Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 4, No. 2, p. 119-129, 2014
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Impact of landuse practices on agrobiodiversity in selected organic and conventional agroecosystems in Bulgaria

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Article published on February 03, 2014

Key words: Agrobiodiversity, organic agriculture, index of Shannon, agroecosystems.

Abstract

Agrobiodiversity in agroecosystems and their role for maintaining their stability in absence of chemical inputs is not sufficiently investigated in Europe. As a first step in a larger study, this investigation focused on the territory of Eastern Rhodope mountain of Bulgaria in June – September 2012. It tried to compare the impact of organic and conventional agricultural landuse on certain agrobiodiversity indicator groups (insects, birds and small mammals). On the basis of determined taxa density and abundance, and in order to assess and compare biodiversity of the selected indicator groups (insects at the level of order), indices of biodiversity of Shannon (Shannon_H index) and 'Diversity profiles' were calculated. The overall biodiversity of the indicator groups in selected organic landuses (cereals, orchard and pasture) was higher (i.e. index of biodiversity Shannon_H and diversity profiles) than in the reference conventional landuses. However, when analysed individually, the three indicator groups showed no statistically significant differences between organic and conventional areas by the index of biodiversity Shannon_H. Nevertheless, a significant difference in exemplar density of class Insecta (2237 exemplars in organic against 712 in conventional landuses) was detected in spring and summer. The results can be attributed to the absence of chemical plant protection inputs in organic cereals and orchards, minimal soil cultivation and the regulated grazing in the organic pastures/meadows. The results are a basis for further more extensive research, comprising a longer period of e.g. 3-4 years, more organic and conventional plots and crops, monitoring agrobiodiversity indicators at the level of species, etc.

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Introduction

Biodiversity protection is in the focus of scientific and nature conservation societies in Europe. In the last few decades the greatest threat to biodiversity is shown by agricultural systems and unsustainable agricultural practices applied in these systems (Tscharntke *et al.,* 2005).

Benefits of organic farming are not solely confined in the well-known facts (IUCN, 1994, Azeez, G., 2000,) that the use of chemical pesticides and synthetic fertilizers is prohibited, the number of animals on a given area is reduced, a greater care for the soil and its fertility is exhibited and a high proportion of semi-natural areas is maintained. There are also benefits to local biodiversity of plant and animal species. In turn, these species provide environmental services such a creating adaptive microclimate, maintaining habitats that are better adapted to changes in the environment, delivering stable yields during dry periods and showing more efficient utilization of the resources on the farm (e.g. local livestock breeds and control over the grazed pastures). Increased biodiversity provides opportunities for joint existence and interactions between beneficial species, which can improve the stability of the crops, natural (not chemical) pest and disease control through greater abundance and variety of natural enemies of insect pests, a completed cycle of nutrients, recycling of organic matter and maintenance of soil fertility, and greater number of bees and better pollination leading to higher yields.

Agrobiodiversity reduces the risk to farmers, particularly in the remote areas with unstable environmental conditions.

The role of maintaining certain level of agrobiodivesity for achieving certain level of stability in agroecosystems in absence of chemical inputs is not sufficiently investigated in Bulgaria and in Europe. Such investigation should involve observations on the diversity of indicator plants and animals in rural areas so as to make a reasonable conclusion on the role of organic agriculture to protect the environment. It is also necessary to highlight issues related to potential conflicts between organic agriculture methods and practices and protection of wild animals, birds and their habitats. For comparison of diversity of designated indicator groups, an index of biodiversity by Shannon (Shannon_H index) is used. Statistical significance of data was tested by t-test, a statistically significant difference is considered at $p \leq 0.05$. A comparison was made between different indices of diversity for further comparison and confirmation of the results. This is accomplished through the use of “Diversity profiles” (Tothmeresz, 1995).

Therefore, the purpose of this study was to compare extensive and environmentally-friendly farming practices typical for organic production with practices used in conventional farming. This is order to conclude upon the potential effect of these practices on certain groups of species that were selected and designated as indicators of agrobiodiversity.

Materials and methods

Territorial scope of the study

The study of the designated indicator groups (insects, birds and small mammals) was conducted on the territory of the Eastern Rhodope mountain in Bulgaria. Organic areas (organic farming type of landuse) and the control areas (conventional type of landuse) include agricultural land within the municipalities of Ivaylovgrad, Madjarovo and Stambolovo, District Haskovo.

The selected organic areas include (Table 1), 20 ha of certified organic rye in the village of Kondovo, Municipality Ivaylovgrad; 12 ha of organic pasture in the village of Gorno pole, Municipality Madjarovo, and 35 hectares of sour cherry orchard in the village of Popovets, Municipality Stambolovo.

The selected control areas include: 8 ha of wheat, grown by a conventional method in the village of Kondovo, Municipality Ivaylovgrad, 37.6 ha of pasture, located in the village of Dolni Glavanak, Municipality Madjarovo, 100 ha of cherry orchard in the village of Svetoslav, Municipality Stambolovo.

It is important to note that in order to offset the impact of differences in the organic and control areas, relatively similar by size areas were observed. Also, the type of landuse can be regarded as a factor that is typical for the observed territories. The control plots in the cherry orchard in the village of Svetoslav involves fertilisation with mineral fertilisers (triple superphosphate, ammonium nitrate), regular soil cultivation including disc-ploughing, application of insecticides (i.e. 'Decis', 'Vaztak') against the cherry fly (*Rhagoletis cerasi L.*), and fungicides against diseases such as white rust (i.e. 'Fulikur'), early and late brown rot (*Monilinia laxa*), etc. In the conventional plots with cereals in Kondovo village, a relatively small amount of ammonium nitrate (50-70 kg/ha) was applied and regular soil cultivations were applied, while conventional grazing land (meadows) aside Dolni Glavanak village were not used for grazing by the local livestock, which could have resulted in a lower amount of grass species compared to extensive organic pastures around Gorno pole village.

Table 1. Type of crops / habitats, type of management, location of sample and control areas.

N	Types of crops / habitats	Nature of production	Property №	Area ha	Location	Municipali-ty	District
1	Rye	Organic	028001	20	Kondovo	Ivaylovgrad	Haskovo
2	Wheat	Conventio-nal	022017	8	Kondovo	Ivaylovgrad	Haskovo
3	Pastures/ meadows	Organic	017013	12	Gorno pole	Madjarovo	Haskovo
4	Pastures/ meadows	Conventio-nal	012006	37,6	Dolni glavanak	Madjarovo	Haskovo
5	Sour-cherry orchard	Organic	057029, 057035, 057040	35	Popovets	Stambolovo	Haskovo
6	Cherry orchard	Conventio-nal	005003	100	Svetoslav	Stambolovo	Haskovo

Prioritisation and selection of the organic and control areas was conducted on the basis of the following criteria:

- Type of farming - organic or conventional
- Type of crops grown
- Block size of agricultural land used for the organic and conventional crops
- Ability to provide access to experimental and control plots in the completion of the study
-

Scope of the species

Subject to field study were species of the groups of insects, birds and mammals designated as indicators of the natural conditions and resources in agricultural land subject to this study. Group selection was carried out based on the existing ecological relationships between them (mainly dietary requirements and similar spatial properties - habitat types), and based on the differences in their biology and ecology, which determine the differences in their adaptation abilities (e.g. degree of movement) and their response to applied agricultural practices. Giving the scope of the fieldwork and the consecutive analysis of the results, species living mainly on agricultural land and in open space are included as a priority. Typical representatives of forest habitat types are excluded from the scope of the study. The study did not observe the presence/absence large mammals, due to the significant size, movement and the diverse nature of the territories occupied by them.

Study period

The study was conducted in the period June to September 2012. It allowed for reporting the breeding adult exemplars, including zero annual exemplars of the groups. Within the period three visits were made, i.e. in 2 to 5 June 2012, in 3 to 4 July, and in 12 to 15 September.

Each of predetermined transects and fixed observation points within the organic and control areas were visited at least two times within the study period. The time between visits was approximately 30 days. The survey of all plots during each visit was completed within three consecutive days.

Study methodology

The studies were focused on availability, species identification and abundance of insects, small mammals and birds within the organic and control areas. Based on the selected indicator groups and the applied field methods, the following components were studied:

1. Insects (class Insecta)

Method description

a. *Transect method*

The identification of and systematic affiliation (order and suborder) of insects within the territory subject to the study is done using a transect method (Heyer *et al.,* 1994; Sutherland, 1996, 2000). The transect width was fixed at 5 m (at 2.5 m from the median line of the survey) and the length was minimum 100 m.

A standard entomological bag with d = 30 cm was used. The scheme for obtaining samples incorporates a cross with 100 m-long arms. Such a way of recording using more than 25 cuts minimises likelihood for errors during counting of the captured exemplars and also the study area is covered in a better way. After a recording of 25 cuts, the next cuts are made at about 100 m from the site of the first cuts.

b. *Soil traps*

Soil traps types 'BARBER' were used. Plastic containers are buried in the soil to the level of the substrate with dimensions d = 9 cm, h = 12 cm, filled halfway with preservative (formalin 10-20%). The content is collected at least once a month (Popov et.al, 2000). The setting up of 10 soil trap at 1ha of area studied was employed.

c. *Method for the accounting of individuals in the group Lepidoptera.*

It is performed visually by uniform motion in a predetermined transect.

2. Small mammals (Micromammalia)

Method description

a. *Transect method*

Establishing the presence and identification of small mammals within the investigated areas were done using a transect method (Heyer *et al.,* 1994; Sutherland 1996, 2000). The transect width was fixed at 5 m (at 2.5 m from the median line of the survey) and the length was minimum100 m.

b. *Quantitative assessment*

The current distribution and abundance of the small mammals was determined as follows:

b.1. The abundance of small mammals was recorded using the method of trap-lines and trap-points (Karaseva and Telicina, 1993). Live-traps type "Longworth" and commercial live-traps (mouse-traps) Bulgarian type were used.

b.2. The relative density of moles, mole rat, porcupine, hare were counted visually by observing evidence left of their vital activity - molehills, burrows, droppings (Popov, 2007) by crossing the transect of minimum 100 m length and 5 m width.

b.3. The presence and abundance of small predators was recorded visually by direct observation or evidence left of their vital activity - holes, droppings, food remains (Popov, 2007).

3. Birds (class Aves)

Method description

The study of the presence, species identification and abundance of the representatives of the avifauna was completed on the base of stationary observations (VIEW POINT) and fixed observation points method. The location of the observation points and their number was subject to the principle of 100% coverage of monitored area of organic and control sites. The walking around and exploration of the points was realised in daylight, in the morning, and between 6 and 7 pm and no later than 9.30 pm. The observations were made with the help of binoculars with a magnification of at least 8x and optical tube and with minimal increase of 20x. The optical tube was used to determine the species and for reporting more distant flocks / groups and individuals.

Fixed observation points were pre-defined and subject to the following criteria:

1) Good visibility in the defined perimeter around the observation points, which includes:
   - A clear view of the observation objects;
   - Availability of lifted plots providing view to the surrounding areas;
   - Distance from forests, forest belts or cliffs, tall buildings that obstruct visibility, especially in the direction of observation;
   - Provision of maximum visibility with minimum number of observation points.

2) Complete / representative coverage of the territory, subject to the study.

Taxonomic ranking of the species and writing of their Latin names are in accordance with Snow and Perrins (1998), and of Bulgarian names according to Simeonov and Mitchev (1991). For determining the status of occupation of the habitat of birds, a categorisation of Simeonov and Mitchev (1991) and Svensson *et al.*,(2000) was used.

Quantitative assessment and data analysis

To assess and compare diversity of indicators groups in organic and conventional areas, an index for biodiversity Shannon (Shannon_H index) was used. The choice of this index was determined by the ability it provides for obtaining accurate quantitative assessment when working with a relatively small sample of data. The index is calculated with the software Past ver. 2.17b (Hammer *et al.,* 2001).

Statistical significance of the data was tested by t-test, where a statistically significant difference is considered $p \leq 0.05$. A factorial ANOVA (STATISTICA, StatSoft, USA) analysed the effect of interaction of main observed factors, i.e.: order (class *Insecta* and *Aranei*), season of sampling (spring and autumn), type of landuse (fruit orchard, cereals, natural pastures/meadows), and method of agriculture (organic, conventional).

The validity of comparing the degree of diversity can be criticized because of the random (arbitrary) choice of the index of variety. In this regard, a comparison between different indices of diversity for the purpose of further comparison and confirmation of results. This is accomplished through the use of “Diversity profiles”. Thus a collection (normalized value) of different indices of diversity, depending on a continuous parameter (Tothmeresz, 1995) is defined.

Results and discussion

Insects (class: *Insecta)*

Within the scope of the study 2.949 exemplars of 15 insect orders are identified. Of these. 2.237 exemplars of 15 orders were identified in the organic areas and 712 exemplars of 14 orders were found in the conventional area. The greatest diversity of orders were found in the samples collected from Popovets (organic cherry orchard), and the lowest diversity was found in the samples near the village of Kondovo (conventional wheat).

The collected material is determined up to level of order. Species density collected in September was significantly lower compared to the spring period. The reason is occurrence of a drought, which dramatically reduced the number of invertebrates.

There were two species found which have a conservation status (Fig.1 and Fig.2).

Fig. 1. Jersey Tiger, day-flying moth (Euplagia quadripunctaria), detected on 13.09.2012.

Larvae Beetle *Calosoma sycophanta* larvae predating

Fig. 2. Forest caterpillar hunter or ground beetle (*Calosoma sycophanta*), detected on 14.06.2012, and its larvae eating a larvae of *Lymantria dispar* , which is a pest damaging the leaves of the fruit trees.

Both species are seen in the area near the village of Svetoslav. Near the plots of the conventional orchard, an oak forest is situated. Both species are reported common for oak forests.

When collecting samples of the conventional sites of the village of Svetoslav, due to failure to apply the same methodology, two 50-meter transects on both sides of the site were used.

The treatment of conventional sites with insecticides would have had a critical impact on both number of species number of exemplars. Apart from the loss of biodiversity, a number of useful species of invertebrates used as bioagents (predators) might have been destroyed.

The analysis of the collected data for the representatives of insects (class *Insecta*), shows that the index of biodiversity Shannon_H within the territories managed organically H (Bio) = 1.918 does not differ significantly from the one in the territories with conventional landuse H (Conv) = 1.923 (Table 2). A difference is observed in the raw data of the identified exemplars, i.e. their density in the investigated organic areas is 2237, whilst the density in the conventional areas is 712. However, there is no statistically significant difference between the indices of the two territories p = 0.993 (t = 0.011366).

Table 2. Values of the different indices of biodiversity on the basis of the data for Class Insecta in the investigated areas of organic and conventional production.

Indexes	Organic	Lower	Upper	Conv.	Lower	Upper
Taxa_S	14	12	15	12	10	14
Individuals	2237	2237	2237	712	712	712
Dominance_D	0.1616	0.1581	0.1662	0.1777	0.1558	0.1708
Simpson_1-D	0.8384	0.8338	0.8419	0.8223	0.8292	0.8441
Shannon_H	1.918	1.905	1.959	1.923	1.878	1.975
Evenness_e^H/S	0.4862	0.4571	0.5802	0.5702	0.4971	0.6855
Brillouin	1.903	1.891	1.945	1.887	1.846	1.94
Menhinick	0.296	0.2537	0.3171	0.4497	0.3748	0.5247
Margalef	1.685	1.426	1.815	1.675	1.37	1.979
Equitability_J	0.7268	0.7109	0.7809	0.7739	0.7351	0.836
Fisher_alpha	1.993	1.666	2.16	2.05	1.647	2.47
Berger-Parker	0.1886	0.1958	0.2257	0.2851	0.191	0.2416

The profile of diversity “Diversity profiles” (Tothmeresz, 1995) shows higher values for the organic areas than conventional ones (Fig. 3).

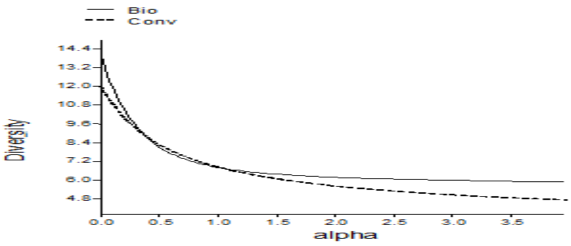

Fig. 3. Profiles of diversity of Class Insecta in the areas under organic and conventional management.

The effect of interactions of the major factors i.e. order, landuse and type of management (organic and conventional) after data approximation for spring and autumn observation showed that the exemplar density in organic plots is generally higher than density in conventional plots (p<0,005, Fig. 4). In both seasons, there are higher values of sub-orders *Cicadomorpha u Heteroptera,* разред *Hymenoptera, Diptera, Coleoptera* and class *Arane*ii were observed in the sour-cherry garden in Popovets, as well as in the organic pastures/meadows.

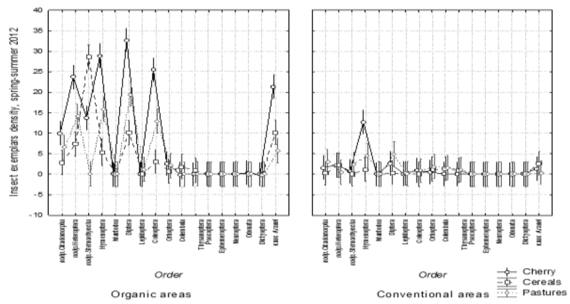

Fig. 4. Effect of interactions among major factors i.e. order, landuse, type of management (organic and conventional) after data approximation for spring and autumn observation, 2012, F(32, 611)=7.3036, p=0.000.

Mammals (class: Mammalia)

Within the scope of the study six taxa of mammals with a total of 26 exemplars were identified. Of these, 17 exemplars of 5 taxa were identified in the organic areas and 9 exemplars of 4 taxa were identified in conventional areas. Accurate determination of the species of the identified mammals (i.e. type of species-twins) without the use of genetic and molecular methods is impossible, but for the purposes of the study it does not affect the analysis and results. Such species are forest mice, i.e. yellow neck forest (*Sylvaemus flavicollis*) and plain forest mouse (*Sylvaemus sylvaticus*), two very similar in appearance and having well overlapping craniometrical performance. These trends are also valid for both types of the common vole - *Microtus arvalis* and *Microtus rossiaemeriodionalis*. That is why in the results these species are presented as *Sylvaemus* sp. and *Microtus* sp.

The analysis of the data for the exemplars of the Class *Mammalia* (Mammals), showed that the index of biodiversity Shannon_H in the organic areas is higher i.e. H (Bio) = 1.335 than the one in conventional areas i.e. H (Conv) = 1.215 (Table 3). There was a difference in exemplars density, i.e. 17 exemplars in organic and 9 exemplars in conventional. However, there was no statistically significant difference between the indices of the two territories p = 0.56815 (t = 0.58028).

Using the profile of diversity “Diversity profiles” (Tothmeresz, 1995) higher values for the territories managed in an organic way are observed (Fig. 5).

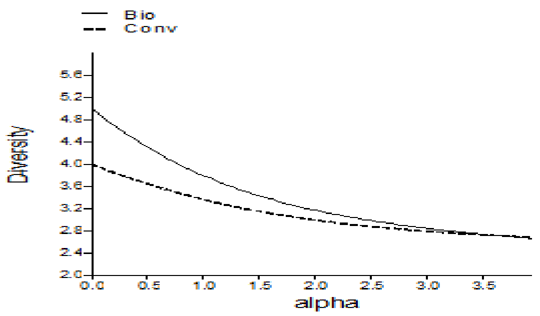

Fig. 5. Profiles of diversity of Class Mammalia in the areas under organic and conventional management.

Birds (class: Aves)

In the modeling of the study 16 observation points were identified and distributed across the different sites according to their size. Two visits were made to the trial sites during the period of 2-4 of June and 13-15 of September.

A total of 629 exemplars of 43 species from four orders were identified. Of these 358 exemplars of 33 species of birds were identified in the organic areas and 271 exemplars of 33 species in the conventional areas.

Table 3. Values of the different indices of biodiversity on the bases of the data for Class Mammalia in organic and conventional areas.

Indexes	Organic	Lower	Upper	Conv	Lower	Upper
Taxa_S	5	3	6	4	2	6
Individuals	17	17	17	9	9	9
Dominance_D	0.3149	0.2249	0.5363	0.3333	0.2099	0.6543
Simpson_1-D	0.6851	0.4567	0.7751	0.6667	0.3457	0.7901
Shannon_H	1.335	0.8083	1.619	1.215	0.5297	1.581
Evenness_e^H/S	0.7597	0.5943	0.9377	0.8425	0.6604	0.9828
Brillouin	1.055	0.649	1.268	0.8702	0.3982	1.114
Menhinick	1.213	0.7276	1.455	1.333	0.6667	2
Margalef	1.412	0.7059	1.765	1.365	0.4551	2.276
Equitability_J	0.8292	0.6451	0.9604	0.8764	0.6224	0.9875
Fisher_alpha	2.387	1.057	3.305	2.759	0.7972	7.867
Berger-Parker	0.4706	0.2941	0.7059	0.4444	0.3333	0.7778

Table 4. Values of the different indices of biodiversity on the bases of the data for Class *Aves* in organic and conventional areas.

Indexes	Bio	Lower	Upper	Conv	Lower	Upper
Taxa_S	33	35	41	33	33	40
Individuals	358	358	358	271	271	271
Dominance_D	0.05427	0.04633	0.05841	0.05718	0.04555	0.06134
Simpson_1-D	0.9457	0.9415	0.9537	0.9428	0.9386	0.9544
Shannon_H	3.126	3.131	3.305	3.121	3.09	3.307
Evenness_e^H/S	0.6906	0.6046	0.7111	0.6867	0.6124	0.7348
Brillouin	2.962	2.957	3.115	2.917	2.883	3.075
Menhinick	1.744	1.85	2.167	2.005	2.005	2.43
Margalef	5.442	5.782	6.802	5.712	5.712	6.962
Equitability_J	0.8941	0.8628	0.9048	0.8925	0.8642	0.913
Fisher_alpha	8.864	9.602	11.94	9.85	9.85	12.96
Berger-Parker	0.09777	0.08659	0.1285	0.1181	0.08487	0.1365

The analysis of the obtained data showed that the index of biodiversity Shannon_H in organic areas is higher i.e. H (Bio) = 3.126 than the one in conventional areas i.e. H (Conv) = 3.121 (Table 4). There was a difference in the exemplars density, i.e. 358 in organic areas and 271 in conventional. However, there was no statistically significant difference between the indices of the two territories p = 0.75954 (t = 0.30623).

Using the profile of diversity "Diversity profiles" (Tothmeresz, 1995) higher values for the territories managed in an organic way are observed (Fig. 6).

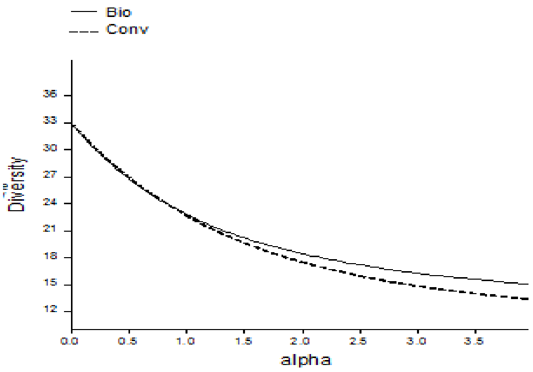

Fig. 6. Profiles for diversity in the areas with organic and conventional production for Class *Aves*.

Analysis of all indicator groups (Aves, Insecta, Mammalia) at a level of order

The analysis of the data for all of the indicator groups at a level of order, showed that the index of biodiversity Shannon_H in organic areas is higher i.e. H (Bio) = 2.128 than the conventional areas i.e. H (Conv) = 2.065 (Table 5). It is important to note that there is a statistically significant difference between the indices of the two territories p = 0.0325 (t = 2.1401).

Table 5. Values of different indices of biodiversity on the bases of the data for all the indicator groups at a level of order.

Indexes	Bio	Lower	Upper	Conv	Lower	Upper
Taxa_S	20	18	22	18	15	20
Individuals	2612	2612	2612	992	992	992
Dominance_D	0.1347	0.1323	0.1388	0.1619	0.1312	0.1416
Simpson_1-D	0.8653	0.8612	0.8676	0.8381	0.8583	0.8687
Shannon_H	2.128	2.109	2.164	2.065	2.081	2.175
Evenness_e^H/S	0.42	0.3868	0.4827	0.4381	0.4234	0.5569
Brillouin	2.111	2.092	2.145	2.028	2.048	2.137
Menhinick	0.3913	0.3522	0.4305	0.5715	0.4763	0.635
Margalef	2.415	2.161	2.669	2.464	2.029	2.754
Equitability_J	0.7104	0.6926	0.7447	0.7145	0.7107	0.7839
Fisher_alpha	2.946	2.604	3.295	3.123	2.507	3.548
Berger-Parker	0.1616	0.1639	0.1872	0.2651	0.1623	0.1966

The profile of diversity (Tothmeresz, 1995) showed higher values for the organic areas compared to conventional (Fig. 7).

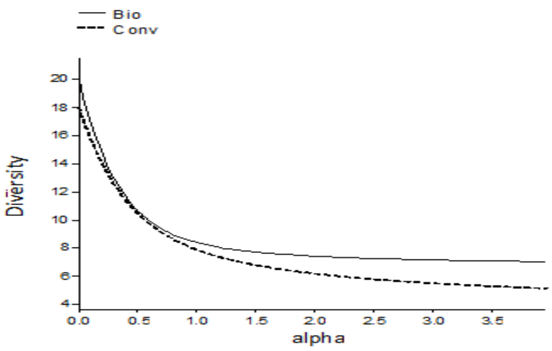

Fig. 7. Diversity profiles in the organic and conventional areas for all indicator groups at a level of order.

Conclusions

The results of the investigation of the selected organic areas (cereals, orchard and pasture) showed higher index of biodiversity Shannon_H and higher profile of diversity (Tothmeresz, 1995) compared to the indices shown by the indicator groups of the conventional areas, but when the three indicator groups were analysed together at a level of order. However, the analysis of the index of biodiversity Shannon_H showed no statistically significant differences between organic and conventional areas when the three indicator groups, i.e. insects, mammals and birds, were observed individually. There was a significant difference in exemplar density of class *Insecta* where 2237 were found in organic but 712 in conventional areas. The differences were observed in both spring and summer. The higher density and indices of diversity observed in organic areas can be attributed to the absence of chemical inputs for plant protection and the minimisation of soil cultivation as well the regulated grazing in the rural pastures/meadows.

The results of this investigation outlined a set of trends that could form a basis for further more extensive work. The following recommendations can be suggested:

- A more extensive research investigation should be undertaken for a period of 3-4 years, in which more organic and conventional plots and crops should be included.
- When selecting indicator groups a special attention should be paid to those groups and species that are not so mobile and are detached to the investigated territory. In this respect, attention should be paid to insects and small mammals. The birds are much more mobile than these two groups; they have extensive habitat requirements and adaptation abilities. But this could easily affect the indices of diversity and bias the overall conclusions.
- When designing the future investigation an identification of exemplars of class *Insecta* should be done at least to a level of genus. It could provide much better comparative data, better sample variation, and representativeness and validity of results.

Nevertheless, this investigation highlighted further the relationship between application of organic agriculture and restoring agrobiodiversity. It should be regarded as a signal to organic agroecosystem managers in Bulgaria on the importance of agrobiodiversity for regulating certain ecosystem processes, e.g. by reducing the number of soil cultivations, reduce harmful pesticide applications and increasing plant biomass and recycling the organic matter in their agroecosystems.

Acknowledgement

The authors express their deep gratitude to the Dutch-Bulgarian project 'New Thracian Gold' (www.newthraciangold.eu) and the Dutch Foundations Avalon and ARK Nature for the financial and logistical support during the implementation of this research.

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