the insect habitat.

Table 2: tree species and their area

Species	**Area (m^2)**	**%**
Eucalyptus sp.	475980.51	45.23064
Cupressus sp.	475587.91	45.19334
Acacia maerensii	4894.89	0.465143
Bamboos + other indiginous	12104.62	1.150257
Eucalyptus sp. + indiginous	83772.84	7.960619
Total	1052340.78	100

Settlement. Settlement is an important element in insect ecology because before settling natural habitats are destroyed and buildings occupy entirely the soil. After settlement, there is frequent application of different chemicals to control different pests in households and the habitat is unstable for insects (Turnbull 1980). In our study area, 1.75% of the area is a settlement (Table 4). A dispersed settlement like the one of Gisorwe village would have no significant impact on the insect ecology if natural habitats surrounded it. Insect ecology is aggravated because settlements are surrounded by unstable ecosystems (croplands, tea plantations, artificial forests and pastures) (Figure 2.3).

Comparison between different land-use classes. The village of Gisorwe is located in the high altitudes of Burundi. The annual medium raining precipitations are 769,2 m. It rains nine months per year. A big network drains the village of permanent small streams (Fig. 2.2). The streams pass through valleys, mostly V-valleys, with high slopes. Insect samples were collected from different classes of land use areas (Table 3) to make a global comparison between the main classes. This analysis was made to make a comparison of the consequences of different land use. Because many valleys are cropland-covered, we decided to use a plot (in the valley) that is not cultivated. ANOVA analysis; P=.0008 (<.05), has shown a big difference in insect populations between valleys, cropland, tea plantations and pastures/artificial forests. A higher population is observed in noncultivated valleys. There is a big need to examine the effects of agricultural practices in the valleys of Burundi. Figure 2.3 and Table 4 present respective areas and proportions of different land use. Their different effects on insect ecology allow us to establish different levels of **"insect ecological sensibility"**. In our study area, some factors are enough to threaten insect ecology. Other factors are not significant alone, but are significant because others aggravate them.

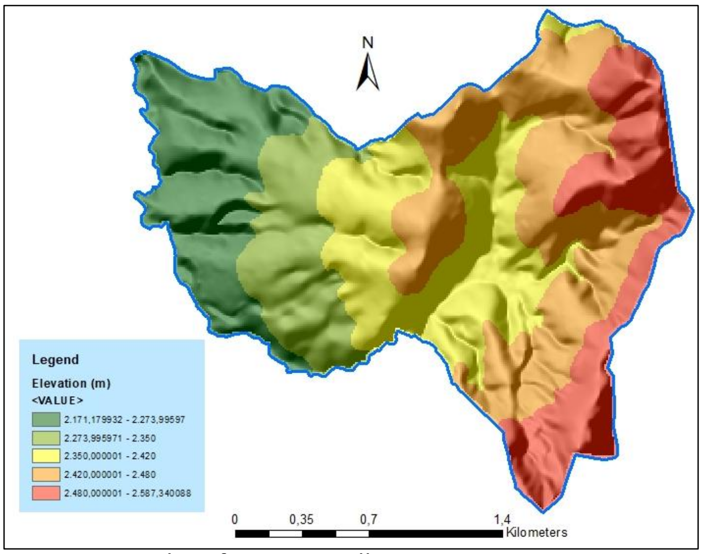
Table 3: Comparison of insect populations in main classes

Site	Order	Species	Site	Order	Species	Site	Order	Species	Site	Order	Species
Valleys	Hymenoptera	32	Cropland	Hymenoptera	5	Pastures+ Forests	Hymenoptera	16	Tea plantations	Hymenoptera	9
Valleys	Coleoptera	21	Cropland	Coleoptera	10	Pastures+ Forests	Coleoptera	33	Tea plantations	Coleoptera	3
Valleys	Lepdoptera	40	Cropland	Lepdoptera	6	Pastures+ Forests	Lepdoptera	20	Tea plantations	Lepdoptera	8
Valleys	Diptera	55	Cropland	Diptera	10	Pastures+ Forests	Diptera	24	Tea plantations	Diptera	11

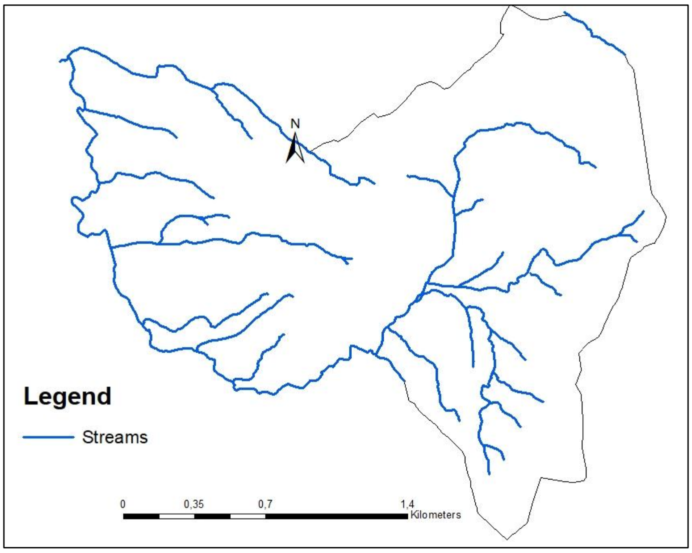
P=.0008 (<.05).

Table 4: Comparison of different land use and their sensibility significance

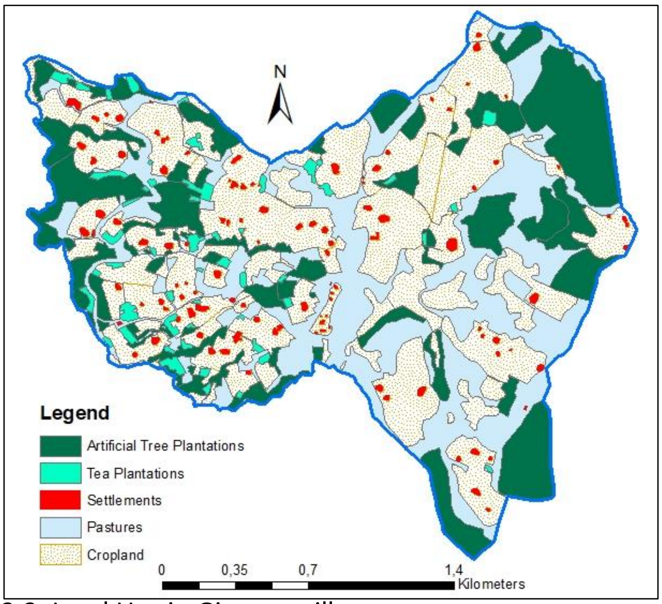
Land Use(m^2)	Land use class	Area (m^2)	%	Insect ecological sensibility level
4199389.67	Cropland	1794152.24	42.72412	Sensitive and significant
	Settlement	73436.85	1.748751	Sensitive, insignificant but aggravated by other factors
	Stabilized road in soil	19614.42	0.467078	Sensitive and insignificant
	Artificial tree plantations	1072373.77	25.53642	Sensitive and significant
	Pastures	1137358.05	27.08389	Sensitive and significant
	Tea plantations	1052340.78	2.439744	Sensitive and significant



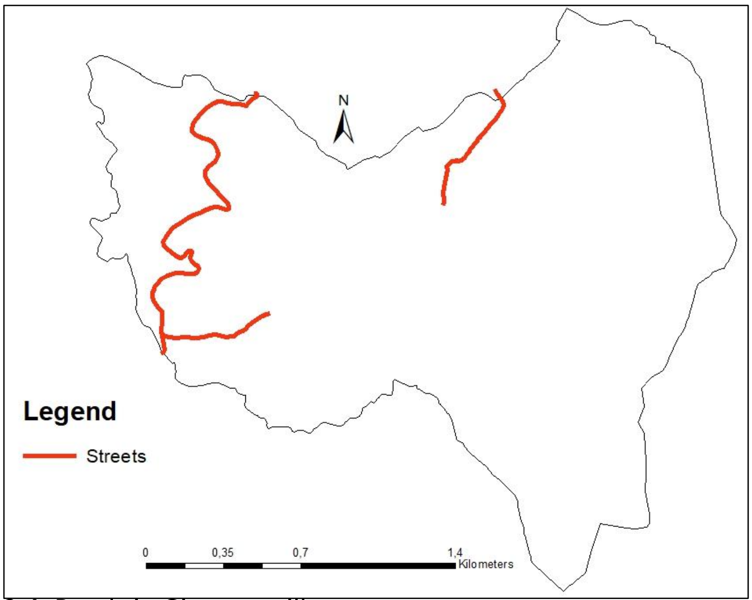
2.1. Topography of Gisorwe village



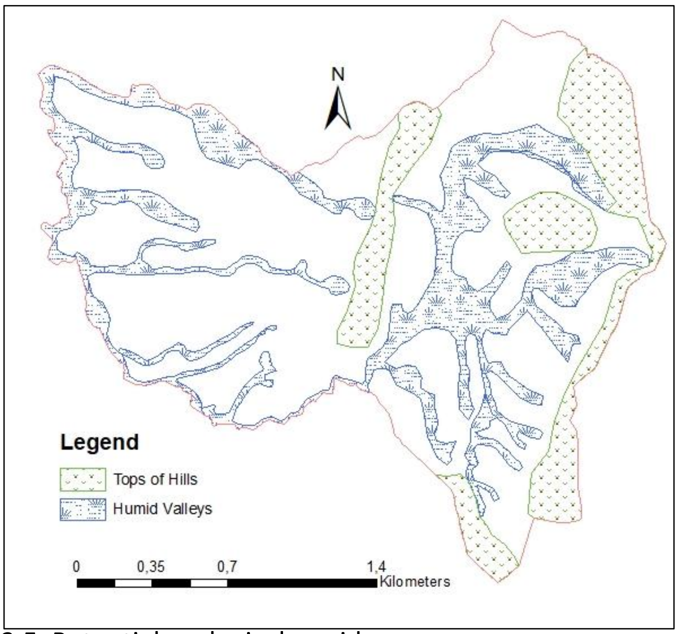
2.2. Streams in Gisorwe village



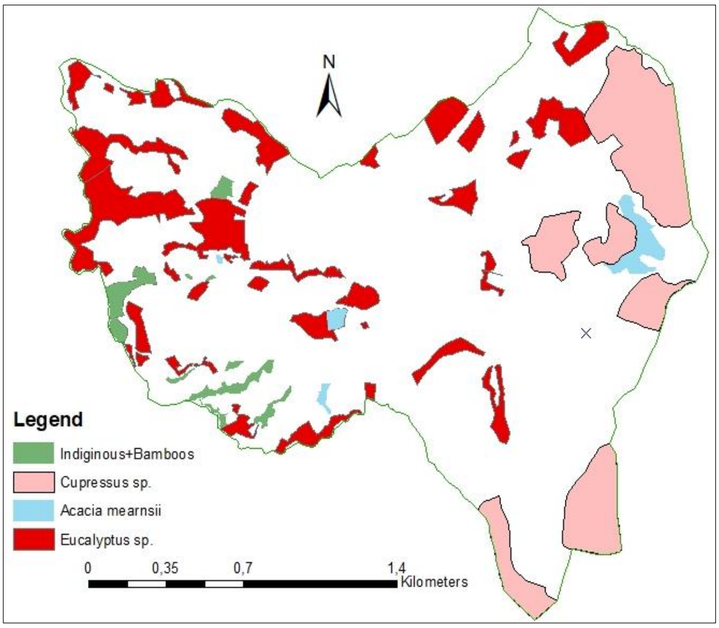
2.3. Land Use in Gisorwe village



2.4. Roads in Gisorwe village



2.5. Potential ecological corridors



2.6. Distribution of main tree species in the village of Gisorwe

Figure 2: Maps about insect sensibility in Gisorwe

Potential protected areas and ecological corridors. Streams and tops of hills need special protection for ecological conservation (Fig. 2.5). Corridors are long, thin strips of habitat that connect otherwise isolated habitat patches. They are thought to reduce local extinction. Corridors have been shown to serve as movement conduits for species of all animal taxa (Thomas 1991). Corridors influence the local foraging behavior of birds and free movements of pollinating insects, thus determining plant dispersal. As corridors effectively direct the dispersal of diverse taxa, these taxa are important in a broad range of ecosystem functions. Corridors have the potential to be valuable tools for landscape-scale conservation of diverse taxa and the biological processes that they direct (Hilty *et al.* 2020). Rivers and streams house a big population of species. Streams and their valleys have to be protected as the top of hills are a special place for water infiltration (forests ought to cover them) and serve as a connection between consecutive protected areas (ecological corridors). In our study area there is no protected area or ecological corridor.

Conclusion

In this research of "**Rural land use design based on an evaluation of insect ecological sensitivity"** we researched the situation of insects based on rural land use in the village of Gisorwe. There is no consideration of ecosystem or insect ecology in rural development and planning. This scenario has severe consequences on ecology and the environment in general. All the village is in the same eco-elevation zone. Light pollution and road factor are not an ecological threats. Settlement, croplands, and exploitation of artificial forests and pastures are the big threats to insects ecology. Furthermore, our study area has nor protected areas neither ecological corridors. In summary, the high sensible areas are: the cropland and tea plantations, artificial tree exploitation and pastures. The areas which would be kept as protected areas and ecological corridors are especially sensitive because they house all kind kinds of human activities. Land use in the village of Gisorwe doesn't care about insect ecology.

References

Rahbek C, Borregaard MK, Colwell RK, Dalsgaard B, Holt BG, Morueta-Holme N *et al.* Humboldt's enigma: What causes global patterns of mountain biodiversity? *Science 2019;365:1108–1113.*

McCain CM Global analysis of bird elevational diversity. *Glob. Ecol. Biogeogr. 2009;18:346-360.*

Amanda EM, Shanon LG, Melissa H, Erik P, Lenore F. Flying insect abundance declines with increasing road traffic. *Insect Conservation and Diversity. 2018;11: 608–613.*

Andersson P, Koffman A, Sjödin NE, Johansson V. Roads may act as barriers to flying insects: species composition of bees and wasps differs on two sides of a large highway. *Nature Conservation. 2017;18: 41–59.*

Baxter-Gilbert JH, RileyJL, Neufeld CJH, Litzgus JD, Lesbarreres D. Road mortality potentially responsible for billions of pollinating insect deaths annually. *Journal of Insect Conservation. 2015;19, 1029–1035.*

Beier P. Effects of artificial night lighting on terrestrial mammals in: Rich C, Longcore T (eds). Ecological consequences of artificial night lighting, February 23–24, 2002. Los Angeles, California. 19-42p. 2006.

Boatman ND, Parry HR, Bishop JD, Andrew GS. Impacts of agricultural change on farmland biodiversity in the UK in: Hester RE, Harrison RM (eds). Biodiversity under threat, RSC Publishing, Cambridge, UK. 1-32p. 2007.

Chivan E, Bernstein A. Sustaining life: how human health depends on biodiversity. Havard University, Center for Health and the Global Environment. 429 pp. 2010.

Eggleton P. The state of world's insects. *Annual Review of Environment and Resources. 2020;45(8) 1–22.*

Eisenbeis G. Artificial night lighting and insects: attraction of insects to streetlamps in a rural setting in Germany in: Rich C, Longcore T (eds). Ecological consequences of artificial night lighting, February 23–24, 2002. Los Angeles, California. 281-304p. 2006.

Frank KD. Effects of artificial night lighting on moths in: Rich C, Longcore T (eds). Ecological consequences of artificial night lighting, February 23–24, 2002. Los Angeles, California. 305-344p. 2006.

Garnett T. Food sustainability: Problems, perspectives and solutions. *Proc. Nutr. Soc.* 2013;72(1):29–39. doi: 10.1017/S0029665112002947

Gauthreaux Jr. SA, Belser CG. Effects of artificial night lighting on migrating birds in: Rich C, Longcore T (eds). Ecological consequences of artificial night lighting, February 23–24, 2002. Los Angeles, California.. 67-93p. 2006.

Gibbs KE, Mackey RL, Currie DJ. Human land use, agriculture, pesticides and losses of imperiled species. *Diversity and Distributions 2009;15(2): 242-253.*

Gullan PJ, Cranston PS. The insects: an outline of entomology. JohnWiley & Sons. 562p; 2014.

Haines-Young R. Land use and biodiversity relationships. *Land Use Policy*. 2009;26:S178–S186.

He C, Zhu C. Nesting and foraging behavior of *Xylocopa valga* in the Ejina Oasis, China. PLoS ONE. 2020;15(7). e0235769. https://doi.org/10.1371/journal.pone.0235769

Hilty J, Worboys GL, Keeley A, Woodley S, Lausche B, Locke H. Guidelines for conserving connectivity through ecological networks and corridors. IUCN, Gland, Switzerland. 117p; 2020.

Kleijn D, Kohle F, Baldi A, Batary P, Concepcion ED, Clough Y *et al.* On the relationship between farmland biodiversity and land-use intensity in Europe. *Proc. R. Soc. 2009;276: 903–909.*

Li X, Jia X, Xiang H, Diao H, Yan Y, Wang Y *et al.* The effect of photoperiods and light intensity on mating behavior and reproduction of Grapholita molesta (Lepidoptera: tortricidae). Environ. Entomol. 2019;48(5):1035–1041. https://doi.org/10.1093/ee/nvz066

Liang C, Li X. The Ecological sensitivity evaluation in Yellow River Delta National Natural Reserve. *Clean Soil Air Water. 2012;40(10)1197–1207*.

Lloyd JE. Stray light, fireflies and fireflyers in: Rich C, Longcore T (eds). Ecological consequences of artificial night lighting, February 23–24, 2002. Los Angeles, California. 345-364p. 2006.

Manriquez PH, Jara ME, Diaz MI, Quijon PA, Widdicombe S, Pulgar J *et al.* Artificial light pollution influences behavioral and physiological traits in a keystone predator species, *Concholepas concholepas*. *Sci. Total Environ. 2019;15(661):543-552.*
doi: 10.1016/j.scitotenv.2019.01.157

Marcos-Martinez R, Bryan BA, Connor JD, King D. Agricultural land-use dynamics: Assessing the relative importance of socioeconomic and biophysical drivers for more targeted policy. Land Use Policy. 2017;63:53–66.

Moore MV, Kohler SJ, Cheers MS. Artificial light at night in freshwater habitats and itspootential ecological effects in: Rich C, Longcore T (eds). Ecological consequences of artificial night lighting, February 23–24, 2002. Los Angeles, California. 365-384p. 2006.

Morand S, Lajaunie C. Biodiversity and health: linking life, ecosystems and societies. UK. 221 pp; 2019.

Payn T, Carnus JM, Freer-Smith P, Kimberley M, Kollert WD, Liu S *et al.* Changes in planted forests and future global implications. *Forest Ecology and Management.2015:352:57–67.*

Perry J, Lojka B, Ruiz LGQ, Van Damme P, Houška J, Cusimamani EF. How natural forest conversion affects insect biodiversity in the Peruvian Amazon: Can agroforestry help? *Forests 2016;7:82*. doi:10.3390/f7040082

Raju AJS, Rao SP. Nesting habits, floral resources and foraging ecology of large carpenter bees (*Xylocopa latipes* and *Xylocopa pubescens*) in India. *Current Science*. 2006;90:9.

Robinson RA, Sutherland WJ. Post-war changes in arable farming and biodiversity in Great Britain. *Journal of Applied Ecology*. 2002;39:157-176.

Romanowski N. Living waters: ecology of animals in swamps, rivers, lakes and dams. Australia. 266 pp; 2013.

Rossi P, Pecci A, Amadio V, Rossi O, Soliani L. Coupling indicators of ecological value and ecological sensitivity with indicators of demographic rressure in the demarcation of new areas to be protected: The case of the Oltrepo Pavese and the Ligurian- Emilian Apennine area (Italy). Landscape Urban Plann. 2008;85(1):12–26.

Samways MJ, Barton PS, Klaus Birkhofer K, Chichorro F, Charl Deacon C, Fartmann T *et al.* Solutions for humanity on how to conserve insects. Biological Conservation. 2020;242:108427.

Sanders D, Gaston KJ. How ecological communities respond to artificial light at night. *J Exp Zool. 2018;329:394-400.*

Schowalt TD. Insect Ecology: an ecosytem approach. Academic Press. 696p; 2016.

Schowalt TD. Insect and society. CRC Press, USA. 288p; 2020.

Smith M. Time to turn off the lights. *Nature. 2009;457:27.*

Thomas CD. Ecological corridors: an assessment. Department of Conservation. Wellington, New Zealand. 53p; 1991.

Turnbull AL. Man and insects: the influence of human settlement on the insect fauna of Canada. Canadian Entomologist. 1980;112(11):1177-1184.

van Langevelde F, Braamburg-Annegarn M, Huigens ME, Groendijk R, Poitevin O, van Deijk JR *et al.* Declines in moth populations stress the need for conserving dark nights. *Glob. Chang. Biol. 2018;24(3):925-932.* PMID: 29215778. doi: 10.1111/gcb.14008

van Langevelde F, van Grunsven RHA, Veenendaal EM, Fijen TPM. Artificial night lighting inhibits feeding in moths. Biol. Lett. 13. , 2017

Van Langevelde F, Van Grunsven RHA, Veenendaal EM, Fijen TPM. Artificial night lighting inhibits feeding in moths. Biol. Lett. 2017;13: 20160874. http://dx.doi.org/10.1098/rsbl.2016.0874

Weller M.W. Freshwater marshes: Ecology and wildlife management, Third Edition. University of Minnesota Press. 111 pp; 1994.

Wolda H, Spitzer K, Leps J. Stability of environment and of insect population. Res. Popul. Ecol. 1992;34:213-225.

Yonglong L, Ruoshi W, Yueqing Z, Hongqiao S, Pei W, Alan J *et al.* Ecosystem health towards sustainability. *Ecosystem Health and Sustainability*. 2015;1(1):1-15.

Zhang J, Xiang C, Li M. Integrative ecological sensitivity applied to assessment of eco-tourism impact on forest vegetation landscape: a case from the Baihua Mountain Reserve of Beijing, China. Ecological Indicators. 2012;18:365–370.

Zhaoqing L, Zhou D. Impacts of intensified agriculture developments on marsh wetlands. *The ScientificWorld Journal. 2013:1-10*. http://dx.doi.org/10.1155/2013/409439