TRANSYLVANIAN REVIEW OF SYSTEMATICAL AND ECOLOGICAL RESEARCH

18.3

The Wetlands Diversity

Editors

Doru Bănăduc & Angela Curtean-Bănăduc

Sibiu – Romania
2016

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IN MEMORIAM

Francis Crick
(1916 – 2004)

Francis Crick was a British molecular biologist, biophysicist, and neuroscientist, born and raised in Weston Favell, a small village near Northampton, in which Crick's father ran a boot and shoe factory.

Walter Crick, his grandfather, was an amateur naturalist. He published a review of local foraminifera, corresponded with Charles Darwin, and had two gastropods named after him.

From childhood, Francis was fascinated by science and by what he could learn about it. , His uncle, also Walter Crick, lived in a small residence in Abington Avenue, near his parent's home; Walter had a shed in his small garden where he instructed Francis do chemical experiments, blow glass, and to make photographic prints. When he was eight Francis moved to Northampton Grammar School. His teacher, Miss Holding, was an inspiring teacher and made all subjects attractive. After 14 years old, he won a scholarship to attend Mill Hill School in London, where he studied physics, mathematics, and chemistry. He shared the Walter Knox Prize for Chemistry in 1933 on Mill Hill School's Foundation Day 7 July, and he asserted that his achievement was stimulated by the quality of teaching he has enjoyed at Mill Hill.

At the age of 21, Crick earned a Bachelor of Science degree in physics from University College London (UCL). He began a PhD at UCL but was interrupted by World War II. He later became a PhD student and Honorary Fellow of Gonville and Caius College, Cambridge and for the most part worked at the Cavendish Laboratory and the Medical Research Council Laboratory of Molecular Biology in Cambridge. Crick was also an Honorary Fellow of Churchill College Cambridge and of University College London.

Crick began his PhD research project on the viscosity of water at high temperatures at University College London. During the second year of his PhD, he was awarded the Carey Foster Research Prize. He did postdoctoral work at the Polytechnic Institute of Brooklyn.

During World War II, he worked for the Admiralty Research Laboratory, from which emerged many notable scientists. He designed magnetic and acoustic mines.

In 1947, Crick started studying biology and was a part of an important migration of physicists into the area of biological research. Crick worked first on the physical properties of cytoplasm at the Strangeways Research Laboratory and Cavendish Laboratory, Cambridge.

Crick was interested mainly in fundamental problems of biology: how molecules make the transition from the non-living to the living, how the brain makes a conscious mind, the origin of life, etc.

He was most famous for being a co-discoverer of the structure of the DNA molecule in 1953 together with James Watson. In addition to his one-third share of the 1962 Nobel Prize, he received many honours and awards, among other things the Royal and Copley Medals of the Royal Society (1972 and 1975), and the Order of Merit (27 November 1991).

He married twice, fathered three children and was grandfather of six grandchildren.

Crick died of colon cancer on the morning of 28 July 2004, he was cremated and his ashes were scattered into the Pacific Ocean.

The Francis Crick Institute biomedical research centre located in north London, United Kingdom, is one of the largest such centres in Europe today.

The Editors

Transylvanian Review of Systematical and Ecological Research

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Preface

In a global environment in which the climate changes are observed from few decades no more only through scientific studies but also through day by day life experiences of average people which feel and understand allready the presence of the medium and long-term significant change in the “average weather” all over the world, the most comon key words which reflect the general concern are: heating, desertification, rationalisation and surviwing.

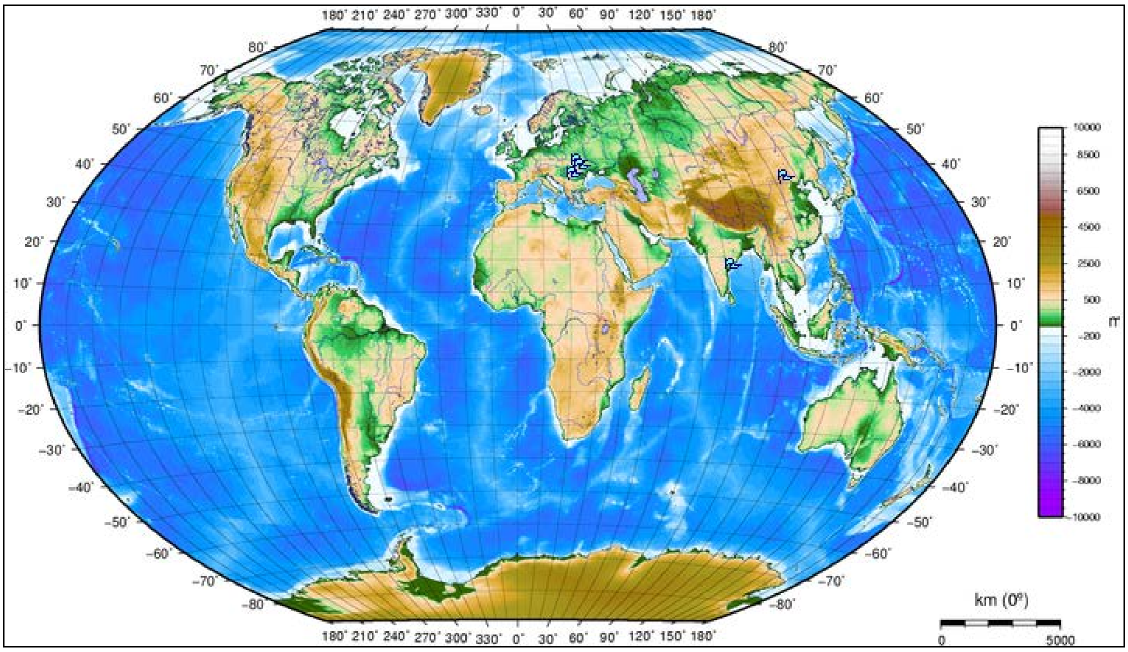
The causes, effects, trends and possibilities of human society to positively intervene to slow down this process or to adapt to it involve a huge variety of aproacess and efforts.

With the fact in mind that these aproaces and efforts shuld be based on genuine scientific understanding, the editors of the *Transylvanian Review of Systematical and Ecological Research* series launch a second annual volumes dedicated to the wetlands, volumes resulted mainly as a results of the *Aquatic Biodiversity International Conference*, Sibiu/Romania, 2007-2015 and The 41st International Association for Danube Research Cnference, Sibiu/Romania, 2016.

The therm wetland is used here in the acceptance of the Convention on Wetlands, signed in Ramsar, in 1971, for the conservation and wise use of wetlands and their resources. **Marine/Coastal Wetlands -** Permanent shallow marine waters in most cases less than six metres deep at low tide, includes sea bays and straits; Marine subtidal aquatic beds, includes kelp beds, sea-grass beds, tropical marine meadows; Coral reefs; Rocky marine shores, includes rocky offshore islands, sea cliffs; Sand, shingle or pebble shores, includes sand bars, spits and sandy islets, includes dune systems and humid dune slacks; Estuarine waters, permanent water of estuaries and estuarine systems of deltas; Intertidal mud, sand or salt flats; Intertidal marshes, includes salt marshes, salt meadows, saltings, raised salt marshes, includes tidal brackish and freshwater marshes; Intertidal forested wetlands, includes mangrove swamps, nipah swamps and tidal freshwater swamp forests; Coastal brackish/saline lagoons, brackish to saline lagoons with at least one relatively narrow connection to the sea; Coastal freshwater lagoons, includes freshwater delta lagoons; Karst and other subterranean hydrological systems, marine/coastal. **Inland Wetlands -** Permanent inland deltas; Permanent rivers/streams/creeks, includes waterfalls; Seasonal/intermittent/irregular rivers/streams/creeks; Permanent freshwater lakes (over eight ha), includes large oxbow lakes; Seasonal/intermittent freshwater lakes (over eight ha), includes floodplain lakes; Permanent saline/brackish/alkaline lakes; Seasonal/intermittent saline/brackish/alkaline lakes and flats; Permanent saline/brackish/ alkaline marshes/pools; Seasonal/intermittent saline/brackish/alkaline marshes/pools; Permanent freshwater marshes/pools, ponds (below eight ha), marshes and swamps on inorganic soils, with emergent vegetation water-logged for at least most of the growing season; Seasonal/intermittent freshwater marshes/pools on inorganic soils, includes sloughs, potholes, seasonally flooded meadows, sedge marshes; Non-forested peatlands, includes shrub or open bogs, swamps, fens; Alpine wetlands, includes alpine meadows, temporary waters from snowmelt; Tundra wetlands, includes tundra pools, temporary waters from snowmelt; Shrub-dominated wetlands, shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils; Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils; Forested peatlands; peatswamp forests; Freshwater springs, oases; Geothermal wetlands; Karst and other subterranean hydrological systems, inland. **Human-made wetlands -** Aquaculture (e. g., fish/shrimp) ponds; Ponds; includes farm ponds, stock ponds, small tanks; (generally below eight ha); Irrigated land, includes irrigation channels and rice fields; Seasonally flooded agricultural land (including intensively managed or grazed wet meadow or pasture); Salt exploitation sites, salt pans, salines, etc.; Water storage areas, reservoirs/barrages/dams/ impoundments (generally over eight ha); Excavations; gravel/brick/clay pits; borrow pits, mining pools; Wastewater treatment areas, sewage farms, settling ponds, oxidation basins, etc.; Canals and channels, ditches; Karst and other subterranean hydrological systems, human-made.

The editors of the *Transylvanian Review of Systematical and Ecological Research* started and continue this new annual sub-series (*Wetlands Diversity*) as an international scientific debate platform for the wetlands conservation, and not to take in the last moment, some last heavenly "images" of a perishing world …

This 18.1 volume included variated researches from diverse wetlands around the world.



The subject areas (⚑) for the published studies in this volume.

No doubt that this new data will develop knowledge and understanding of the ecological status of the wetlands and will continue to evolve.

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The editors would like to express their sincere gratitude to the authors and the scientific reviewers whose work made the appearance of this volume possible.

The Editors

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THE EFFECTS OF ENCLOSING CULTIVATED LAND ON THE PHYSICAL PROPERTIES OF SOIL IN THE LOESS HILL REGION OF ORDOS

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KEYWORDS: Soil bulk density, porosity and moisture, Ordos Region, China.

ABSTRACT

Protection of the environment by returning farmland to forest and grassland through enclosing areas of land to permit regeneration of native flora is being implemented in the Loess hill region of China. Soil physical properties are important components of ecological systems, as comparisons between cultivated and enclosed areas demonstrate. The results showed: the soil moisture content in the enclosed area was 14.6% and that in the cultivated area was 14%; the soil bulk density and soil porosity were respectively 1.45 g/cm^3 and 45.28% in the enclosed areas, and respectively 1.46 g/cm^3 and 44.79% in cultivated land. The alteration of soil physical properties was not big between cultivated areas and enclosed areas in the short term.

ZUSAMMENFASSUNG: Die Auswirkungen umfriedeter Nutzflächen auf die physikalischen Eigenschaften des Bodens im Loesshügelgebiet von Ordos.

Der Schutz der Umwelt durch Rückführung von Ackerland zu Wald und Grünland durch Einbeziehung von Landflächen, die Regenerierung der einheimischen Flora ermöglichen wurde in der Loesshügel Region von China umgesetzt. Die physikalischen Eigenschaften des Bodens sind wichtige Bestandteile der Ökosysteme, wie es der Vergleich zwischen bebautem und dem eingefriedeten Feld belegt. Die Ergebnisse zeigen, dass die Bodenfeuchtigkeit im eingefriedeten Bereich 14,6% und der im freien angebauten 14% betrug. Die hohe Bodendichte und Bodendurchlässigkeit zeigte jeweils 1,45 g/cm^3 und 45,28% im abgeschlossenen Bereich sowie 1,46 g/cm^3 and 44,79% im offenen bebauten Land. Die Veränderung der physikalischen Eigenschaften des Bodens wies im kurzfristigen Vergleich der beiden Flächen keine großen Unterschiede auf.

REZUMAT: Efectele împrejmuirii terenurilor cultivate asupra proprietăților fizice ale solului în podișul de loess al Ordosului.

În podișul loessoid al Ordosului în China mediul este protejat prin redarea terenurilor agricole utilizării în regim forestier și pășunatului prin împrejmuirea parcelelor de teren pentru a permite regenerarea florei native. Proprietățile fizice ale solului sunt componente importante ale sistemelor ecologice, așa cum o demonstrează comparația dintre parcelele cultivate și cele necultivate. Rezultatele au arătat următoarele: umiditatea din sol în parcela împrejmuită a fost de 14,6% iar cea din zona cultivată a fost de 14%; densitatea brută a solului și porozitatea au fost de 1,45 g/cm^3 și 45,28% în parcelele împrejmuite, respectiv de 1,46 g/cm^3 și respectiv 44,79% în cele cultivate. Pe termen scurt, proprietățile fizice ale solului nu au variat semnificativ de la parcelele cultivate la cele împrejmuite.

INTRODUCTION

The loess hills are the main landforms of the Loess Plateau in China, accounting for 48% of the total area of the Loess Plateau. The Loess Plateau is the largest loess deposition area in the world, with low precipitation, sparse vegetation and serious soil erosion (Yan et al., 2014). The loess hills are one of the main soil erosion areas in China: the terrain is fragile, the soil is loose and the vegetation and ecosystem are severely damaged. This situation is the result of an intertwined combination of ecological degradation and poverty, and the region is the focus of national ecological re-construction. In recent decades vegetation restoration has improved and soil erosion has been gradually contained through the implementation of a series of major ecological projects by national and local governments, including projects on returning farmland to forest and grassland, a natural forest protection project, and key soil and water conservation projects. This paper reports on one of these projects, the project of returning farmland to forest and grassland, the ultimate goal of which is to stop agricultural production and associated serious soil and water loss on the slopes of the upper reaches of the Yangtze River and the middle and upper reaches of the Yellow River and to encourage the restoration of forest and grassland to improve the ecological environment in the western region, the adjustment of economic and the sustainable development of the whole society (Yuan, 2006).

Returning farmland to forest and grassland is a basic measure to control soil and water loss on the Loess Plateau. The change in the underlying surface conditions will inevitably lead to change of soil physical properties and thus affect the regional material migration and transformation. Soil physical properties are one of the important physical characteristics of soil and are an important part of ecological benefits. Soil is a natural body, which is non-uniform and continuously changing. Soil properties are affected by internal factors (including parent material and soil formation processes, etc.) and external factors (including land management methods, fertilization, rotation, etc.). The physical properties of soil are affected by factors such as geomorphological factors, vegetation coverage, vegetation types and tillage degree under the combined influence of natural conditions and human factors.

The result of soil modification is important for the realistic use and conservation of regional soil and water resources. Returning farmland to forest improves the ecological environment by improving soil physical properties through the vegetation litter layer, thereby changing the surface characteristics of the root system, and affecting the abundance and composition of surface organism species (Xiang-hua et al., 2005).

Soil is the main limiting factor for vegetation here, due to the nature of loess deposits, which have poor soil water retention capacity, low soil nutrient content, and are eroded (Zhang et al., 2009). Soil bulk density is considered to be a useful parameter of soil structure (Hernanz et al., 2000). It is related to other soil properties, such as soil porosity, soil water content and hydraulic conductivity, as an important indicator to measure the quality of soil (Dam et al., 2005). The soil bulk density is an important index of soil tillage quality and fertility (Huang Changyong, 2000). The soil bulk density is the basic physical properties of the soil, and refers to the quality and weight of unit volume body (including soil particles and voids) in the natural state (Walker 1993; Zheng et al., 2004), which has an important influence on soil permeability, infiltration capacity, water holding capacity, solute transport and soil anti erosion ability (Zheng et al., 2004). Under natural conditions, the soil bulk density is a soil property with high degree of variability due to the influence of the soil-forming parent material, soil forming process, climate, and biological effects (Qiu et al., 2015). It is not only an important supplementary standard to measure the quality of soil fertility (Wang, 1996), but also an important indicator to evaluate the soil erosion resistance of sloping land (Wilson et al., 2005), which is of great significance in this study of returning farmland to forest and grassland.

The soil physical properties of farmland that has been returned to grassland/forest in Jixian County of Shanxi Province were studied based on the ring sampler method. Returning farmland to forest had great influence on various soil physical properties, which could lead to the evolution of degraded farmland soil to forest soil in a short time. The soil structure improved with time: total porosity increased, soil water and heat coordination increased, soil water holding capacity increased, the nutritional richness and supply of water was strengthened which is important for water preservation, and soil and water conservation, and soil corrosion resistance were enhanced significantly.

The modifications in the physical properties of soil in diverse croplands transformed to forest land were researched by Xing Juxiang in Wuqi County. The results showed that soil non-capillary porosity varied significantly according to different types of land use after returning farmland to forest, but that soil depth had no significant effect on soil porosity. No matter what type of land conversion, soil clay content in reforestation regions was higher than those in arable lands. Soil clay content did not increase significantly at depths between 0-20 cm, but was largely increased at depths of 20-40 cm and 40-60 cm. Soil was improved significantly in 0-20 cm soil layer and the soil bulk density in the 0-20 cm soil layer was significantly lower than that in the 20-40 cm soil layer and 40-60 cm soil layer. (Xing et al., 2010)

Grassland degradation results in the increase of soil bulk density and the decrease of water content in soil (Zhou et al., 2005; Zhao et al., 2010), it alters the coarseness of surface soil particles and leads to deterioration of soil structure (Liu et al., 2009).

In this paper, soil moisture content, soil bulk density and soil porosity were compared and analyzed in enclosing region and cultivated region in loess hilly region. It could provide scientific reference for the implementation of ecological environment protection in hilly areas.

MATERIAL AND METHODS

Study area

The Huangpu River is a tributary of the middle Yellow River, located at latitude 39.2°-39.9° N, longitude 110.3°-111.2° E with an elevation of 1,482 m a.s.l. at the highest point and 833 m elevation at its estuary elevation, a total height difference of 649 m. The Huangpu River originates in the transitional zone of the Ordos Plateau and the Loess Plateau, mainly flows through Zhungeer Banner in Inner Mongolia Autonomous Region and Fugu County in Shaanxi Province, and flows to the Yellow River in Fugu County. It belongs to the continental monsoon climate in the basin. The annual precipitation is 309.5-414.9 mm, precipitation is concentrated in July-September, which accounts for more than 70% of the annual rain fall, and more in the form of heavy rain. The area is prone to drought and is windy in winter and spring, with an average of 28.5 windy days, up to a maximum of 50 windy days per year. The average wind speed is 19 ms^{-1}, the maximum wind speed 24 ms^{-1}. The annual average temperature of the whole basin is 6.2-7.2℃, the average temperature in January is 12℃, the average temperature in July is 23℃, the extreme minimum temperature is –32.8℃ and the extreme maximum temperature is 39.1℃.

The study area was located in farmland near Gezhen Village, located in Xuejiawan locality, Zhungeer Banner, Erdos City, Inner Mongolia Autonomous Region. The longitude is 111° 8.6’ E and latitude is 39° 45.4’ N. The study area is located in a small watershed of the Ten-Miles-Long River, which is a tributary of the Huangpu River, near the soil and water conservation test station in Hejiawan Village of Zhungeer Banner. It is sparsely populated near the study area, inhabited by only a few farmers. Traditional farming methods are widespread and affected by the local terrain conditions, by the temperature, precipitation and other meteorological factors. Typically, one crop per year is taken, and the most common crops are corn, sorghum and potato. Sowing time is generally in mid-April each year, and harvest in late September. The surface remains bare in the rest of time.

The enclosing plots selected in this paper began to be enclosed in 2011. They belonged to natural returning farmland, and the enclosure time was three years. Soil samples were extracted in 2014. In this paper, the enclosed area is compared with soil samples taken from farmland areas which have not been enclosed or cultivated in order to investigate whether the soil physical properties may be improved after the enclosure. A control observation plot was selected to illustrate the problem.

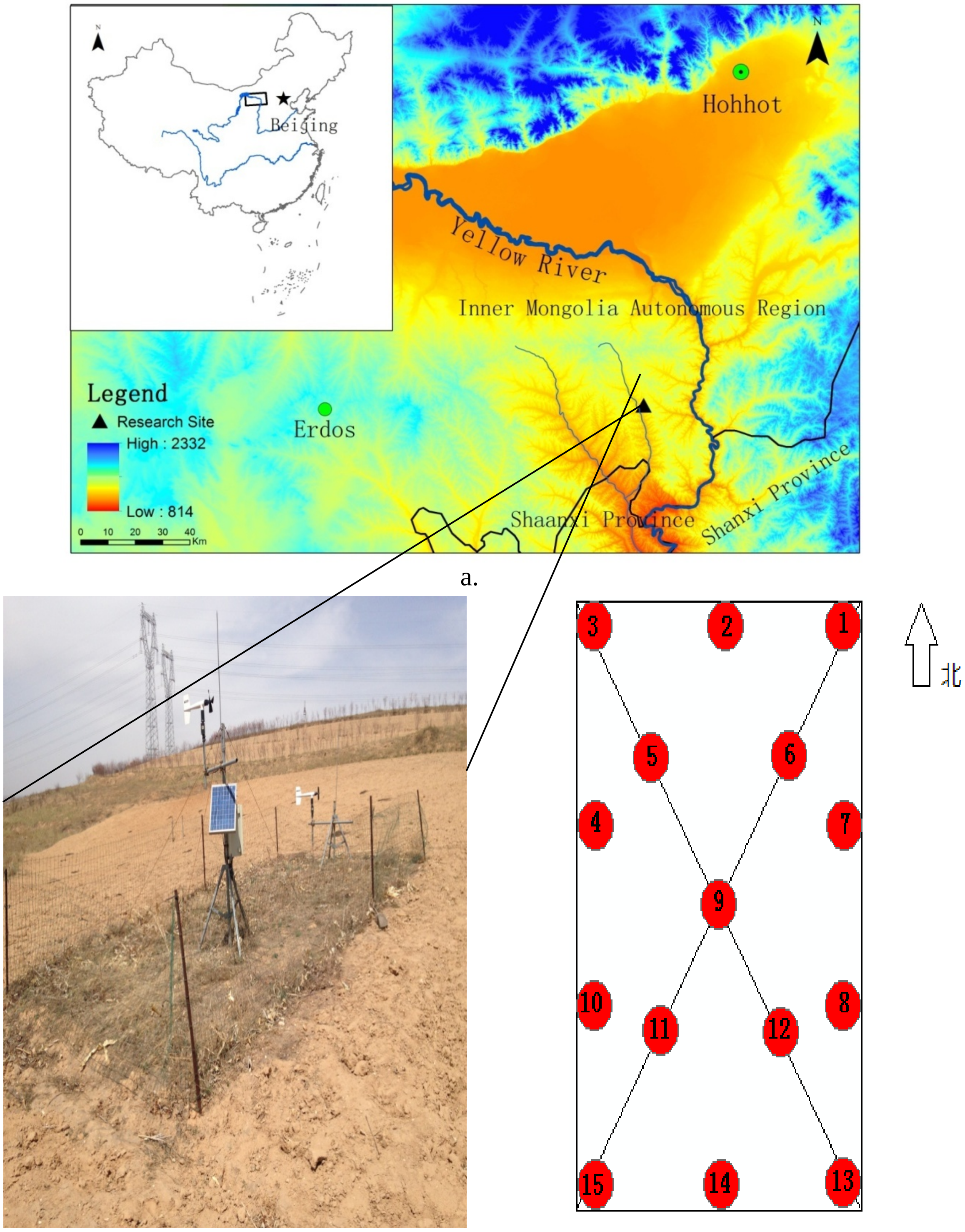
Field survey was conducted in March, 2014, and the enclosed and cultivated study areas were selected. Soil samples were collected in the study areas under the sunny weather in order to minimize the impact of external conditions on soil indicators, which would be tested. The research area selected in this paper is located in Erdos City, Inner Mongolia Autonomous Region (Fig. 1a). The enclosed area (Fig. 1b) was selected as the study area in the loess hilly region, and 15 sampling sites were evenly distributed in the enclosed area (Fig. 1c). The samples are diagonally distributed. The selected cultivated area is located on the right side of the enclosed area. Considering the conditions of the area, slope degree and slope position of the cultivated area and the enclosed area, the soil physical properties of the two studied areas should be studied under the same external conditions. The sampling method is the same as that of the enclosed area, and the sampling unit is distributed in a contrasting manner.

Determination of soil moisture content

Soil moisture content was determined by weighing samples before and after drying. In this paper, the determination of soil moisture is the natural soil moisture content. After collection, samples from the soil profile were backed into pre-numbered and weighed (analysis accurately to 0.0001) aluminium boxes. These boxes were then weighed (analysis accuracy to 0.0001 g) indoors to achieve the wet weight. Soil samples were then oven dried for six-eight h at 105-110°C, then the weight of dried soil was determined. The soil moisture was then calculated.

Soil bulk density and soil porosity

The soil bulk density was measured by the ring method. The soil samples were taken in the field by ring method. These samples were dried to a constant weight under the condition of 105°C for six-eight h. The weight after cooling and drying by the dryer (weighing balance accuracy is 0.0001) was determined. The data was used to calculate the soil bulk density. Soil porosity is not measured directly, but is calculated by specific gravity and bulk density.



a.

b. c.

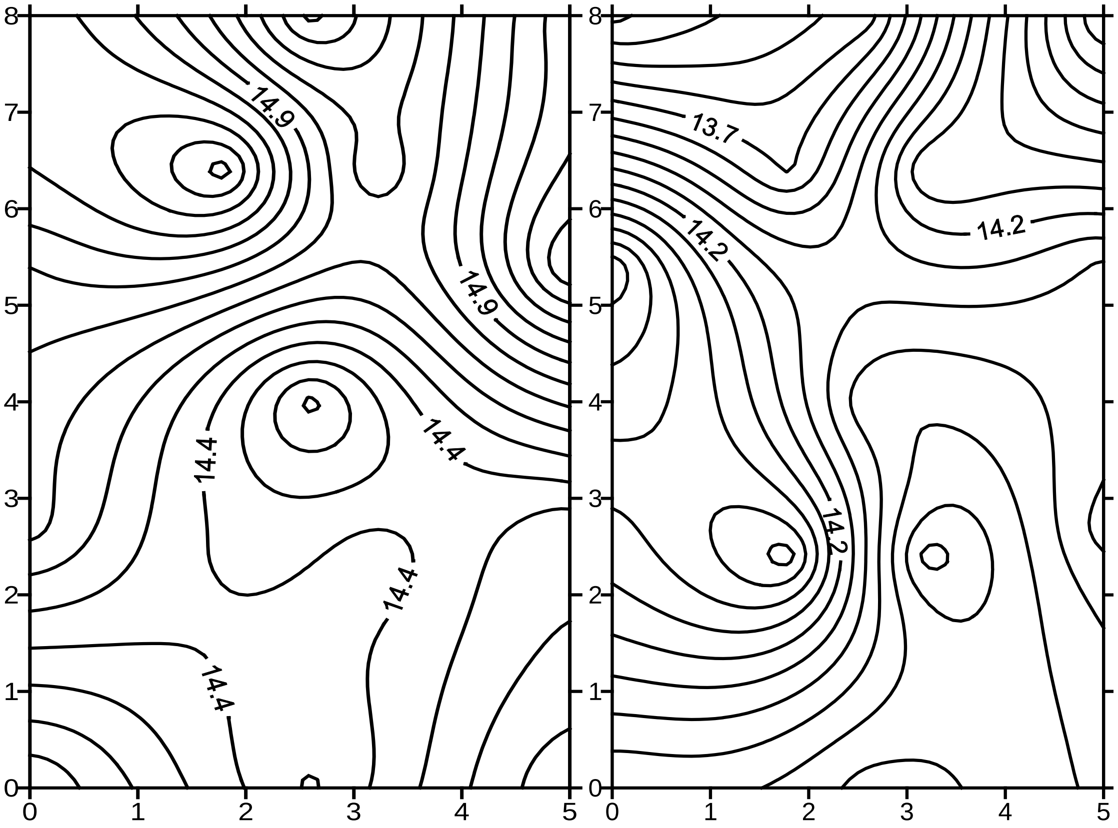
Figure 1a, b, c: Study area and sampling site layout.

RESULTS AND DISCUSSION

Distribution characteristics of surface soil moisture in enclosed and cultivated areas

Soil water is an important part of the soil and plays an important role in the process of soil formation. The migration of various substances is mainly in the form of solution in the soil layers of the soil profile. Soil water is also involved in a great deal of material transformation in the soil. In addition, soil water is a major source of crop water uptake and is an important link in the natural water cycle. Environmental changes, human damage and other external factors will have great impact on soil moisture content. Soil moisture is the main limiting factor to vegetation restoration and reconstruction in the Loess Plateau, and is also an important factor to determine soil productivity (Fu Bojie et al., 1999). Surface water is mainly derived from precipitation in loess hilly areas, which is absorbed by vegetation through runoff or infiltration in the surface.

Distribution characteristics of surface soil moisture in the enclosed areas



Soil moisture content in enclosure region   Soil moisture content in arable region

Figure 2: Soil moisture content in enclosed and cultivated areas.

The soil moisture content in the enclosed area decreased from the north to the south, and the soil moisture content in the southern region was the lowest (14%). The maximum soil moisture content was 15.4% in the middle and upper regions, and the average soil moisture content in the enclosed area is 14.6% (Fig. 2).

In the enclosed area, the height, density and coverage of the grass layer decreased obviously in the southern area. However, with the reduction of vegetation coverage in the ground surface, soil water evaporation increased and soil water holding capacity decreased, so overall the soil moisture content decreased. Soil moisture content also varies due to the influence of slope degree, which lead to different runoff velocities and runoff amounts after rainfall, and different rates of infiltration (Han Rui-lian et al., 2003; Yang et al., 2012). In addition, from the aspect of slope degree in the enclosed area, the elevation in the northern region is higher than that in the southern region, so the surface runoff flows from the north to the south. The infiltration rate in the south is faster than that in the north, and surface water evaporation is also faster in the south. Soil moisture is thus mainly concentrated in the surface in the northern region, so soil moisture content in the northern region is generally higher than that in the southern region. Because the selected study area is relatively small, the influence of wind direction as a factor is negligible. The purpose of this analysis is to provide a scientific basis for improving soil ecological environment and improving soil quality.

Distribution characteristics of surface soil moisture in cultivated areas

The change of soil moisture is relatively flat on the vertical profile in farmland under the continuous drought condition because of its lower consumption of deep soil moisture. Therefore, the surface soil moisture content in the cultivated area was studied in this paper. The high value area appeared in the north (Fig. 2). The maximum soil moisture content was 14.9%, the minimum moisture content was 13.3% and the average value was 14%. Because corn was perennially planted in the cultivated areas and the natural condition and the growth and development characteristics of corn are the same, the effect of field management can be ignored. There was no obvious change in the soil moisture content in cultivated land. The reason may be that the soil condition of cultivated land was the same, and there was not much difference between soil surface water absorption and evaporation. The soil moisture in the loess hill area mainly comes from rainfall runoff and interflow, but in some areas the soil moisture content was high: a possible reason may be due to the loose soil in the cultivated areas after rainfall. The surface water infiltration rate is also important, due to the slow infiltration speed of surface moisture focused on the soil surface, leading to high moisture content in the cultivated areas.

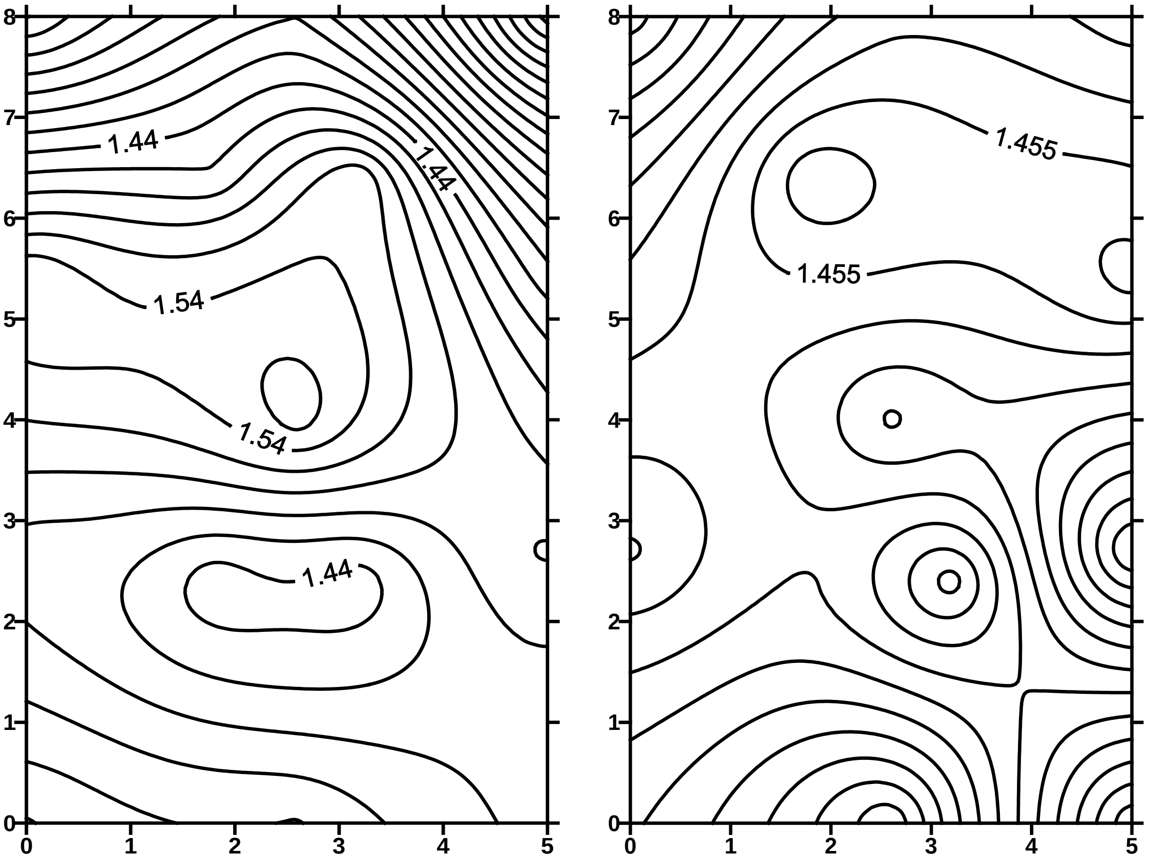
Distribution characteristics of surface soil bulk density and soil porosity in enclosed and cultivated areas

Soil moisture content and bulk density are two important indices of soil physical properties, which have important effects on soil nutrient availability and productivity. The bulk density of soil can be used as one of the indicators of soil maturity. It is shown that the higher the degree of soil matures, the lower the degree of soil bulk density. The soil bulk density is usually 1.00-1.50 g/cm^3. The surface soil bulk density is 1.25-1.35 g/cm^3 after natural deposition and compaction. The soil bulk density of natural soil is lower than that of tilled soil. According to the literature, the soil bulk density of cultivated land, forest and grassland is 0.80-1.60 g/cm^3, and it is only in original *Pinus koraiensis* forest that the soil bulk density is 0.47 g/cm^3 in the 0-10 cm layer (Man et al., 1997). Under certain conditions, the soil bulk density will change greatly. For example, the surface soil bulk density in newly cultivated farmland and in paddy fields can be reduced to less than 1.00 g/cm^3 (Guo Ying-jie et al., 1999), because of water flow and natural compaction. The bulk density of compacted soil and sandy soil can increase to 1.40-1.60 g/cm^3 (Feng et al., 2005; Wu et al., 2005).

Distribution Characteristics of Soil Bulk Density and Soil Porosity in the Enclosed areas

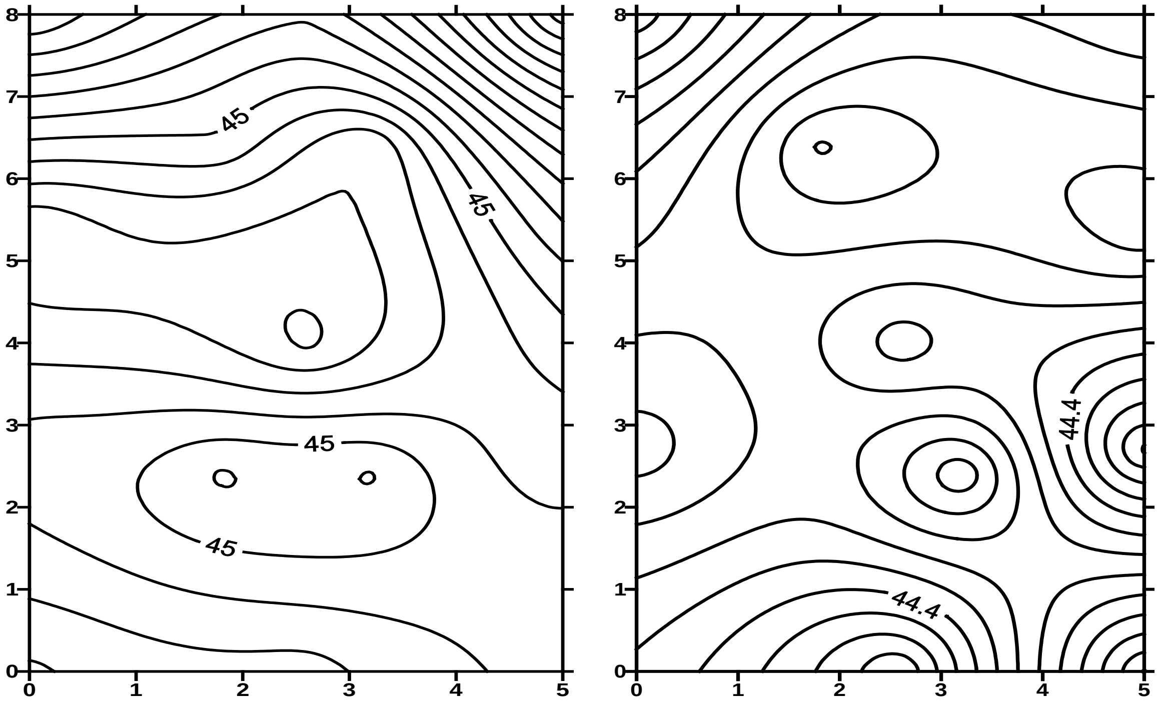
Table 1: Relation of soil bulk density, soil porosity and soil compactness; note: this information is from the Agricultural Division Report in Chunhua County.

Soil bulk density (g/cm^3)	Soil porosity (%)	Soil compactness
< 1.00	> 60	Very loose
1.00 ~ 1.14	60 ~ 56	Loose
1.14 ~ 1.26	56 ~ 52	Suitable
1.26 ~ 1.30	52 ~ 50	Less compact
1.30 ~ 1.45	50 ~ 45	Compact
> 1.45	< 45	Very compact



Soil bulk density in the enclosed areas Soil bulk density in the cultivated areas

a.



Soil porosity in the enclosed areas **Soil porosity in the cultivated areas**

b.

Figure 3a, b: Soil bulk density and soil porosity in the enclosed and cultivated areas.

Soil bulk density reflects the level of soil structure, permeability and water retention capacity. The bulk density is generally greater with increased soil depth. Low soil bulk density illustrates good soil structure and permeability, and high fertility. In constrast, high soil bulk density indicates soil compaction, poor structure and low permeability. Porosity reflects the soil pore condition and tightness. Soil porosity of coarse sand is generally 33-35% with larger pores. The porosity of clayey soil is about 45-60% with smaller pores. The porosity of loam is about 55-65% with almost equal proportions of large and small pores. Bulk density and porosity are closely and inversely related to each other (Fig. 3), such that the lower the bulk density, the greater the porosity.

The average soil bulk density in the enclosed area (Fig. 3) was 1.45 g/cm^3 and the average soil porosity was 45.28%. The soil was compact from the aspect of soil compactness (Tab. 1). The maximum soil bulk density was 1.57 g/cm^3 with a corresponding compactness of “very compact”. The minimum soil bulk density was 1.15 g/cm^3, with a corresponding compactness of “suitable” (Tab. 1). The soil bulk density in the enclosed area increased from north to south as a whole. The soil bulk density in the down slope was bigger than that in the up slope in the same slope direction. The soil compactness was greater when the sample position is more to the south. It showed that the soil structure, permeability, water permeability and water-holding capacity in the south of the enclosed area were poor and the fertility was low. The difference between soil bulk density and soil porosity in the south and north of the enclosed area was mainly related to the surface vegetation status of the grassland, the ability of the root layer to hold water and the humus on the surface layer. The vegetation was basically low shrubs and herbs in the sample area.

Distribution characteristics of soil bulk density and soil porosity in the area of cultivated land.

The bulk density in tilled soil (Fig. 3) was 1.46 g/cm^3 on average. The soil porosity was 44.79% on average. The soil was “compact” from the soil compactness table (Tab. 1). The maximum soil bulk density was 1.5 g/cm^3, and the minimum value of soil bulk density was 1.43 g/cm^3, which indicates it to be very compact, reflecting the farming methods in this area. The soil bulk density in the no tillage area was lower than that in the tillage area. The difference of soil bulk density and soil porosity between north and south was not obvious (Fig. 3), making it difficult to draw any general conclusions. It suggests that the distribution of soil bulk density and soil porosity was uniform in farming area. The reason may be that soil texture in the farmland was relatively uniform, which results in little change of the soil bulk density and soil porosity.

Comparison of the characteristics of soil physical properties in the enclosed area and cultivated area

(1) The soil moisture content in the enclosed area increased by 0.6% compared with that in the cultivated area. The rainfall runoff and the surface evaporation decreased due to the good surface vegetation cover in the enclosed area, in constrast to the cultivated area where the surface coverage was low and the surface evaporation was high. In addition, the roots of grass species were relatively deep in the enclosed area, which mainly absorb the lower water resulting in high soil moisture in the upper layers of the soil profile. This conclusion is consistent with the results of research by Wang Zhiqiang on the typical vegetation of *Pinus tabulaeformis* plantations, natural shrubs, abandoned grassland and farmland in the northwest of Shanxi province in semi-arid loess hilly region, which indicated that the soil moisture is reduced due to the low vegetation coverage in farmland, and concentration of rainfall, low precipitation and severe drought resulted in a large amount of surface water evaporation (Wang Zhi-qiang et al., 2002).

(2) The soil bulk density in cultivated land increased by 0.01 g/cm^3 compared to that in enclosed areas, and the soil porosity increased by 1% due to shallow and numerous fibrous root of herbaceous plants in the enclosed areas. Grass roots increased soil porosity and decreased soil bulk density. In addition, the litter of herbaceous plants on the soil surface was easy to decompose to form soil organic matter, which also reduces the soil bulk density. The increase of soil nutrients in the enclosed areas was good for the survival of a variety of microorganisms and soil animals, promoting their activities, increasing the soil porosity, and indirectly reducing the soil bulk density. Finally, the soil bulk density was relatively high in the cultivated land due to the impact of human activities, which led to soil compaction and reduced soil porosity.

In short, the variance of soil moisture content, soil bulk density and soil porosity in the enclosed area and cultivated area is mainly due to the intense influence of human activities (e.g. tillage, fertilization, mulching, *Platycodon grandiflorum* cover etc.), ecological and hydrological processes (soil dry wet alternate, surface crust, expansion, and shrinking, etc.) and plant characteristics (e.g. root distribution and canopy effect, rhizosphere microbial activity etc.) in the surface soil.

CONCLUSIONS

The variation of soil moisture content, soil bulk density and soil porosity was not significant in the enclosed area and cultivated area. The reason may be the close distance of the two study regions, and the small size of the selected sample areas. Climatic factors like windy days are also likely to be important to consider: there were windier days in the loess hilly area than is the case in other studies, and the soil sampled in this study was primarily top-soil, which is sensitive to wind-related effects and other natural external factors. This means that changes in the physical properties of soil as a result of enclosure were not that obvious. In future studies, it would be useful to expand the sampling area, try to collect deeper soil, and avoid the effect of other factors on the surface soil properties.

None the less, there are some general indications from this study that can provide reference for future research work. Loess soils in the Loess hill region are poor with low nutrient availability. Soil properties were changed in the cultivated region due to human activities. The status of soil moisture, soil porosity and soil solid particles in grassland (enclosed) areas was different with that in cultivated areas. Notably, mulching can improve soil water holding capacity, increase soil fertility, and improve soil development. The enclosure of farmland areas has effects on water, fertility, atmosphere and heat conditions of soil and agricultural production. The implementation of the project of returning farmland to forest and grassland will alleviate soil erosion in the loess hill region, and help improve the ecological environment. This study will provide a scientific reference for theoretical research of the ecological environment.

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RIPARIAN VEGETATION ON THE LEFT TRIBUTARIES OF THE DANUBE ALONG THE "CLISURA" CROSS VALLEY

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ABSTRACT

The author presents the riparian vegetation of the left tributaries of the Danube in the "Clisura" area including the habitat types 91E0* Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae), 6430 Hydrophilous tall herb fringe communities and other interlocking habitats. They are analysed from the ecological and the phytocoenological point of view. Discussed are also their phytogeographical particularities. Furthermore are emphasized the changes of the vegetation on the lower part of the tributaries as a consequence of the construction of the Iron Gate power plant and the backwater situation. Finally the conservation status of the riparian habitats is analysed in the context of their importance for the European Natura 2000 network.

ZUSAMMENFASSUNG: Die Ufervegetation der linken Zuflüsse der Donau im Durchbruchtal "Clisura".

Vorliegende Arbeit befasst sich mit den Ufer begleitenden Pflanzengesellschaften, der linken Nebenflüsse der Donau in ihrem "Clisura" genannten Durchbruchtal, die den Habitattypen 91E0* Erlen und Eschenwälder und Weichholzauenwälder an Fließgewässern, 6430 Feuchte Hochstaudensäume der planaren bis alpinen Höhenstufe sowie anderen mit ihnen eng verbundenen Habitattypen zugeordnet sind. Sie werden aus ökologischer und phytocoenologischer Sicht analysiert, wobei auch auf ihre pflanzengeographischen Besonderheiten aufmerksam gemacht wird. Weiterhin wird auf die Veränderungen der hydrologischen Verhältnisse infolge des Staustufenbaus am Eisernen Tor und dessen Einfluss auf die Vegetation hingewiesen. Schließlich wird der Zustand der Uferhabitate aus naturschutzfachlicher Sicht im Kontext ihrer Bedeutung für das europäische Netzwerk Natura 2000 dargestellt.

REZUMAT: Vegetaţia ripariană a tributarilor de stânga în "Clisura" Dunării.

Lucrarea prezintă comunităţile de plante ripariene ale afluenţilor de stânga ai Dunării de-a lungul „Clisurii" incluse în tipurile de habitat 91E0* Păduri aluviale de *Alnus glutinosa*, *Fraxinus excelsior* şi de zăvoaie de salcie, 6430 Comunităţi de lizieră cu ierburi înalte şi higriofile, precum şi alte tipuri de habitate cu care se întrepătrund. Comunităţile sunt analizate din punct de vedere ecologic şi fitocenologic cu referiri şi la particularităţile lor fitogeografice. Sunt discutate de asemenea schimbările condiţiilor hidrologice în urma construcţiei barajului de la Porţile de Fier şi consecinţele acesteia asupra vegetaţiei habitatelor din cursul inferior şi a gurilor râurilor tributare Dunării. În sfârşit habitatele ripariene sunt discutate în contextul importanţei lor pentru reţeaua Europeană Natura 2000.

INTRODUCTION

Given that on the "Clisura" stretch of the Danube, i.e. the canon like cross valley through the Carpathians, the cliffs with corresponding vegetation reached till the riverbank, riparian vegetation was less represented. However the Danube tributaries are accompanied by riparian vegetation with changing characteristics from the upstream to the downstream stretches of their courses in function of the geomorphologic structure of the valley.

In its natural state, before the construction of the Iron Gate power plant and the water storage lake, riparian vegetation existed on the Danube upstream the gorge stretch in small floodplains on alluvial deposits and alluvial soils from downstream Baziaş to Moldova Veche (including the Moldova Veche Island) and Pescari, from Cruşeviţa, including Cameniţa and Oreviţa, to Berzasca and Drencova, downstream Plavişeviţa to Orşova and further to Vârciorova (Posea et al., 1972; Glăvan and Geanana, 1972). The larger area where floodplains with typical vegetation existed before 1972, are well delimited by the depressions presented on the map of the Carpathian valley of the Danube by Iancu (1972). They are emerging from Belobreşca to Pescari, Cruşeviţa to Berzasca, a small one around Sviniţa and as well around Dubova, and from Ogradena to Orşova, continuing to the Bahna Valley. The higher area on the level of hardwood or transition forests from soft- to hardwood forests were almost used for small scale agriculture, the riparian vegetation being reduced by man and remained only as gallery-like forest belts. These belts are bordered by tall herbaceous vegetation and in some places covered with curtains of Wilde grape (*Vitis sylvestris*) (Meusel and Niedermaier, 1985). As typical softwood forest on the Danube in the Iron Gate area is mentioned the association Salici-Populetum (Tx. 1931) Mejer-Drees 1936 (Morariu and Danciu, 1970). These authors mention also the expansion of *Amorpha fruticosa* which changed the local phytocoenoses.

The secondary herbaceous vegetation replacing the natural communities were – apart from the arable lands – grasslands of Common chouch (*Elymus repens*), Creeping bentgrass (*Agrostis stolonifera*), Field meadows foxtail (*Alopecurus pratensis*) and on the terraces predominantly Golden bluestem (*Chrysopogon gryllus*) (Doniţă and Roman, 1976). Before flooding the depression of Dubova downstream the gorge of Cazanele Mici were covered by wet grasslands and wetlands interlocking with Willow stands of White and Crick willow (*Salix alba, S. fragilis*), White poplar (*Populus alba*), and with sedge (*Carex*) species. Representative were the abundance of Summer snow flake (*Leucojum aestivum*), typical for floodplain forests of the association Leucojo-Fraxinetum, and transition stages from soft- to hardwood forests.

Due to the backwater situation of the Danube as a consequence of the dam construction, the small area of riparian vegetation along the Danube River almost disappeared. Riparian gallery like vegetation remained only on the middle and lower streches of the tributaries. But on the lasts they were and are also supposed to many changes, due to the lack of hydrological dynamic on the mouth of tributaries. Taking into account these facts, the objective of the present study is to analyse the riparian habitats with their typical vegetation included in the habitat types 91E0* Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae), 6430 Hidrophilous tall herb fringe communities of plains and of the montane to alpine levels, and also the habitat type 9180* Tilio-Acerion forest of slopes, screes and ravines strongly interlocked with the other two mentioned habitats. An other objective is to highlight the phytogeographical particularities of riparian vegetation of the tributaries in the Clisura area and as well to state changes after the construction of the "Iron Gates" Dam and their consequences, and finally to analyse the conservation status of the riparian habitats with importance for the Natura 2000 network.

MATERIAL AND METHODS

During the vegetation period of the year 2014 field researches concerning the riparian habitats were realised on the left tributaries of the “Clisura”, the Danube gorge break valley. For comparison have been used also data from previous field activities. Samples were taken according to the method of Braun-Blanquet with the seven degree abundance-dominance scale (Braun-Blanquet, 1964; Borza and Boşcaiu, 1965). Considered were as well aspects concerning the structure of the habitats in strong relation with the water dynamics of the tributaries, the grain size of sediments and the succession of the vegetation along ecological gradients from the river banks to the higher elevations of the river valleys. From upstream to downstream the following valleys have been studied: Ribişel Valley (1), Radimna Valley (2), Boşneag-Valea Mare with Valea Rea and Valea Găurii (3), Liborajdea (= Polevinii) Valley (4), Berzasca Valley with Toroniţa (5), Şirinia Valley near Cozla (6), Liubotina Valley (7), Plavişeviţa Valley (8), Ponicova/râul Morii near Cazanele Mari and Valea Satului (Dubova) (9), Mraconia Valley (10), Ogradena Valley (11) and Eşelniţa Valley (12).

The taken samples are included in phyto-coenological tables and grouped according to characteristic species of the different phytocoenological units or according to ecological gradients and presented as well in the context of the European Union habitats (EUR28, 2013; Gafta and Mountford, 2008). A synthetic table including the phytocoenoses of Beech, Ash, Sycamore (C1), of Ash and Black alder (C2), of Black alder (C3) and of Willow species (C4), represents the associations with their constancy classes as follows I = 1-20%, II = 21-40%, III = 41-60, IV = 61-80, V = 81-100%. The indicator values for wetness (W) and nitrogen (N) are included as well according to Ellenberg et al. (2001). The nomenclature of species is used according to Sârbu et al. (2013) and Ciocârlan (2009).

RESULTS AND DISCUSSION

The tributaries of the Danube present a large diversity according to the size of their sub-basin and the hydro-morphodynamics, the flow velocity depending on the slope and the discharge of the river. In dependence of these factors, the riparian vegetation of the tributaries on the “Clisura” stretch of the Danube is represented by different plant communities. They are gallery like distributed along the river courses from upstream to downstream.

The structure of the phytocoenoses, according to different layers from the herbaceous to the shrubs and trees, as well their species composition, depends on varying site conditions like the size of the basin of each of the tributaries, the geomorphologic structure of the valley from the springs to the mouth into the Danube (deep incision, width of the valley, etc.), the rocky underground and soil conditions, the length of the river, its flow velocity, discharge and dynamics and as well the changes of the natural conditions by men’s intervention, like hydraulic measures. On all the studied tributaries the river banks have a natural morphological structure and the rivers a natural or near-natural hydro-morphological dynamics with erosion and deposition processes. The river dynamics can be observed on the upper and the middle stretch of the streams and rivers and constitutes the base for the structure of the vegetation on the river banks (Fig. 1).

Following the river from upstream to downstream in areas where the river valley is widening, the riparian habitats and their vegetation presents different aspects. The succession along the valley is from stands of beech (*Fagus sylvatica*), to those of beech and Common ash (*Fraxinus excelsior*), ash and Black alder (*Alnus glutinosa*), Black alder as most abundant and dominant species of the tree layer, Black alder and Willow species, in particular Brittle willow (*Salix fragilis*) and finally to White willow (*Salix alba*) stands (Tab. 1).

In general the typical riparian vegetation is poorly represented in the deep incised valleys. On these stretches forests characteristic for narrow ravine like valleys with steep slopes – included in the habitat type 9180* Tilio-Acerion forests of slopes, screes and ravines – reach to the border of the water courses. In that area, where the beech (*Fagus sylvatica*) is the most abundant and dominant species, can be found isolated trees or small groups of Common ash (*Fraxinus excelsior*), Sycamore (*Acer pseudoplatanus*), Elm (*Ulmus montana*) and some other species (Doniţă et al., 2005, 2006). As well can be found fragments of phytocoenoses of mountainous tall herbaceous vegetation edified by *Petasites hybridus* and *Telekia speciosa*, located on the river banks and on stony islets in the river bed between river anastomoses. These tall herbaceous fragmentary fringes are included in the habitat type 6430 Hydrophilous tall herb fringe communities of plains and of the mountainous to alpine levels. Remarkable is that *Telekia speciosa*, a typical mountainous species of the beech forest level, edifies together with other tall herbaceous species, characteristic fringes. Such fragments of fringes have been observed in the Mraconia Valley on the lowest site of Carpathians at 50 m height above a.s.l. and in Berzasca Valley at 83 m a.s.l.

Figure 1: Gravel banks on the Şirinia tributary of the Danube (near Cozla) after high rainfalls and floods in summer 2014.

Table 1: Synthesis of the riparian phytocoenoses of the Clisura tributaries; Column C1 phytocoenoses of Beech, Ash, Sycamore; C2 phytocoenoses of Ash and Black alder; C3 phytocoenoses of Black alder; C4 phytocoenoses of willow species.

		Number of column	C1	C2	C3	C4	
		Number of samples	11	7	7	7	
		Frequency class	K	K	K	K	
W	N	**Tree layer**					
x	7	*Fraxinus excelsior*	**V**	**V**	–	–	
5	x	*Fagus sylvatica*	**III**	I	–	–	
6	7	*Acer pseudoplatanus*	**III**	–	–	–	
6	7	*Ulmus glabra*	III	III	III	III	
5	6	*Acer campestre*	IV	II	III	I	
9 =	x	*Alnus glutinosa*	I	**V**	**V**	II	
8 =	6	*Prunus padus*	II	II	–	–	
x	x	*Carpinus betulus*	II	II	II	–	
5	5	*Cerasus avium*	I	II	–	I	
6	7	*Juglans regia*	I	III	III	II	
		Carpinus orientalis	–	–	II	I	
4	8	*Robinia pseudoacacia*	I	–	I	II	
5	8	*Ailanthus altissima*	I	I	–	I	
8 =	6	*Salix fragilis*	II	I	I	III	
8 =	7	*Salix alba*	I	–	I	IV	
		Morus alba	I	I	I	III	
8 =	7	*Populus nigra*		–	–	III	
7 ~	6	*Populus alba*		–	–	I	
x	5	*Corylus avellana*	IV	V	IV	II	
5	x	*Cornus sanguinea*	II	II	II	II	
5	9	*Sambucus nigra*	II	I	III	III	
4	4	*Crataegus monogyna*	I	III	II	I	
5	5	*Evonymus europaea*	III	III	I	–	
x	7	*Rubus caesius*	III	V	V	V	
4	4	*Cornus mas*	I	I	I	–	
9 =	x	*Alnus glutinosa*	–	I	II	–	
4	x	*Rosa canina*	–	–	I	III	
8 =	6	*Salix fragilis*	–	I	I	I	
x =	x	*Salix purpurea*	–	–	I	V	
8 =	5	*Salix triandra*	–	–	I	II	

Table 1 (continued): Synthesis of the riparian phytocoenoses of the Clisura tributaries; Column C1 phytocoenoses of Beech, Ash, Sycamore; C2 phytocoenoses of Ash and Black alder; C3 phytocoenoses of Black alder; C4 phytocoenoses of Willow species.

		Number of column	C1	C2	C3	C4	
		Number of samples	11	7	7	7	
		Frequency class	K	K	K	K	
W	N	**Tree layer**					
		Shrubs layer					
		Regeneration					
x	7	*Fraxinus excelsior*	II	I	II	–	
6	7	*Acer pseudoplatanus*	II	I	–	–	
5	6	*Acer campestre*	I	III	–		
		Lianas					
5	7	*Clematis vitalba*	III	III	III	IV	
5	x	*Hedera helix*	III	II	II	–	
8 ~	8	*Solanum dulcamara*	I	I	I	–	
6	9	*Calystegia sepium*	I	I	III	II	
8 =	8	*Humulus lupulus*	–	–	I	III	
6	6	*Vitis sylvestris*	–	–	II	–	
		Tall herbaceous fringe species					
8 =	8	*Petasites hybridus*	II	II	III	–	
7	7	*Telekia speciosa*	II	III	II	–	
7	8	*Eupatorium cannabinum*	III	II	III	III	
8	5	*Equisetum telmateija*	I	I	II	I	
6	8	*Lunaria rediviva*	II	–	I	–	
6	7	*Salvia glutinosa*	II	–	I	–	
		Herbaceous regional characteristic sp.					
4	4	*Daphne laureola*	II	I	–	–	
5	5	*Dioscorea communis*	II	I	–	–	
5	6	*Asperula taurina*	I	I	–	–	
		Ruscus hypoglossum	–	I	–	–	
		Ruscus aculeatus	–	I	–	–	
		Helleborus odorus	I	I	–	I	
		Knautia drymeia	I	I	–	I	
5	6	*Aremonia agrimonioides*	–	I	–	–	

Table 1 (continued): Synthesis of the riparian phytocoenoses of the “Clisura” tributaries; Column C1 phytocoenoses of Beech, Ash, Sycamore; C2 phytocoenoses of Ash and Black alder; C3 phytocoenoses of Black alder; C4 phytocoenoses of willow species.

		Number of column	C1	C2	C3	C4	
		Number of samples	11	7	7	7	
		Frequency class	K	K	K	K	
		Shrubs layer					
		Other heraceous layer species					
5	7	*Parietaria officinalis*	III	V	V	II	
8 =	8	*Polygonum hydropiper*	III	IV	IV	III	
6	8	*Urtica dioica*	IV	III	V	III	
6	8	*Aegopodium podagraria*	II	III	III	II	
6	8	*Lamium maculatum*	III	III	III	I	
6	9	*Rumex obtusifolius*	I	III	II	I	
9 =	8	*Bidens tripartita*	I	II	II	III	
8	8	*Symphytum officinale*	I	I	I	I	
8 =	8	*Myosoton aquaticum*	I	–	III	III	
5	8	*Chelidonium majus*	II	II	–	I	
8 =	7	*Mentha longifolia*	I	–	I	I	
6	7	*Glecoma hederacea*	II	IV	III	II	
7	7	*Stachys sylvatica*	I	III	III	I	
7 ~	x	*Ranunculus repens*	II	III	II	III	
		Other herbaceous layer species					
x ~	7	*Elymus repens*	I	I	I	II	
9 =	7	*Lycopus europaeus*	–	III	I	I	
9 =	7	*Scrophularia alata*	–	–	I	II	
8	x	*Carex remota*	I	III	II	–	
6 ~	7	*Dipsacus fullonum*	I	III	I	–	
6	7	*Circaea lutetiana*	I	I	–	I	
5	7	*Geum urbanum*	I	III	III	–	
5	6	*Mycelis muralis*	III	IV	III	I	
5	6	*Dryopteris filix mas*	III	I	II	I	
5	6	*Galeopsis tetrahit*	I	II	II	I	
6 ~	x	*Lysimachia nummularia*	I	I	I	I	
7	6	*Athyrium filix femina*	I	III	I	–	
7	4	*Juncus effusus*	–	II	I	I	
5	5	*Stellaria holostea*	I	–	II	II	
7	6	*Festuca gigantea*	II	III	III	–	

Table 1 (continued): Synthesis of the riparian phytocoenoses of the “Clisura” tributaries; Column C1 phytocoenoses of Beech, Ash, Sycamore; C2 phytocoenoses of Ash and Black alder; C3 phytocoenoses of Black alder; C4 phytocoenoses of willow species.

		Number of column	C1	C2	C3	C4	
		Number of samples	11	7	7	7	
		Frequency class	K	K	K	K	
5	6	*Brachypodium sylvaticum*	II	III	III	I	
5	6	*Asarum europaeum*	II	IV	I	–	
5	6	*Pulmonaria officinalis maculosa*	III	II	I	–	
7	6	*Viola reichenbachiana*	II	II	–	–	
x	7	*Geranium robertianum*	III	I	–	–	
3	2	*Scabiosa ochroleuca*	I	–	I	I	
4	3	*Coronilla varia*	–	I	I	I	
4	3	*Calamintha vulgaris*	–	I	II	I	
11	4	*Polygonum amphibium*	–	–	–	II	
x =	5	*Agrostis stolonifera*	I	I	I	III	
4	5	*Cichorium intybus*	I	I	–	III	
4	5	*Achillea millefolium*	I	I	–	I	
6	6	*Ajuga reptans*	II	–	II	–	
5	5	*Dactylis polygama*	I	–	–	II	
8 ~	x	*Lythrum salicaria*	–	–	I	I	
8	4	*Scirpus sylvaticus*	–	–	III	–	
x	8	*Stellaria media*	–	–	III	–	
		Other accompaining species					
–	–	*Phytolacca americana*	I	II	I	II	
5	8	*Arctium minus*	–	II	I	I	
5	8	*Solanum nigrum*	–	III	I	I	
6	8	*Erigeron annuus*	I	III	–	II	
4	5	*Conyza canadensis*	I	II	–	III	
5	6	*Plantago major*	I	I	II	–	
4	5	*Linaria vulgaris*	I	–	I	III	
5	7	*Verbena officinalis*	–	I	–	III	
6	7	*Physalis alkegengi*	I	I	–	I	
6	8	*Artemisia vulgaris*	I	–	I	I	
4	8	*Artemisia absinthium*	I	–	–	II	
6 ~	x	*Tussilago farfara*	I	II	–	–	
5	8	*Galeopsis speciosa*	III	–	–	–	
4	6	*Artemisia annua*	–	–	I	III	
4	7	*Setaria viridis*	–	–	I	II	

Species only in one column with constancy I (1-20%)
C1: *Fagus sylvatica regeneration, Poa nemoralis, Hypericum tetrapterum, Vincetoxicum officinale, Gentiana asclepiadea, Lapsana communis, Luzula sylvatica, Carex elata, Phyllitis scolopendrium, Syringa vulgaris, Euphorbia amygdaloides, Fragaria vesca, Oxalis acetosella, Lathyrus niger, Alliaria petiolate, Dentaria bulbifera, Senecio nemorensis, Angelica sylvestris*; C2: *Castanea sativa, Fraxinus ornus, Quercus cerris, Poa annua*; C3: *Alnus glutinosa regeneration, Ailanthus altissima regeneration, Salix viminalis, Berteroa incana, Potentilla tormentilla, Saponaria officinalis, Salix cinerea, Viola mirabilis, Marchantia polymoprpha, Rumex crispus, Stachys palustris, Mentha aquatic, Taraxacum officinale, Anthriscus sylvestris*; C4: *Populus canescens, Amorpha fruticose, Salix caprea, Echinocystis echinata, Aster lanceolatus, Anchusa officinalis, Melandrium album, Pulicaria vulgaris, Veronica beccabunga, Coronilla emerus, Melilotus albus, Coronilla varia, Cirsium vulgare, Galega officinalis, Portulaca oleracea, Cynodon dactylon, Galium album, Convolvulus arvensis, Eragrostis minor, Silene vulgaris*.

Species in two columns with constancy I (1-20%): C1, C2: *Galium schultesii*; C1, C3: *Ambrosia artemisiifolia, Asplenium trichomanes, Pyrus pyraster (tree layer), Trifolium repens*; C1, C4: *Potentilla reptans, Robinia pseudoacacia* (regen.), *Sambucus ebulus*; C2, C3: Echinocloa crus-gallii, *Fraxinus excelsior, Galinsoga parviflora, Morus alba, Physocaulis nodosus, Robinia pseudoacacia*; C3, C4: *Astragalus glycyphyllos, Centaurea biebersteinii, Cynodon dactylon, Lythrum salicaria, Myrrhoides nodosa, Xanthium strumarium*. Species in one column with constancy II (21-40%) in one column: C1: *Geranium macrorhizum, Prunella vulgaris, Sedum telephium* ssp. *maximum*; C3: *Veronica chamaedrys*; C4: *Chenopodium botrys, Pulicaria dysenterica*.

Phytocoenoses of Common ash (*Fraxinus excelsior*) and Black alder (*Alnus glutinosa*) and as well those edified by White and Brittle willow and other willow species – including as well all transition stages – take part of the habitat type 91E0*Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae).

Between 450 and 200 m height a.s.l. the Black alder (*Alnus glutinosa*) is in general poorly represented, but downstream at the height of 200 m it is more apparent edifying together with the ash characteristic phytocoenoses, with high abundance-dominance values, its optimum being clear visible (Tab. 2).

Phytocoenoses of Black alder have been described from the Clisura area i.e. the Radimna Valley by Coste 1975 as association Stellario-Alnetum glutinosae (Kästner 1938) Lohm. 1957 (Coste 1984). Remarkable in the phytocoenoses is the high number of nitrophilous species with indicator values 7, 8, 9 (Ellenberg et al., 2001) such are *Parietaria officinalis, Glecoma hederacea, Polygonum hydropiper, Urtica dioica, Aegopodium podagraria, Lamium maculatum, Rumex obtusifolius* and many others (Tabs. 1 and 2). The high number and abundance-dominance of nitrophilous species indicate a similarity to the association Aegopodio-Alnetum glutinosae Kárpáti and Jurko 1964, described from the Crişul Repede Gorge valley (Sanda et al., 2008).

The observations concerning high number of nitrophilous species, i.e. eutrophication, corresponds to those of the Lower Danube Cama Dinu area, upstream Giurgiu (Mölder and Schneider-Binder, 2011).

Table 2: Phytocoenoses with Black Alder (*Alnus glutinosa*) and Common Ash (*Fraxinus excelsior*) in the middle and lower stretches of the tributaries (2 = Radimna, 4 = Liborajdea, 5 = Berzasca, 6 = Şirinea, 7 = Liubotina, 10 = Mraconia, 11 = Ogradena, 12 = Eşelniţa).

No. of column	1	2	3	4	5	6		7	8	9	10	11	12	
No. of river valley	12	2	12	11	6	7		4	5	5	7	10	11	
No. of field sample	3	19	4	27	10	9	F	22	24	23	8	6	26	F
m above a.s.l.	194	130	127	112	91	85		103	104	83	104	50	169	
Trees layer														
Alnus glutinosa	**4**	**3**	**4**	**3**	**3**	**4**	V	**4**	**4**	**4**	**3**	**3**	**3**	V
Fraxinus excelsior	**1**	**2**	**1**	**3**	**1**	**1**	V	.	.	.	.	.	.	–
Fagus sylvatica	.	.	.	+	.	.	I	.	.	.	.	.	.	–
Ulmus glabra	1	1	1	.	.	.	III	.	+	1	.	+	.	III
Acer campestre	.	.	1	.	.	1	II	.	+	.	.	1	1	III
Juglans regia	.	.	.	1	+	+	III	1	1	.	.	+	.	III
Carpinus betulus	.	.	.	.	+	.	II	.	.	.	+	.	1	II
Carpinus orientalis	.	.	.	.	.	+	I	.	.	.	+	+	.	II
Morus alba	.	.	.	.	+	+	II	1	.	.	.	.	.	I
Cerasus avium	.	+	.	.	+	.	II	.	.	.	.	.	.	–
Prunus padus	+	.	.	.	1	.	II	.	.	.	.	.	.	–
Castanea sativa	.	.	.	.	.	1	I	.	.	.	.	.	.	–
Pyrus pyraster	.	.	.	.	.	.	–	.	.	.	1	.	.	I
Salix fragilis	.	.	1	.	.	.	I	.	1	.	.	.	.	I
Salix alba	.	.	.	.	.	.	–	1	.	.	.	.	.	I
Shrubs layer														
Corylus avellana	+	+	.	+	+	+	V	+	+	.	+	+	+	V
Rubus caesius	3	2	2	3	3	3	V	2	3	3	+	2	2	V
Crataegus monogy.	.	+	.	.	.	+	II	.	+	.	.	+	.	II
Sambucus nigra	.	.	.	.	.	+	I	.	+	.	+	.	+	III
Cornus sanguinea	.	.	.	.	+	.	I	.	+	.	.	+	.	II
Cornus mas	.	.	.	.	.	+	I	.	.	.	.	+	.	I
Evonymus europae.	.	.	.	.	+	+	II	.	.	.	+	.	.	I
Salix fragilis	.	.	.	.	.	.	–	.	.	+	.	.	.	I
Alnus glutinosa	.	.	.	.	.	.	–	.	.	+	.	.	.	I
Robinia pseudoaca.	.	.	.	+	.	.	I	.	.	+	.	.	.	I
Morus alba	.	.	.	.	.	.	–	.	.	+	.	.	.	I
Fraxinus excelsior	.	.	.	.	.	.	–	.	+	.	.	.	.	I
Regeneration layer														
Fraxinus excelsior	.	+	.	.	.	.	I	.	+	.	.	+	.	II
Acer campestre	.	.	.	.	+	+	II	.	.	.	.	.	.	–
Ailanthus altissima	.	.	.	.	.	.	–	.	.	.	.	.	3	I

Table 2 (continued): Phytocoenoses with Black Alder (*Alnus glutinosa*) and Common Ash (*Fraxinus excelsior*) in the middle and lower stretches of the tributaries (2 = Radimna, 4 = Liborajdea, 5 = Berzasca, 6 = Şirinea, 7 = Liubotina, 10 = Mraconia, 11 = Ogradena, 12 = Eşelniţa).

Lianas			.											
Clematis vitalba	.	+	.	.	+	+	III	.	.	+	+	.	.	II
Hedera helix	.	+	.	.	+	.	II	.	+	.	.	3	.	II
Solanum dulcamara	.	+	.	.	.	.	I	.	.	+	.	.	.	I
Calystegia sepium	.	.	.	.	+	.	I	.	+	+	.	.	.	II
Tall herb. fringe layer														
Petasites hybridus	+	+	.	.	.	.	II	.	.	2	.	+	.	II
Telekia speciosa	+	+	+	.	.	.	III	.	.	+	.	+	.	II
Eupatorium cannabinum	+	.	.	.	.	.	II	.	.	+	.	+	.	II
Equisetum telmateija	+	.	.	.	.	.	I	.	.	+	.	.	.	I
Herbaceous layer														
Parietaria officinalis	3	2	2	+	+	+	V	3	4	+	2	3	3	V
Polygonum hydropiper	+	+	+	+	.	.	IV	+	+	+	.	.	+	IV
Mycelis muralis	+	+	+	.	+	.	IV	.	+	.	+	.	.	II
Glecoma hederacea	.	+	3	+	+	.	IV	+	+	.	.	+	.	III
Urtica dioica	+	.	.	+	.	+	III	+	+	+	+	+	+	V
Aegopodium podagraria	.	+	.	.	+	.	II	.	+	+	.	+	+	IV
Rumex obtusifolius	.	.	+	+	.	.	II	.	.	+	.	.	.	I
Lamium maculatum	+	+	.	.	+	.	III	+	+	.	+	.	.	III
Festuca gigantea	.	+	+	.	.	.	II	+	.	.	.	+	+	III
Stachys sylvatica	.	+	+	.	+	.	III	+	.	+	.	+	.	III
Ranunculus repens	+	+	+	+	.	.	IV	.	+	.	.	.	.	I
Brachypodium sylvaticum	+	+	+	.	.	.	III	+	+	.	.	+	.	III
Asarum europaeum	+	2	.	+	1	.	III	.	.	.	.	+	.	I
Geum urbanum	.	+	+	+	.	.	III	+	+	.	.	+	+	IV
Pulmonaria o. maculosa	.	+	.	.	+	.	II	.	.	.	.	+	.	I
Lathyrus niger	.	+	.	+	.	.	II	.	.	.	.	.	.	–
Carex remota	1	+	+	+	.	.	IV	+	.	.	.	.	+	II
Galeopsis tetrahit	+	.	.	.	.	.	I	+	+	.	.	.	.	II
Myosoton aquaticum	.	.	.	.	.	.	–	.	+	3	+	.	.	III
Stellaria holostea	.	.	.	.	.	.	–	+	.	+	.	.		II
Ajuga reptans	.	.	.	.	.	.	–	+	+	.	.	.	.	II
Agrostis stolonifera	.	.	.	.	.	+	I	.	.	+	.	.	.	I
Bidens tripartita	+	+	.	.	.	.	II	.	.	+	.	.	.	I

Table 2 (continued): Phytocoenoses with Black Alder (*Alnus glutinosa*) and Common Ash (*Fraxinus excelsior*) in the middle and lower stretches of the tributaries (2 = Radimna, 4 = Liborajdea, 5 = Berzasca, 6 = Şirinea, 7 = Liubotina, 10 = Mraconia, 11 = Ogradena, 12 = Eşelniţa).

Carex pendula	3	.	.	.	.	.	I	.	.	.	.	.	.	–
Lysimachia nummularia	3	.	.	.	.	.	I	.	.	.	.	.	.	–
Lycopus europaeus	+	+	.	.	.	.	II	.	.	.	.	.	.	–
Juncus effusus	+	+	.	.	.	.	II	+	.	.	.	.	.	I
Athyrium filix femina	+	.	+	.	.	+	III	.	+	.	.	.	.	I
Scirpus sylvaticus	.	.	.	+	.	.	I	.	+	+	.	.	+	III
Dryopteris filix mas	.	.	.	.	+	.	I	.	.	.	+	.	+	II
Elymus repens	.	.	+	.	.	.	I	.	.	.	+	.	.	I
Plantago major	.	.	.	.	.	.	I	.	.	.	.	.	+	I
Solanum nigrum	+	.	.	.	.	+	II	.	.	.	.	.	.	I
Saponaria officinalis	.	.	.	.	.	.	–	.	.	.	.	.	.	I
Calamintha vulgaris	.	.	.	.	.	.	I	.	.	+	.	+	.	II
Ruscus aculeatus	.	.	.	.	+	.	I	.	.	.	.	.	.	–
Daphne laureola	.	.	.	.	+	.	I	.	.	.	.	.	.	–
Asperula taurina	.	.	.	.	+	.	I	.	.	.	.	.	.	–
Tamus communis	.	.	.	+	+	.	II	.	.	.	.	.		–
Arctium minus	.	+	.	.	.	.	I	+	.	.	.	.	.	I
Stellaria media	.	.	.	+	.	.	I	.	+	+	.	+	.	III
Anthriscus sylvestris	.	.	.	+	.	.	I	.	.	.	.	.	+	I
Dipsacus fullonum	+	+	+	.	.	.	III	.	.	.	.	.	+	I
Phytolacca americana	.	.	.	.	.	+	I	.	.	.	+	.	.	I
Chelidonium majus	+	.	.	.	.	+	II	.	.	.	.	.	.	–
Tussilago farfara	.	+	.	.	.	+	II	.	.	.	.	.	.	–
Erigeron annuus	+	+	+	.	.	.	III	.	.	.	.	.	.	–

Species noted with + (I) in one sampling site: 1 – *Geranium robertianum, Knautia drymeia, Galium schultesii*; 2 – *Acer pseudoplatanus* reg., *Circaea lutetiana, Helleborus odorus, Oxalis acetosella, Polygonatum odoratum, Sambucus ebulus, Verbena officinalis*; 3 – *Achillea millefolium*; 4 – *Ailanthus altissima* reg., *Fagus sylvatica, Aremonia agrimonioides*; 5 – *Melandrium album, Poa annua*; 6 – *Physalis alkekengi*; 7 – *Cichorium intybus, Quercus cerris reg.*; 8 – *Alnus glutinosa reg., Artemisia annua*; 9 – *Sisymbrium sophia, Taraxacum officinale*; 10 – *Humulus lupulus, Lythrum salicaria, Mentha aquatica, Mentha longifolia, Rumex crispus, Salix purpurea, Stachys palustris, Ulmus glabra, Vitis sylvestris, Xanthium strumarium*; 11 – *Berteroa incana, Echinocloa crus galli, Viola mirabilis*; 12 – *Artemisia vulgaris, Astragalus glycyphyllos, Centaurea stoebe, Cynodon dactylon, Linaria vulgaris, Salix viminalis, Scabiosa ochrleuca, Scrophularia alata, Setaria viridis, Silene vulgaris, Trifolium repens*; 13 – *Lunaria rediviva, Salvia glutinosa.*

Place of sampling: **1** (field sample 3) Ieşelniţa Valley: N 44 44 18, E 22 20 00; **2** (field sample 19) Radimna Valley: N 44 49 26, E 21 33 37; **3** (field sample 4) Eşelniţa Valley: N 44 43 05, E 22 21 19; **4** (field sample 27) Ogradena Valley: N 44 40 14, E 22 18 03; **5** (field sample 25) Ogradena Valley: N 44 41 31, E 22 20 35; **6** (field sample 10) Şirinia Valley: N 44 37 19, E 22 01 22, **7** (field sample 9) Liubotina Valley: N 44 32 41, E 22 12 31; **8** (field sample 22) Liborajdea Valley: N 44 40 43, E 21 46 21; **9** (field sample 24) Berzasca Valley: N 44 39 50, E 21 58 30; **10** (field sample 23) Berzasca Valley: N 44 39 10, E 21 57 44; **11** (field sample 8) Liubotina Valley: N 44 39 16, E 22 12 34; **12** (field sample 5) Mraconia Valley: N 44 39 16, E 22 16 03; **13** (field sample 6) Mraconia Valley downstream the previous sampling point at 50 m altitude; 14 (field sample 26) Ogradena Valley: N 44 40 35, E 22 17 45.

The riparian gallery like Black Alder forest occurs in the studied area on the tributaries in two different variants (Tab. 2). The first is characterized by high constancy (V) of Black alder and Common ash (Tab. 2, samples column 1-7), in the second the tree layer being edified mostly by Black alder (Tab. 2, samples column 8-14). In both variants the Elm (*Ulmus glabra*) is present with constancy III. Apart from the tree layer in the Ash-Alder forest (samples column 1-7) the herbaceous layer presents visible differences by the occurrence of some beech forest species of the Fagetalia order like the European ginger (*Asarum europaeum*), Lungwort (*Pulmonaria officinalis* ssp. *maculosa*), *Viola reichenbachiana*, Black pea (*Lathyrus niger*), Common spindle tree (*Euonymus europaeus*) and others.

The regional character of the riparian ash-alder forest is given by some thermophilous-subthermophilous Balcanic and sub-Mediterranean species like Pink woodruff (*Asperula taurina*), Black bryony (*Dioscorea communis*), Spurge laurel (*Daphne laureola*) and Butcher's broom (*Ruscus aculeatus, Ruscus hypoglossum*). The low constancy was given as a consequence of the exceptional torrential flood in 2014, which washed away a part of the riparian forest herbaceous vegetation. Such situations were stated in Şirinia and Plavişeviţa valleys. The above mentioned species present interest for the area from the phytogeographical point of view (Borza, 1931a, b; Horvat et al., 1974).

The occurrence of Butcher's broom (*Ruscus aculeatus*) is remarkable as similar occurrences have been observed on the Lower Rhône River in a Mediterranean floodplain forest of White poplar (*Populus alba*) accompanied by Small leafed ash (*Fraxinus angustifolia*), Field elm (*Ulmus minor*) and other species (Grillas and van Wyijck, 1990).

On lower altitudes the Black alder stands are interlocking with willow stands. On the whole the gallery like willow stands with White and Brittle willow (*Salix alba*, *Salix fragilis*), as well as White poplar (*Populus alba*) are poorly represented (Tab. 1, column 4). They occurred on larger scale at the mouth of the tributaries into the Danube and are known as Salici-Populetum Meijer-Drees 1936 (Morariu and Danciu, 1970; Morariu et al., 1973). Due to the backwater situation of the impounded Danube and the loss of river dynamics they mostly disappeared on the lower river stretches being replaced by Magnocaricion and Phragmition reeds characteristic for borders of standing waters.

Apart from the above mentioned habitat types and phytocoenoses, it has to be mentioned as characteristic for the studied riparian habitats a pioneer community edified by Purple willow (*Salix purpurea*) on open gravel banks (Tab. 1, column 4), locally also with regeneration of Black poplar (*Populus nigra*), included in the association Saponario-Salicetum purpureae (Br.-Bl. 1930) Tschou 1946. These fragmental phytocoenoses are near to those included in the habitat type 3240 Alpine rivers and their ligneous vegetation with *Salix elaeagnos*. In this habitat type are included as well pioneer gravel and sandy bank habitats with *Salix purpurea*, as they have been described before the construction of the Iron Gate power plant (Morariu and Danciu, 1970; Morariu et al., 1973; Sanda et al., 2008). Such fragments of Purple willow communities have been observed and studied during our field trips on the lower part of Liborajdea and Plavişeviţa tributaries.

At that time when the Danube and its tributaries were still supposed to natural hydrological dynamics with changes between high and low water levels, on the mouth of the tributaries and as well on the Danube River banks, it developed during low water levels pioneer communities edified by therophyte species constituting phytocoenoses of the association Dichostyli-Gnaphalietum uliginosi (Horvatic 1931) Soó and Timár 1947 (Morariu and Danciu, 1970). As a consequence of the "Iron Gates" Dam construction and the backwater situation on the tributaries pioneer communities are very rare at present. They are developed only fragmental in very small patches, identified for example on the lower Plaviseviţa Stream and edified by *Chenopodium ambrosioides, Portulaca oleracea* and *Heleochloa alopecuroides.*

All the valleys and their rivers and streams are supposed to human activities and interventions. In particular on the lower stretches of the tributary rivers and streams are visible major impacts due to the hydrotehnical constructions and the back water situation created by the accumulation lake and the changes of the hydrological dynamics on the mouth of the tributaries. On these places the riparian vegetation suffered a remarkable shifting from dynamic running waters accompanying vegetation to one of more or less standing waters. Due to this fact also the Wild grape (*Vitis sylvestris*) which occurred curtain like in softwood riparian galleries (Meusel and Niedermaier, 1985) on the Clisura stretch of the Danube, became continuously rare. In general a large part of the characteristic vegetation of softwood stands disappeared. Impacts are given also through the spreading of alien species, some of them being invasive. Before the construction of the "Iron Gates" Dam was mentioned the association Salici-Populetum (Tx. 1931) Meijer-Drees in 1936 with a facies amorphosum fruticosae "on the whole area of the Iron gate, in particular on the island Moldova Veche, occupying large area as well along the Danube River banks" (Morariu and Danciu, 1970; Morariu et al., 1973). On the Danube the species is present on larger scale, also in the back water situation, but on the tributaries Indigo-shrub (*Amorpha fruticosa*) is scarcely represented. On some of the tributaries (Ogradena, Plavişeviţa) another alien species, the American pokeweed (*Phytolacca americana*) occurs, but to date not as an invasive species.

The Tree of heaven (*Ailanthus altissima*), originally from China (Sârbu et al., 2013), is cultivated and used in forest plantations also in the Clisura area, but the species is as well naturalized in riparian habitats, in particular in the Ogradena Valley presenting a large natural regeneration (Tab. 2, column 14). In the management of the Natural Park of the Iron Gate including many habitats of community interest, between them the priority habitat type 91E0, this fact has to be treated with high attention because the Tree of heaven is replacing the natural riparian vegetation.

A considerable impact for the riparian vegetation and the rivers can be stated in the larger valleys of tributaries by misuse of the river banks for diverse waste deposition which enters also the rivers generating water pollution and changing the habitats quality.

CONCLUSIONS

The riparian vegetation of all the tributaries have common characteristics, but there are also some distinct differences between the vegetation and habitat types of the studied valleys. These depend on the size of the basin of each of the tributaries, the geomorphological structure of the valley from the springs to the mouth into the Danube, the length of the river, its discharge and its dynamics and as well the changes of the natural conditions by men's intervention like hydraulic measures.

The upper parts of the rivers are in a natural or near natural state, with small alluvial vegetation, the adjacent forests reach the river banks mostly. On the middle and lower stretches the riparian vegetation is well represented by the priority habitat type 91 E0 Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* with the subtype 44.3: Alno-Padion and 44.13: Salicion albae. The latter suffers on the lower part of the rivers by human impact due to the backwater situation from the Danube water reservoir.

On some of the rivers occur the habitat type 6430 Hydrophilous tall herb fringe communities of plains and of the mountainous to alpine levels being represented with phytocoenoses edified by *Petasites hybridus* and *Telekia speciosa*. These characteristic mountainous phytocoenoses attains on the Clisura tributaries area their lowest distribution point in the Carpathians.

Although the riparian vegetation is considered more azonal, it is of interest from the biogeographical point of view, due to some thermophilous and sub-termophilous Mediterranean and sub-Mediterranean species. These species occurs due to the geographical position of the Clisura with influences of a sub-Mediterranean climate. For that reason the riparian vegetation of the South-western part of the country differs from that of other parts of the Carpathians.

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REPRODUCTIVE BIOLOGY OF MANGROVE PLANTS *CLERODENDRUM INERME, DERRIS TRIFOLIATA, SUAEDA MARITIMA, SUAEDA MONOICA, SUAEDA NUDIFLORA*

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ABSTRACT

Floral biology, sexual system, breeding system, pollinators, fruiting and seed dispersal aspects of five mangrove associate species, namely, *Clerodendrum inerme*, *Derris trifoliata*, *Suaeda maritima*, *S. monoica*, and *S. nudiflora* were studied. All these species are hermaphroditic, self-compatible, and exhibit mixed breeding systems adapted for pollination by external agents. *C. inerme* and *D. trifoliata* are principally entomophilous, while *Suaeda* species are ambophilous. The study suggests that these plant species are important constituents of mangrove forests. *C. inerme* and *D. trifoliata* are useful in stabilizing the banks of back water creeks, while *Suaeda* species are useful to carpet the saline areas and desalinate the soils which are subsequently useful for agricultural activities.

ZUSAMMENFASSUNG: Fortpflanzungsbiologie der Mangrovenpflanzen *Clerodendrum inerme, Derris trifoliata, Suaeda maritima, Suaeda monoica, Suaeda nudiflora.*

Die Arbeit stellt Untersuchungen zu Blütenbiologie Sexual- un Fortpflanzungssystem, Bestäubern, Fruchtbildung sowie Aspekte der Samenverbreitung von fünf zu den Mangroven gehörenden Arten vor, und zwar *Clerodendrum inerme, Derris trifoliata, Suaeda maritima, S. monoica* und *S. nudiflora*. Alle diese Arten sind hermaphroditisch, selbstverträglich und weisen gemischte Fortpflanzungssysteme auf, die an die Fremdbestäubung angepasst sind. *Clerodendron inerme* und *Derri trifoliata* sind hauptsächlich entomophil, während die *Suaeda* Arten ambophil sind. Die Studie weist darauf hin, dass diese Pflanzenarten wichtige Komponenten des Mangrovenwaldes darstellen. *C. inerme* und *D. trifoliata* sind für die Uferbefestigung von Gezeitenästuaren von Bedeutung, während sich Suaeda-Arten in der Bedeckung von Salzflächen als nützlich erweisen und Böden entsalzen, die in der Folge für landwirtschaftliche Tätigkeiten von Nutzen sind.

REZUMAT: Biologia reproductivă a plantelor de mangrove *Clerodendrum inerme, Derris trifoliata, Suaeda maritima, S. monoica, S. nudiflora.*

Articolul prezintă studiul asupra biologiei florale, sistemului sexual, sistemului de creștere, polenizatorilor, rodirii și răspândirii semințelor la cinci specii de mangrove asociate, *Clerodendrum inerme, Derris trifoliata, Suaeda maritima, S. monoica* și *S. nudiflora.* Toate aceste specii sunt hermafrodite, auto compatibile și prezintă sisteme de creștere mixte adaptate pentru polenizare de către agenții externi. *C. inerme* și *D. trifoliata* sunt în principal entomofile în timp ce speciile *Suaeda* sunt ambophilous. Studiul sugerează că aceste specii de plante sunt constituenți importanți ai pădurilor de mangrove. *C. inerme* și *D. trifoliata* sunt utile în stabilizarea malurilor cursurilor de apă, în timp ce speciile *Suaeda* sunt utile pentru covorul zonelor saline și desalinizarea solurilor care sunt ulterior utile pentru activități agricole.

INTRODUCTION

Mangrove conservation has received an increased importance in the recent past as research has increased the understanding of the values, functions, and attributes of mangrove ecosystems and the role they play in providing important ecological services and livelihoods for the mangrove associated communities. Mangrove forests are among one of the world's most productive tropical ecosystems. They are now one of the most threatened ecosystems in the world due to natural and demographic pressures (Roy and Krishnan, 2005). The mangrove vegetation is comprised of unique plant communities consisting of evergreen trees and shrubs belonging to several unrelated families growing in tropical and subtropical intertidal regions where there is constant intertidal exchange of sea water and freshwater (Spalding et al., 1997).

The focus of research on the reproductive biology of mangrove plants has almost exclusively been on the fruit and seed or seedling dispersal stage. Surprisingly, less is known about floral biology, pollination, and breeding systems, although knowledge of the effectiveness of floral mechanics and genetic isolating mechanisms is an important pre-requisite to the study of successful dispersal and establishment (Primack et al., 1981; Tomlinson, 1986; Juncosa and Tomlinson, 1987; Clarke and Meyerscough, 1991; Azuma et al., 2002; Ge et al., 2003; Chiou-Rong et al., 2005; Coupland et al., 2006). In India, a few studies provide some preliminary accounts of floral biology and pollination in some mangrove plants (Solomon Raju, 1990; Solomon Raju et al., 1994; Subba Reddi and Solomon Raju, 1997; Solomon Raju et al., 2006; Solomon Raju and Jonathan, 2008; Jonathan and Solomon Raju, 2009; Pandit and Choudhury, 2001; Jonathan, 2009; Rama Mohan, 2009). The available information relates to viviparous and crypto-viviparous species, but not non-viviparous true mangroves or mangrove associate species.

This study provides information on the ecological aspects of sexual reproduction of *Clerodendrum inerme* (L.) Gaertn. (Verbenaceae), *Derris trifoliata* Lour. (Fabaceae), *Suaeda maritima* (L.) Dum., *S. monoica* Forsk. Ex. J. F. Gmel. and *S. nudiflora* (Willd.) Moq. (Chenopodiaceae) in Godavari-Coringa mangrove forest in India. Floral biology, sexual system, breeding system, floral rewards, pollinators, and foraging behaviour have been studied. Further, fruit and seed dispersal aspects have also been studied to the extent possible.

MATERIAL, METHODS AND STUDY AREA

The mangrove forests in Andhra Pradesh are located in the estuaries of the Godavari and the Krishna rivers. They are also found in small patches or lesser known estuaries along the coast of Visakhapatnam, West Godavari, Guntur and Prakasam districts. The present study was conducted in the Godavari Coringa mangrove wetlands. The Godavari mangrove forest is the second largest mangrove area on India's East Coast; the first largest being the Sundarbans Mangrove Forest situated in the State of West Bengal which is a part of India.

The Godavari mangrove wetland (16^o 30'-17^o00'N and 82^o10'-80^o23'E) is located in the delta of the river Godavari which is 1,330 km long and the second longest river in India. It branches into Vasishta and Gautami near Dowleswaram, which is considered the head of the delta. Two distributaries, Coringa and Gaderu branching-off the northern bank of the rivers Gautami and Godavari, supply freshwater to the Coringa mangroves. Freshwater flows into the mangrove wetlands of the Godavari delta for a period of six months and peak flow normally occurs from July to September, coinciding with the southwest monsoon season. During this period the entire delta, including the mangrove wetland, is submerged under freshwater since penetration of sea water is completely blocked by the large amount of incoming freshwater. Brackish water condition prevails from October to February and sea water dominates the entire mangrove wetland from March to May due to absence of freshwater discharge.

The total area of the forest is 188 km^2 (State of Forest Report, 2003, by Forest Survey of India, Dehradun, Government of India) and it is divided into nine Reserve Forests – Corangi, Corangi Extension, Bhairavapalem, Rathikalava, Masanitippa, Matlatippa, Balusutippa, Kothapalem, and Kandikuppa. Of these, the first three Reserve Forests make up The Coringa Wildlife Sanctuary while the remaining Reserve Forests are situated on the southern side of Nilarevu River and fall under non-sanctuary area. The mangroves of the Coringa Wildlife Sanctuary receive tidal flushes through the Matlapalem Canal, Corangi River, and the Gaderu River; the last two rivers are the distributaries of the river Godavari. Most of the mangroves in the Coringa Sanctuary are not directly connected to the bay of Bengal. There are 36 mangrove plant species in 21 families present in this estuarine area. They include *Acanthus ilicifolius* (Acanthaceae), *Sesuvium portulacastrum* (Aizoaceae), *Sarcolobus carinatus* (Asclepiadaceae), *Avicennia alba, A. marina, A. officinalis* (Avicenniaceae), *Caesalpinia crista* (Caesalpiniaceae), *Salicornia brachiata, Suaeda maritima, S. monoica, S. nudiflora* (Chenopodiaceae), *Lumnitzera racemosa* (Combretaceae), *Ipomoea pes-caprae, I. tuba* (Convolvulaceae), *Fimbristylis ferruginea* (Cyperaceae), *Excoecaria* a*gallocha* (Euphorbiaceae), *Derris spinosa, D. trifoliata* (Fabaceae), *Hisbiscus tiliaeceus*, *Thespesia populnoidea, Malachra capitata* (Malvaceae), *Xylocarpus moluccensis* (Meliaceae), *Aegiceras corniculatum* (Myrsinaceae), *Aleuropus lagopoides, Myriostachia wightiana, Porteresia coarctata* (Poaceae), *Scyphiphora hydrophyllacea* (Rubiaceae), *Bruguiera cylindrica, B. gymnorrhiza, Ceriops decandra, Rhizophora apiculata, R. mucronata* (Rhizophoraceae), *Sonneratia apetala, S. alba* (Sonneratiaceae), *Brownlowia tersa* (Tiliaceae), *Tamarix troupii* (Tamariaceae), and *Clerodendron inerme* (Verbenaceae). In this area, only the Coringa Wildlife Sanctuary is rich in species diversity and represents healthy mangroves.

The Coringa mangrove forest region falls under the category of “tropical humid climate” with the monsoon season commencing from June and extending up to December. The rainfall here is influenced by Southwest and Northeast monsoons. Major quantities of rainfall is contributed by the Southwest monsoon (June-September) followed by Northeast monsoon (October-December). The winter and summer months also contribute a small percentage of rainfall. During this period, the salinity is very low (< 5 ppt). From January the weather is mainly dry and progresses, gradually, to the hot summer months of March to May. The average maximum and minimum temperatures recorded are 32.36 and 24.4^{o}C.

STUDIED MANGROVE PLANT SPECIES

Five mangrove associate species, *Clerodendrum inerme* (L.) Gaertn. (Verbenaceae), *Derris trifoliata* Lour. (Fabaceae), *Suaeda maritima* (L.) Dum., *S. monoica* Forsk. Ex. J. F. Gmel. and *S. nudiflora* (Willd.) Moq. (Chenopodiaceae), were selected for the present study. All five species occur in the Godavari mangrove forest. Of these, *C. inerme* grows along the creeks and towards land, it is distributed sparsely in this mangrove forest. *D. trifoliata* also grows along the creeks, but it does not grow towards land. It has small populations here and there in the mangrove forest. All three *Suaeda* species form thick mats in upper and low salt marshes in the estuarine area and towards land as well. *S. maritima* and *S. monoica* grow together successfully, while *S. nudiflora* grows mostly in areas which are not occupied by the other *Suaeda* species. The locals use *C. inerme* and *D. trifoliata* as a source of firewood and *Suaeda* species for treating certain skin diseases by external application.

Collection of data on different aspects of reproductive biology

Field trips to the Godavari Coringa mangroves were made prior to selecting the plant species for the study. Based on this prior field experience, five mangrove associate species as noted above were selected for study. Field investigations and experiments were conducted during the period from February 2011 to June 2014. After having preliminary field knowledge on flowering seasons of the selected species, regular field studies were made to collect information and data on the reproductive aspects selected for the study. The functional events of individual flowers, sexual status, floral rewards and their details, breeding system, flower visitors and their behaviour and pollination role, natural fruit and seed output rates and duration of fruit maturation, were carefully observed. Experiments were also conducted where essentially required. Seed dispersal aspects were also examined in the field, but only observations were made.

Examination of flowering at inflorescence level

Observations regarding the organization of inflorescences, the spatial positioning of flowers, and their position (terminal, axillary, etc.) on the plants were made since these features are regarded as important for foraging and effecting pollination by flower-visitors. The flower life was recorded by marking the just anthesed flowers and following them until fall off.

Determination of anthesis and anther dehiscence

Anthesis was initially recorded by observing marked mature buds in the field. Later, the observations were repeated three to four times on different days in order to provide accurate anthesis schedule for each plant species. Similarly, the mature buds were followed for recording the time of anther dehiscence. The presentation pattern of pollen was also investigated by recording how anthers dehisced and confirmed by observing the anthers under a 10x hand lens.

Examination of flower morphology

The details of flower morphology such as flower sex, shape, size, colour, odour, sepals, petals, stamens, and ovary were described. Further, the position of stamens, exposed or hidden, was described. The order of wilting or dropping off of floral parts was recorded. These details for the selected plant species were provided due to inadequate and confusing taxonomic descriptions.

Flower behaviour

Observations regarding the position and spatial relationships of stamens and stigma in mature bud, at anthesis, and after during the flower-life with reference to self and/or cross-pollination were made very carefully.

Determination of pollen output

Mature undehisced anthers were collected from plants and placed in a Petri dish. Later, each time, a single anther was taken out and placed on a clean microscope slide (75 x 25 mm) and dabbed with a needle in a drop of lactophenol-aniline-blue. The anther was then observed under the microscope for pollen, if any. If pollen grains were not there, the tissue was removed from the slide. The pollen mass was drawn into a band, and the total number of pollen grains was counted under a compound microscope (40x objective, 10x eye piece). This procedure was followed for counting the number of pollen grains in each anther collected. Based on these counts, the mean number of pollen produced per anther was determined. The mean pollen output per anther was multiplied by the number of anthers in the flower to obtain the mean number of pollen grains per flower. The characteristics of pollen grains were also recorded.

Determination of Pollen-Ovule Ratio

The pollen-ovule ratio was determined by dividing the average number of pollen grains per flower by the number of ovules per flower. The value thus obtained was taken as pollen-ovule ratio (Cruden, 1977).

Examination of nectar characters

The presence of nectar was determined by observing the mature buds and open flowers. It was also observed whether the nectar secreted was in measurable quantity. When found measurable, the volume of nectar from 10 flowers of each plant species studied was determined. Then, the average volume of nectar per flower was determined and expressed in µl. The flowers used for this purpose were bagged at mature bud stage, opened after anthesis, and the nectar was squeezed into micropipettes for measuring the volume of nectar. Nectar sugar concentration was determined using a Hand Sugar Refractometer (Erma, Japan) for *C. inerme* and *D. trifoliata*. Ten samples were used from these species to examine the range of sugar concentration in the nectar. For the analysis of sugar types, a paper chromatography method described by Harborne (1973) was followed. Nectar was placed on Whatman number one filter paper along with standard samples of glucose, fructose and sucrose. The paper was run ascendingly for 24 hours with a solvent system of n-butanol-acetone-water (4:5:1), sprayed with aniline oxalate spray reagent, and dried at 120^{o}C in an electric oven for 20 minutes for the development of spots from the nectar and the standard sugars. Then, the sugar types present, and also the most dominant sugar type, were recorded based on the area and colour intensity of the spot. The sugar content/flower is expressed as the product of nectar volume and sugar concentration per unit volume, mg/µl. This is done by first noting the conversion value for the recorded sugar concentration on the refractometer scale, and then by multiplying it with the volume of nectar/flower. Table 5.6 given in Dafni et al. (2005) was followed for recording the conversion value to mg of sugars present in one µl of nectar. The protocols given in Sadasivam and Manickam (1997) were followed for the quantitative estimation of sucrose, glucose, and fructose in mg/flower. Dinitrosalicylic acid method was followed for the first two sugar types while Resorcinol method for the last sugar type. Nectar amino acid types were recorded as per the paper chromatography method of Baker and Baker (1973) only for *C. inerme*. Nectar was spotted on Whatman number one filter paper along with the standard samples of nineteen amino acids, namely, alanine, arginine, aspartic acid, cysteine, cystine, glutamic acid, glycine, histidine, isolecuine, leucine, lysine, methionine, phenylalanine, proline, serine, threonine, tryptophan, tyrosine and valine. The paper was run ascendingly in chromatography chamber for 24 hours with a solvent system of n-butanol-glacial acetic acid-water (4:1:5). The chromatogram was detected with 0.2% ninhydrin reagent and dried at 85^{o}C in an electric oven for 15 minutes for the development of spots from the nectar and the standard amino acids. The developed nectar spots were compared with the spots of the standard amino acids. Then, the amino acid types were recorded.

Determination of Stigma Receptivity

The stigma receptivity was observed visually and by H_2O_2 test. In the visual method, the stigma physical state (wet/dry) and the unfolding of its lobes were considered to record the commencement of receptivity, withering of the lobes was taken as loss of receptivity. The H_2O_2 test (Dafni et al., 2005) was followed for noting the stigma receptivity period. This test is widely followed, although it does not indicate the exact location of the receptive area. In this study, the period of slow release of bubbles from the surface of stigma following the application of hydrogen peroxide was taken as stigma receptivity.

Assessment of Breeding Systems

Breeding systems were conducted only with *C. inerme* and *D. trifoliata*. Mature flower buds of some inflorescences on different individuals were tagged and enclosed in paper bags. They were tested in the following way, and the number of flower buds used for each mode of pollination for these species was given in the concerned tables. 1. The stigmas of flowers were pollinated with the pollen of the same flower manually by using a brush; they were bagged and followed to observe fruit set in manipulated autogamy. 2. The flowers were fine-mesh bagged without hand pollination to observe fruit set in spontaneous autogamy. 3. The emasculated flowers were hand-pollinated with the pollen of a different flower on the same plant. They were bagged and followed for fruit set in geitonogamy. 4. The emasculated flowers were pollinated with the pollen of a different individual plant. They were bagged and followed for fruit set in xenogamy.

All these categories of flower pollinations were followed for fruit set. If fruit set was there, the percentage of fruit set was calculated for each mode.

Determination of Natural Fruit Set

The flowers/inflorescences were tagged on different plant species prior to anthesis and followed for fruit and seed set rate in open-pollinations. The number of flowers used for each plant species was different and mentioned in the concerned tables for *C. inerme* and *D. trifoliata*. In case of the *Suaeda* species, 50 inflorescences of ten different individuals consisting of 3,239 to 4,259 flowers were tagged and followed for fruit set. Fruit maturation period, fruit dehiscence and seed dispersal were observed in detail.

Observations of Flower-Visitors

After making preliminary observations on the categories of flower visitors, a thorough knowledge of the local insect species was obtained by observing the representative species of insects available with the Pollination Ecology Laboratory in the Department of Environmental Sciences, Andhra University, Visakhapatnam. Some insect species were identified to genus level only and a few insect species could not be identified at all, even by the Insect Taxonomic Group with the Division of Entomology, Indian Agricultural Research Institute, New Delhi. With the knowledge of local insect species, attempts were made to observe flower visitors on each plant species chosen for the study. The insect species were observed visually and by using binoculars. The insect species that could not be identified on spot were captured and later identified with the help of the identified specimens available in the Department. The hourly foraging visits of each insect species on each plant species were recorded on three or four occasions, depending on the possibility, and the data was tabulated to use the same for further analysis. For each species, 15-20 inflorescences were selected to record the foraging visits of insects. The data obtained was used to calculate the percentage of foraging visits made by each insect species per day, and also to calculate the percentage of foraging visits of each category of insects per day, to find the importance of each insect species or category of insects.

Determination of pollen carryover efficiency of insects

The flower visitors were captured during 10.00 to 12.00 each plant species and were brought to the laboratory. For each insect species, ten specimens were captured and each specimen was washed first in ethyl alcohol and the contents stained with aniline-blue on a glass slide and observed under microscope to count the number of pollen grains present. In case of pollen collecting insects, the pollen loads on their corbiculae were separated prior to washing them. From this, the average number of pollen grains carried by each insect species was calculated to know the pollen carryover efficiency of different insect species.

Determination of Foraging Behaviour of Insects

The foraging activity of insect species was confined to daytime only, but in case of *C. inerme*, one hawk moth visited during dawn and dusk hours. The insects were observed on a number of occasions on each plant species for their foraging behaviour such as mode of approach, landing, probing behaviour, the type of forage they collect, contact with essential organs to result in pollination, inter-plant foraging activity in terms of cross-pollination, etc. Observations were also made on bud, flower, and fruit feeding activity by insects.

Photography

Study area, habitat, plant, flower and fruit details together with insect foraging activity on the flowers of the studied plant species were photographed with Nikon D40X Digital SLR (10.1 pixel) and TZ240 Stereo Zoom Microscope with SP-350 Olympus Digital Camera (8.1 pixel). Olympus Binoculars (PX35 DPSR Model) were also used to make field observations. Magnus Compound Microscope – 5x, 10x, 40x and 100x magnification was used for studying the pollen characteristics.

RESULTS

Clerodendrum inerme (L.) Gaertn. (Verbenaceae)

Phenology

It is an evergreen sprawling perennial shrub of mangrove margins that grows to a height of up to two m. It sheds leaves continually, but leaf shedding is prominent during the dry season and exhibits profuse leaf flushing during rainy season. The flowering occurs during August-October with profuse flowering during September. The inflorescence is characteristically a three-flowered cyme borne in axillary position and all the three flowers have a common base point. Individual cymes produce all three flowers either on the same day, or within two-three days. The production of flowers within cymes is dependent on the developmental stage of individual flowers. Usually, the central flower emerges first, followed by the lateral flowers. The flowers orient completely or partly erect.

Flower Morphology

The flowers are pedicellate, large (35 to 40 mm), fragrant, zygomorphic and bisexual. Calyx is green, gamosepalous consisting of five sepals, cup-shaped, eight mm long, three-four mm wide and valvate at the tip. Corolla is white, tubate (30 mm long), four-five lobed at the tip; each lobe 10-12 mm long and four-five mm wide, and reflexed. The ratio of four and five petal lobes is 1:21. On the inner surface, the corolla tube is covered with short fine hairs up to the point of attachment of staminal filaments. The stamens are four or five, epipetalous, exserted, extend up to 30 mm from the corolla mouth when the flowers first open. The included part of the filaments is white while the excluded part of the filaments is purple. The ratio of five-stamened and four-stamened flowers is 1:12. There is a great variation in the length of stamens despite their common point of origin on the corolla tube. In case of four-stamened flowers, two long and two short or all are equal in length while in case of five-stamened flowers, two long and three short in length. The anthers have versatile fixation, are dark-coloured, dithecous and introrse. The ovary has two carpels but it is tetra-locular due to formation of a false septum. The ovules vary in number from two to four but fur-ovuled flowers are most common. They are erect, anatropous, and arranged on axile placentation. The total length of style is 45 mm in just opened flowers and 56 mm in the 2nd and 3rd day flowers. The included part of the style length is 30-33 mm while the excluded part of the style length is 15-18 mm in just open flowers. In case of 2nd and 3rd day flowers, the excluded style part is of 25-28 mm. The style ends with bifid stigma.

Floral Biology

The mature buds with coiled stamens inside open at from 15.00 to 18.00 afternoon by the splitting of petal lobes. Petals expand and reflex immediately, then the stamens, style, and stigma extend beyond the rim of the corolla tube. The pattern of stamens and style positions is different and is distinguished into three forms. In the first form of flowers, the stamens and style are elongated and in proximity to each other soon after anthesis which facilitates contact with each other. In the second form of flowers, the stamens and style are splayed. In the third form of flowers, the stamens are fully extended, but the style is curved away from them. The style in some flowers moves away to the left side, while in some others, to the right side. Later, the stamens curl inward and style is left elongated. These three forms occur even within the cyme. These three forms occur almost in equal numbers at plant level. The anthers dehisce one hour after anthesis by longitudinal slits exposing the golden yellow pollen. All the stamens in both four-stamened and five-stamened flowers are fertile and produce almost the same number of pollen grains. The pollen output per anther is 796 ± 51.2. The total pollen productivity in individual four-stamened flowers is 3,184 and in five-stamened flowers is 3,980. The pollen grains are tricolporate, prolate, ectocolpus long narrow with acute ends, reticulate-rugulate with spinules widely distributed and 66.4 ± 1.32 µm long and 52.2 ± 0.8 µm wide. The stigma with forked lobes is not receptive at, and after anthesis, but it is receptive with divergent lobes on the 2nd and 3rd day. Nectar is secreted during post-anthesis period. Its secretion is gradual from anthesis onwards, but its volume is measurable on the 2nd and 3rd day. A flower produces 3.5 ± 1.2 µl of nectar which is secreted around the ovary and well protected due to the tubular nature of the corolla. The nectar sugar concentration is 13-21% and the common sugars include sucrose, glucose and fructose. The total sugar content in the nectar of a flower is 0.37 ± 0.06 mg (Range 0.24-0.46). The nectar amino acids include the essential amino acids such as isoleucine, valine, lysine, methionine and threonine, and non-essential amino acids such as alanine, butyric acid, glutamic acid, hydroxyl-proline, serine and aspartic acid. The corolla, together with stamens and stigma, falls off after three days. The calyx is persistent, gradually bulges, and encloses the fruit in case of fertilized flowers. The entire flower, together with pedicel, falls off if it is not pollinated or fertilized.

Breeding Systems

The results of breeding systems indicate that the flowers are self-compatible and self-pollinating. The fruit set is absent in autonomous and facilitated autogamy, 30% in geitonogamy, 83% in xenogamy and 38% in open pollinations (Tab. 1).

Table 1: Results of breeding experiments on *Clerodendrum inerme*.

Mode of pollination	Number of flowers pollinated	Number of flowers set fruit	Fruit set (%)
Autonomous autogamy (bagged)	30	0	0
Facilitated autogamy (hand-pollinated and bagged)	25	0	0
Geitonogamy	30	9	30
Xenogamy	30	25	83
Open-pollination	70	27	38

Foraging Activity and Pollination

The flowers are specialized and the stamens and stigma are exposed when the petals unfold and reflex. The hawk moth, *Macroglossum gyrans*, was the first visitor to the flowers. It began its nectar-foraging activity as soon as the flowers opened during late evening and dusk hours. Again, this moth foraged during dawn hours from 05.00-07.00 h. It did not forage at other times of the day. The bees (*Xylocopa pubescens* and *Anthophora bicincta*) and butterflies (*Pareronia valeria*, *Danaus genutia* and *Borbo cinnara*) foraged during day time from 08.00 to 17.00 h, but the bees showed more activity during 08.00-12.00 h while butterflies during 08.00-11.00 h (Tab. 2). However, the overall foraging activity of these daytime foragers was not very intense, and their foraging visits were not very frequent. Of the total foraging visits of these insects, *M. gyrans* made 39%, butterflies 38%, and bees 23% of visits. The body washings of these foragers collected from the flowers, revealed the presence of pollen in different numbers depending on the frequency of foraging visits, extent and certainty of contact between the stamens and stigma, and the wings and the abdomen of the foragers (Tab. 3). *M. gyrans* was anmefficient carrier of pollen and were also consistent foragers with great intensity towards the flowers during the entire period of flowering. The daytime foragers were not efficient carriers of pollen, not very frequent foragers, and also not consistent ones.

Table 2: List of insect foragers on *Clerodendrum inerme*.

Order	Family	Genus	Species	Common name	Forage sought
Hymenoptera	Apidae	*Xylocopa*	*pubescens* L.	Large Carpenter Bee	Pollen + Nectar
	Anthophoridae	*Anthophora*	*bicincta* F.	Blue Banded Bee	Pollen + Nectar
Lepidoptera	Pieridae	*Pareronia*	*valeria* Cr.	Common Wanderer	Nectar
	Nymphalidae	*Danaus*	*genutia* Cr.	Striped Tiger	Nectar
	Hesperiidae	*Borbo*	*cinnara* Wallace	Rice Swift	Nectar
	Sphingidae	*Macroglossum*	*gyrans* Walker	Diurnal hawk moth	Nectar

M. gyrans was a very swift flier and spun around the flowers in quick succession collecting nectar from a number of flowers on the same plant. It also made inter-plant movements frequently for nectar collection from the fresh, as well as, 2nd and 3rd day flowers. This moth, with 32.5 mm long proboscis, was very successful in reaching the nectar location at the corolla base. While approaching the flower and collecting nectar from the flowers, it always contacted the stamens and stigma of the same or different flowers with its wings and abdomen and this foraging behavior ended up in pollination. The just open flowers available during dusk hours with little nectar volume was considered to be driving the moth to make multiple visits to these flowers as well as 2nd and 3rd day flowers in which nectar is richly available, on the same and different plants. Such a foraging behaviour was considered to be increasing opportunities for cross-pollination.

Table 3: Pollen recorded in the body washings of insects on *Clerodendrum inerme*.

Insect species	Sample size (N)	Number of pollen grains		
		Range	Mean	S.D.
Xylocopa pubescens	10	13 – 48	30.3	10.70
Anthophora bicincta	10	54 – 126	85.3	22.87
Parerонia valeria	10	21 – 56	38.1	11.63
Danaus genutia	10	14 – 73	35.9	16.12
Borbo cinnara	10	11 – 21	13.6	2.4
Macroglossum gyrans	10	131 – 214	179.1	32.5

Among bees, *X. pubescens* was an exclusive nectar forager and *A. bicincta* was both a pollen and nectar forager. The two bee species robbed nectar by biting holes through the corolla tube and bypassing the floral sex organs. *X. pubescens* made a hole at the mid-part of the corolla tube to collect nectar; the exact point where the hole was made was mostly at the origin point of the epipetalous stamens covered with short hairs. The flower hung downwards when this bee species with its heavy body weight landed on the corolla tube. Then, the nectar flowed freely through the grooves present on the inside of the corolla tube from the flower base to this fixed position of stamens. The short hairs present at the fixed point of stamens prevent the flow of nectar beyond this point towards the mouth of the corolla tube. On the contrary, *A. bicincta* made a hole through the corolla tube at the flower base and robbed nectar by bypassing the floral sex organs. The flower did not hang downwards when this bee species with light body weight landed, and this was considered to be the reason for the bee to move to the corolla base to rob the nectar. The nectar-robbing by these two bee species did not contribute to effecting pollination. However, these bees with vibrating wings in flight mode, contacted the stamens and stigma occasionally while approaching the flowers. Such individual bees captured pollen on their wings and underside of the abdomen, and these could be effecting pollination. Further, *A. bicincta* also collected pollen from individual anthers.

Among butterflies, the foraging visits of *P. valeria* and *D. genutia* were relatively frequent when compared to those of *B. cinnara*. In *P. valeria*, the body length is 25.6 mm and the proboscis length is 29.5 mm. In *D. genutia*, the body length is 23.9 mm and the proboscis length is 12.2 mm. In *B. cinnara*, the body length is 14.1 mm and the proboscis length is 17.5 mm. In *P. valeria* and *D. genutia*, their body length was found to facilitate them having contact between the stamens and stigma in flight mode, and while approaching the flowers. Such approaching behaviour could make the butterflies capture pollen onto their wings as well as underside of the abdomen, and eventually effect pollination. Such contacts were found to be related to the path and position the butterflies take to access the flowers. In *B. cinnara*, the body length was very short and its contact with the stamens and stigma was found to be rare while approaching the flowers. All the three butterfly species probed the flowers by inserting their proboscis into the throat of the corolla tube. But, the corolla tube length, far in excess of the length of proboscis of these butterflies, did not allow the latter to collect nectar situated at the flower base. The flowers in erect or partially erect position were found to be depriving the foraging butterflies of nectar. The butterflies however, were successful in gaining access to nectar in the hanging flowers in which the nectar reaches to the mid-part of the corolla tube. Such flowers acquired this orientation due to visits to them previously by *X. pubescens*.

Fruiting Behaviour

Pollinated and fertilized flowers initiate fruit development immediately and take 20-25 days to produce mature fruits. Fruit is a capsule, oval-shaped, 10-15 mm long, initially green, and black when ripe and dry. Dry fruits split or break into two to four lobes depending on the number ovules fertilized, each with thick corky wall and a nutlet. Fruit dispersal occurs during November-December. Birds such as *Acridotheres tristis* (Indian Myna), *Corvus splendens* (House Crow), *Corvus macrorhynchos* (Jungle Crow) and *Turdoides caudatus* (Common Babbler) were found to feed on the nutlets and in the process, disperse them to different places. Nut-lets germinate during rainy season soon after the first monsoon rains in June.

Derris trifoliata **Lour. (Fabaceae)**

Phenology

It is a deciduous woody climber with pinnate leaves, growing to a length of up to 15 m. The stem is covered with a smooth, dark brown, corky bark with orange lenticels. Young stems are dark red, strongly ridged, and have prominent lenticels. Flowering occurs from 1st week of July to 1st week of August. It exhibits massive blooming. An individual flowers for about one-two weeks. The inflorescence is a raceme of 112 ± three mm length (Range 50-160) which is borne in the axils of stems growing horizontally, along the ground. An inflorescence produces 56.03 ± 33.19 (Range 15-182) flowers over a period of two-three days in acropetal manner. The flowers are arranged horizontal to the inflorescence axis.

Flower Morphology

Flowers are pedicellate, small, 10 mm long, pinkish white, odourless, delicate, papilionaceous, bisexual, and zygomorphic. Sepals are five, slightly fused at base forming a shallow cup, two mm long, light green, and glabrous. Petals are five, one pinkish white 10 mm long standard petal, two light pink five mm long wing petals and two white five mm long keel petals. The standard petal is broad with a light greenish-white nectar guide at the centre and hook-like structures at the base, it is posterior in position and encloses the margins of wing petals, which in turn, overlap on the margins of keel petals. The keel petals represent a boat-shaped structure in which the stamens and stigma are embedded. Stamens are 10, diadelphous with nine stamens united into one bundle, while the tenth one is free. The bundled stamens form staminal tube at the base and the filaments become free towards the apex and bear monomorphic, dithecous basifixed anthers. All the ten stamens have a common origin at the flower base, their filaments are whitish green, slender, and delicate. The bundled stamens bend inward and form a conical-shaped tube at the extreme flower base, while the tenth stamen arises separately without any bending and forms open gaps on both sides towards the staminal tube. The tenth stamen is quite opposite to the standard petal. All the ten stamens have prominent upward arching. The ovary is semi-inferior with a single carpel, having six light green and shiny ovules arranged in a linear manner on marginal placentation. It has a light green style terminated with a wet, light yellow capitate stigma; the terminal portion arches upwards and extends two mm beyond the height of the anthers.

Floral Biology

The mature buds open during 06.00-11.00 h with peak anthesis at 08.00 h. Unfolding of the standard petal indicates flower opening. The wing and keel petals do not unfold and remain in their original position as in mature bud stage, but in tensed state. All the ten anthers dehisce by longitudinal slits in mature bud stage. The number of pollen grains per anther is 1,123.9 ± 96.76 (Range 1,020-1,303) and per flower is 11,239. Pollen grains are granular, triangular, smooth exine, tricolporate at equal distance, and 41.5 µm in size. The pollen-ovule ratio is 1,873:1. The pollen protein content per anther is 0.6 µg and per flower is six µg. The stigma attains receptivity one hour after anther dehiscence and continues until the standard petal closes back, but strong receptivity occurs during 09.00-15.00 h. Nectar secretion begins inside the staminal tube at the base an hour after anthesis. Its secretion is continuous for five hours during flower-life. The total amount of nectar produced per flower is 1.50 ± 0.2 (Range 1.2-1.9) µl. The nectar sugars included sucrose, glucose, and fructose with the first as dominant, and sugar concentration varies from 21 to 32% (24.5 ± 5.3%) through the day. The total nectar sugar content per flower is 0.43 mg. Nectar is concealed by the hook-like structures of the standard petal, which hold the basal part of wing and keel petals intact. It gets exposed through openings between adjacent filaments towards the side of standard petal when wing and keel petals are depressed by the forager. The flowers begin to close slowly from 16.00 h onwards and close completely at 18.00 h. Gradual movement of the standard petal to enclose the wing and keel petals completely indicates closure of the flower. The closed flowers remain so permanently and look similar to mature buds. In pollinated flowers, the petals fall off on the third day, staminal tube after seven days, and sepals after 10 days. The ovary gradually enlarges and grows into a fruit. Unpollinated flowers fall off on the 2nd day.

Breeding Systems

Floral bud abortion is 6%. The results of breeding systems indicate that the flowers are self-compatible and self-pollinating. The fruit set is 2.66% in spontaneous autogamy, 31% in insect-assisted pollination, and 28.8% in open pollination (Tab. 4). Of the fruit set in open pollination, 2% of fruits abort without reaching to maturity. Fruit set per inflorescence in open pollination is 9.52 ± 5.72 (Range 1-30).

Table 4: Results of breeding experiments on *Derris trifoliate*.

Test	Treatment	Pollen source	Number of flowers/plants	Fruit set (%)
Control	Un-bagged	Open pollination	250/25	28.8
Autonomous autogamy	Fine-mesh Bagged	Within flower	150/10	2.66
Insect-assisted cross-pollination	Un-bagged, Emasculated	Other flowers on the same or different plants	200/25	31

Foraging Activity and Pollination

The flowers are specialized in that the stamens, style, and stigma are in a tensed state and concealed in keel and wing petals, even after the unfolding of standard petal. They were foraged by bees and a butterfly throughout the day from 06.00 to 17.00 h for pollen and/or nectar (Tab. 5). The foraging activity was mainly concentrated around noon time only. The foragers were bees such as *Apis dorsata*, *A. cerana*, *A. florea*, *Ceratina simillima*, *Nomia* sp., *Megachile* sp., *Pithitis binghami*, *Xylocopa latipes*, *X. pubescens*, *Xylocopa* sp., an unidentified bee; and the butterfly, *Catopsilia pyranthe*. The percentage of foraging visits varied with each forager species. *Megachile* and *Pithitis* bees made 56.2% of total visits of foragers while the other forager species made two to 8.5% of visits. All forager species probed the flowers from the front side without any side-working. *Xylocopa* bees and the butterfly collected only nectar, while all other bees collected both pollen and nectar. Bees on landing, depressed wing and keel petals and reached the nectar area for nectar collection, then the stamens and stigma were released violently from the keel petals. Simultaneously, the stigma and pollen ejected explosively from the anthers stuck to the ventral side of these bees. The bees such as *Apis*, *Megachile*, *Pithitis* and *Xylocopa* were highly efficient in depressing keel petals to access nectar. The other bees were relatively inefficient to trip the keel petals, but they appeared to be successful mostly with previously visited flowers. To collect pollen, the bees in the same or consecutive visits, gradually turned their head away from the standard petal and moved towards the location of the anthers and stigma. In doing so, they invariably contacted the stigma, effecting pollination. With the departure of these bees, the keel and wing petals returned to their original state concealing the nectar, stamens and stigma. All the bees were found to collect forage from each flower very fast, and in quest of more forage, they quickly moved between inflorescences on the same or different individual plants, contributing to self- and cross-pollination. Further, they also carried more pollen on their ventral side and pollen collecting bees stored pollen in their pollen baskets (Tab. 6). The lone butterfly, *C. pyranthe*, landed on the flower and inserted its proboscis slowly into the nectar location by the side of standard petal to collect nectar. It was unable to trip the keel petals to cause pollination, but it could effect pollination in the tripped flowers which received multiple visits by bees. Its proboscis was found with an average number of 91 ± 21.0 pollen grains (Tab. 6). Of the foragers, *Megachile* and *Pithitis* bees were consistent foragers, while all other foragers were relatively inconsistent during the entire flowering period. Red coloured thrips were found to breed in buds; when mature buds open, they move within and between inflorescences for collecting more nectar and pollen. In some flowers, numerous thrips were found and they exhausted all the secreted nectar making it unavailable for the appropriate foragers. Thrips were found to have a little role in pollination. Thrips feeding appeared to compel the bees to pay visits to a number of flowers in order to get the required quantity of forage for them.

Table 5: List of insect foragers on *Derris trifoliate*.

Order	Family	Genus	Species	Common name	Forage sought
Hymenoptera	Apidae	*Apis*	*dorsata*	Rock bee	Pollen + Nectar
		Apis	*cerana*	Asiatic hive bee	Pollen + Nectar
		Apis	*florea*	Dwarf honey bee	Pollen + Nectar
	Anthophoridae	*Xylocopa*	*latipes*	Carpenter bee	Nectar
		Xylocopa	*pubescens*	Carpenter bee	Nectar
		Xylocopa	sp.	Carpenter bee	Nectar
		Ceratina	*simillima*	Small carpenter bee	Pollen + Nectar
		Pithitis	*binghami*	Green bee	Pollen + Nectar
		Anthophora	*bicincta*	Blue Banded Bee	Pollen + Nectar
	Halictidae	*Nomia*	sp.	–	Pollen + Nectar
	Megachilidae	*Megachile*	sp.	Leaf cutter bee	Pollen + Nectar
		Unidentified Bee	–	–	Pollen + Nectar
Lepido-ptera	Pieridae	*Catopsilia*	*pyranthe*	Mottled Emigrant	Nectar

Fruiting Behaviour

Pollinated and fertilized flowers initiate fruit development immediately and take about a month to produce mature fruits. Fruit is one-three seeded flat, oval, leathery, and slightly wrinkled pod. It is 30-40 mm long and 20 mm across, green at first, turning light brown when ripens. Air cavities were present between the pod and seed and these cavities assist in buoyancy when the fruit falls from the plant in water. The leathery pod breaks open exposing the seed by absorbing water. Both the pod and seeds float in water and disperse to different distances depending on tidal flow and direction. During low tide period, the forest floor is exposed and the pods/seeds, if fallen at that time, settle right at the mother plant, then pods break and seeds germinate to produce new plants.

Table 6: Pollen carrying capacity of insect foragers on *Derris trifoliate*.

Insect species	Sample size	Range	Mean ± S.D.
Apis dorsata	10	525-989	736.1 ± 141.4
A. cerana	10	306-810	562.2 ± 171.9
A. florea	10	329-781	574.4 ± 147.3
Ceratina simillima	10	124-321	232.3 ± 71.0
Nomia sp.	10	76-156	121.3 ± 27.4
Megachile sp.	10	295-864	508.2 ± 197.0
Pithitis binghami	10	356-835	599.6 ± 190.2
Xylocopa latipes	10	716-1,043	888 ± 102.7
X. pubescens	10	674-1,176	913.1 ± 168.3
Xylocopa sp.	10	560-910	710.6 ± 129.8
Catopsilia pyranthe	10	86-132	91 ± 21.0

S*uaeda maritima* (L.) Dum., S*uaeda monoica* Forsk. Ex J. F. Gmel. and *Suaeda nudiflora* (Wild.) Moq. (Chenopodiaceae)

Phenology. *S. maritima, S. monoica, S. nudiflora* are halophytic mangrove associates. The first two are erect glabrous annual herbs, growing to a height of up to one foot, the last one is a perennial prostrate herb growing to a height of up to 1.5 m tall. All the three species grow in high and low salt marshes and along tidal banks. These three species invariably show different growth responses depending on the locality; high or low salt marshes. The growth forms could be distinguished, the one which grows in low marsh locality is smaller and less branched than the other one, which grows in high marsh locality. In case of *S. maritima*, the plants that grow at high tide mark, without other species, grow taller with many lateral branches. *S. maritima* and *S. monoica* usually form dense communities, they are usually shiny light green in colour, and turn reddish as they age. *S. nudiflora* grows in more widely spaced communities in relatively semi-dry areas, tend to be grey in colour, and turn blackish as it ages. Leaves are long, sickle-shaped when young, base truncate and apex acute in *S. maritima*; alternately, it is crowded, linear-oblong, spathulate, flat, rounded at tip and narrowed at base in *S. monoica*; and linear, ovate, fleshy, terete base acute, apex sub-acute in *S. nudiflora*. Seeds germinate in April and new plants mature to reproductive phase in three months and flowers during July-October in *S. maritima* and *S. monoica*. In *S. nudiflora*, the flowering occurs throughout the year with concentrated flowering during July-September. Inflorescences are axillary in position and the flowers are clustered in cymes; the number of flowers at each leaf axil is 9-18 in *S. maritima*, five-eight in *S. monoica* and two-four in *S. nudiflora*.

Flower Morphology. The flowers are green and erect in *S. maritima* and *S. monoica*, while them greenish-yellow and semi-erect in *S. nudiflora*. The flowers are bisexual. They are three mm long, four mm wide in *S. maritima*, two-three mm long and three mm wide in *S. monoica*, and one-two mm long and two mm wide in *S. nudiflora*. The flowers in all the three species have rosaceous perianth represented by five free equal succulent, glabrous and keeled lobes or tepals. The tepals are abaxially rounded and distally hooded at maturity. The stamens are five, free, basifixed, the anthers globose-ellipsoid, exserted, introrse, dithecal and tetra-sporangiate in all species. The staminal filaments are white and ban-shaped in *S. maritima* and *S. monoica*, while they are light yellow and cylindrical in *S. nudiflora*. In all the three species, the filaments are soft and glabrous, and inserted near the tepal bases. In all species, the ovary is pear-shaped, uni-locular with solitary ovule on basal placentation, one mm long and one mm wide, whitish green, succulent, and glabrous. Stigmas are sessile, filiform, hairy-papillate, and arise from a pit in the top of ovary; they are three in *S. maritima* and *S. monoica* and two in *S. nudiflora*.

Table 7: List of insect foragers on *Suaeda maritime*.

Order	Family	Genus	Species	Common name	Forage sought
Hymenoptera	Halictidae	*Nomia*	sp.	Alkali Bee	Pollen + Nectar
		Bee (unidentified)	–	–	Pollen + Nectar
Eumenidae	*Eumenes*	*petiolata* F.	Potter Wasp	Nectar	
	Ropalidia	sp.	Paper Wasp	Nectar	
Vespidae	*Rhynchium*	sp.	Potter Wasp	Nectar	
		Wasp (unidentified)	–	–	Nectar
		Wasp (unidentified)	–	–	Nectar
		Wasp (unidentified)	–	–	Nectar
	Syrphidae	*Helophilus*	sp.	Hover Fly	Nectar
	Sarcophagidae	*Sarcophaga*	sp.	Flesh Fly	Nectar
	Formicidae	*Camponotus*	sp.	Carpenter Ant	Nectar
Lepidoptera	Nymphalidae	*Danaus*	*chrysippus* L.	Plain Tiger	Leaf/dry fruited inflorescences sap
		Danaus	*genutia* Cr.	Striped Tiger	Leaf/dry fruited inflorescences sap
	Hesperiidae	*Borbo*	*cinnara* Wallace	Rice Swift	Leaf/dry fruited inflorescences sap
Coleoptera	Curculionidae	*Chrysochoris*	sp.	Beetle	Pollen

Floral Biology

The flowers are open from 08.00-11.00 h in all the three species. In all, the papillate stigma lobes protrude out of the maturing (bulging) bud and are receptive a day before anthesis. The lobes gradually wither and become unreceptive by the time the anthers protrude out due to unfolding of the hooded perianth lobes during anthesis. The protruded stamens extend beyond the height of withered stigma lobes and dehisce by longitudinal slits exposing the bright yellow coloured and powdery pollen grains. In all the three species, the pollen grains are spheroidal, pantoporate, multiporate and vary in size. It is 25.5 ± 0.86 µm in *S. maritim*, 20.37 ± 1.22 µm in *S. monoica* and 18.21 ± 0.29 µm in *S. nudiflora*. The pollen output per anther is 3,818 ± 28.34 in *S. maritima*, 3,253 ± 17.34 in *S. monoica* and 2,035 ± 21.23 in *S. nudiflora*. The pollen output per flower is 19,090 in *S. maritima*, 16,265 in *S. monoica* and 10,175 in *S. nudiflora*. The pollen-ovule ratio is equal to the pollen out per anther due to one-ovuled flowers in all the three species. The flowers in all species produce 1.2 ± 0.21 µl of nectar; it is available only during staminate phase. In these species, the perianth lobes close back and cover the ovary, but not the anthers by the evening of 2nd day. The stamens fall off subsequently on 3rd or 4th day. The perianth lobes gradually bulge along with the growing seed, and hence the perianth acts as seed cover.

Table 8: Pollen recorded in the body washings of insects on *Suaeda maritime*.

Insect species	Sample size (N)	Number of pollen grains		
		Range	Mean	S.D.
Nomia sp.	10	78 – 206	142.4	36.81
Bee (unidentified)	10	93 – 227	156.5	41.58
Eumenes petiolata	10	25 – 113	81.7	26.92
Ropalidia sp.	10	36 – 75	55.2	12.61
Rhynchium sp.	10	45 – 87	68.3	14.91
Wasp (unidentified)	10	26 –74	52.5	16.72
Wasp (unidentified)	10	43 – 91	64.4	15.53
Wasp (unidentified)	10	16 – 52	36.1	11.49
Helophilus sp.	10	20 – 64	45.3	12.80
Sarcophaga sp.	10	24 – 58	41.1	10.80
Camponotus sp.	10	32 – 84	50.7	16.45

Table 9: List of insect foragers on *Suaeda monoica*.

Order	Family	Genus	Species	Common name	Forage sought
Hymenoptera	Apidae	*Apis*	*dorsata* F.	Rock Honey Bee	Pollen + Nectar
		Apis	*cerana* F.	Indian Honey Bee	Pollen + Nectar
		Apis	*florea* F.	Dwarf Honey Bee	Pollen + Nectar
	Eumenidae	*Eumenes*	*petiolata* F.	Potter Wasp	Nectar
	Sarcophagidae	*Sarcophaga*	sp.	Flesh fly	Nectar

Table 10: Pollen recorded in the body washings of insects on *Suaeda monoica*.

Insect species	Sample size (N)	Number of pollen grains		
		Range	Mean	S.D.
Apis dorsata	10	128 – 263	195.1	44.04
Apis cerana	10	154 – 235	203.3	28.25
Apis florea	10	135 – 276	219.2	39.55
Eumenes petiolata	10	46 – 115	78.3	19.84
Sarcophaga sp.	10	31 – 73	46.4	12.74

Table 11: List of insect foragers on *Suaeda nudiflora*.

Order	Family	Genus	Species	Common name	Forage sought
Hymenoptera	Halictidae	*Nomia*	sp.	Alkali Bee	Pollen + Nectar
	Vespidae	*Rhynchium*	sp.	Black Potter Wasp	Nectar
Lepidoptera	Nymphalidae	*Danaus*	*chrysippus* L.	Plain Tiger	Leaf/dry fruited inflorescences sap
		Danaus	*genutia* Cr.	Striped Tiger	Leaf/dry fruited inflorescences sap
	Lycaenidae	*Euchrysops*	*cnejus* F.	Gram Blue	Leaf/dry fruited inflorescences sap

Table 12: Pollen recorded in the body washings of insects on *Suaeda nudiflora*.

Insect species	Sample size (N)	Number of pollen grains		
		Range	Mean	S.D.
Nomia sp.	10	74 – 213	142.6	43.36
Rhynchium sp.	10	35 – 92	60.9	15.08

Breeding behavior

In all the three species, the flowers are strikingly protogynous, the mature bud stage is pistillate due to the protrusion and receptivity of stigmatic lobes whilein the post-anthesis stage is staminate due to the cessation of stigma receptivity by the time of anthesis and dehiscence of anthers after anthesis. The pistillate and staminate phases are therefore temporally separated and this situation is a type of temporal dioecy. This sexual system completely prevents autonomous and facilitated autogamy, but facilitates both geitonogamy and xenogamy. Geitonogamy occurs due to pollen transfer from the pollen of staminate phase flowers to the stigmatic lobes of pistillate phase mature buds within the plant; if pollen transfer occurs between flowers of different plants within or across populations, it results in xenogamy. The hairy-papillate stigmatic lobes in all the three species, standing out distinctly from the mature buds, were found to be capturing pollen driven by wind. The powdery and multi-porate nature of pollen grains enable them to fly and disperse easily by wind and their dispersal is further propelled by vast uniform mats of populations of *Suaeda* species. The wind-driven pollen deposition on the stigmatic lobes and leaves can be seen with the naked eye, and hence, anemophily was considered to be effective. Anemophily was very effective in high salt marshes devoid of water-logged conditions. In the low salt marshes where water-logged or water-saturated conditions occur, water currents were found to carry and disperse pollen effectively; here considerable aerial parts of the plants were merged or intermittently exposed, and hence pollen was wet, making anemophily mostly ineffective. In all the three species, fruit set in open-pollinations is 93-95% indicating the success rate of both geitonogamy and xenogamy. This high success rate could be due to the production of a single ovule in the flowers for which the deposition of a few viable pollen grains on the stigmatic lobes is sufficient.

Foraging Activity and Pollination

In all the three species, the flowers were foraged by bees, wasps, and flies during daytime from the 08.00 to 17.00 h with more foraging activity during the 09.00-12.00 h, and less activity during afternoon period in high salt marshes and in low salt marshes where soil was not saturated with water (Tabs. 7, 9 and 11). The foraging activity pattern of all these categories of insects was almost similar and coincided well with the standing crop of floral rewards. *S. maritima* was foraged by *Nomia* bees and one unidentified bee for pollen and nectar; by wasps, *Eumenes petiolata, Ropalidia* sp., *Rhynchium* sp. and three unidentified wasp species; and by flies *Helophilus* sp. and *Sarcophaga* sp. for nectar only. *Camponotus* ants also foraged for nectar, but they were resident foragers and remained on the plants throughout the flowering season. *S. monoica* was foraged by honey bees, *Apis dorsata, A. cerana,* and *A. florea* for both pollen and nectar; by wasps, *Eumenes petiolata, Rhynchium* sp.; and by the fly, *Sarcophaga* sp. for nectar only. *S. nudiflora* was visited by *Nomia* bees for both pollen and nectar while *Rhynchium* wasps for nectar only. In all the three species, thrips were nectar and pollen feeders; they have collected most of the nectar during mature bud stage and after anthesis, and also pollen during post-anthesis stage as soon as the anthers dehisce. Further, the iridescent green tortoise beetle, *Chrysochoris* (Scuteleridae), collected *S. maritima* pollen voraciously while an unidentified immature stage of an insect was found to feed on the nectar and pollen of *S. nudiflora*. The percentage of foraging visits made each category of insects varied with each *Suaeda* species. In *S. maritima*, bees made 21%, wasps 62%, and flies 17% of total foraging visits. In *S. monoica*, bees made 54%, wasps 35%, and flies 11% of total foraging visits. In *S. nudiflora, Nomia* bee made 48% and *Rhynchium* wasp made 52% of total foraging visits.

In all the three plant species, the flowers with dehisced anthers representing staminate phase attracted bees due to clear-cut display of bright yellow pollen. The bees, while collecting pollen and nectar from such flowers, invariably also accidentally contacted the flowers in pistillate phase occurring in the same cluster or nearby clusters on the same flowering branch due to their close proximity to each other, and, this foraging behaviour was considered to be effecting geitonogamy. The production of a few staminate phase flowers each day at branch or plant level was found to be driving the bees to make frequent inter-plant visits within and between populations in the entire area in order to collect more nectar and pollen. They were effective carriers of pollen and their body washings revealed the presence of 142-156 pollen grains in case of *S. maritima* (Tab. 8), 195-219 pollen grains in case of *S. monoica* (Tab. 10), and 142 pollen grains in case of *S. nudiflora* (Tab. 12). Wasps, flies and ants attempted to collect nectar from pistillate and staminate phase flowers without any discrimination; such a foraging behaviour was considered to be facilitating both geitonogamy and xenogamy. The flowers with minute traces of nectar were found to be driving the wasps to make frequent inter-plant visits in order to collect more or optimal levels of nectar due to their high energy requirement. They were found to carry 36-82 pollen grains on their bodies in case of *S. maritima* (Tab. 8), 78 pollen grains in case of *S. monoica* (Tab. 10), and 61 pollen grains in case of *S. nudiflora* (Tab. 12) indicating their pollen carrying capacity. In case of flies, they tended to remain on the same plant for long time collecting nectar from as many flowers as possible due to their low energy requirement. Their body washings revealed the presence of an average of 41 to 45 pollen grains in case of *S. maritima* (Tab. 8), 46 pollen grains in case of *S. monoica* (Tab. 10), and hence they were also pollen carriers to some extent. Ants, as resident foragers and with low energy requirement, were considered to be important for geitonogamy if they confined to the same plant, and for xenogamy if they crawled to other nearby plants for nectar collection. They were found to carry an average of 50 pollen grains due to their nectar foraging activity. The nectar and pollen feeding activity of thrips was found to be an important driver, especially for bees and wasps to collect forage from a number of individual flowers within and between populations. Certain insects recorded were common to all the three plant species which co-exist in the same area and their alternate foraging visits could lead to the deposition of mixed pollen on each of these plant species. Such mixed pollen deposition could block the receptive area of the stigma lobes and reduce the opportunities for legitimate geitonogamous and xenogamous pollinations in each plant species.

In all the three *Suaeda* species, the nymphalid butterflies, *Danaus genutia, D. chrysippus*, the lycaenid *Euchrysops cnejus*, and the hesperiid, *Borbo cinnara*, were found to feed on the sap of leaves prior to flowering and on dry fruited branches. These butterflies mainly concentrated on *S. maritima* and *S. monoica* for sap collection. Further, they never visited the flowers for nectar collection and hence were not pollinators.

Fruiting Behaviour

In all the three species, fruit is an urticle with 1.5 mm wide and one mm long persistent perianth. Hooded perianth segments cover seeds over the margins. It matures within three-four weeks. Each fruit invariably produces a single seed. Seeds ripen during August-October. Seeds are brownish-black, smooth, glossy, ovoid, 1.2-1.5 mm diameter, finely punctuate near the edges and beaked. Whole plants break off easily and roll on the floor while shedding its diaspores. Fruits with seeds intact, and/or seeds shed from fruits, float on water due to their ability for buoyancy. The fruits and seeds thus disperse and settle in the entire extent of salt marshes or coastal areas.

DISCUSSION

The reproductive biology of mangrove plants displays characteristics of pioneer species such as possessing self-compatibility and utilizing a wide variety of pollinators including insects, birds, and bats. The characteristic wide distribution and long-range seed dispersal of mangrove plants may also favour a broad range of pollen vectors (Azuma et al., 2002). Mangroves are adapted to a generalized type of pollinators and thus competition for the available pollinators is reduced (Tomlinson, 1986). Since flowers are available throughout the year, at least on a few mangrove plants, pollinators are able to perform foraging activities on a regular basis (Fernandes, 1999). The capacity of mangroves to convert floral visitation to flower fertilization and fruit set is an important step in the recruitment process, and ultimately to the maintenance of existing mangrove communities (Coupland et al., 2006).

Mangrove plants must interact, or even compete for the available pollinators, and the interaction minimizes the competition for pollinators so that the pollinator resource is used in the most efficient manner possible. In mangroves, the spectrum of pollinators is broad so that no plant is highly dependent on one specific pollinator and the plants are specialized only to the extent of being associated with a given class of pollinator. These conclusions have a reasonable explanation in the wide geographical range of mangroves, plants are not constrained by a dependence on a specific pollinating agent with a limited geographic range. Since each mangrove plant species adapts primarily to a generalized type of pollinator, competition for the available pollinator resource is reduced (Tomlinson, 1986).

Few studies have assessed how successful mangroves are at utilizing pollinators, how much reproductive effort is required to produce a single propagule, and whether propagule production is limited by resources or by pollinators. A more complete understanding of the reproductive biology of mangroves is useful for effective mangrove rehabilitation programmes (Coupland et al., 2006).

Fruit and seed characteristics in non-viviparous mangrove species, especially mangrove associates, have been little studied. Mangrove associates have been in fact largely ignored, and most of the studies conducted are related to viviparous and prominent non-viviparous species. The shrub and herb species that constitute mangrove associates have been little studied and the documented information does not provide any clue to understanding their reproductive biology with reference to their floral ecology, breeding systems, pollination syndromes, fruiting ecology, and fruit or seed dispersal. Field observations and experimental results obtained in the present study on certain aspects of reproductive ecology on *Clerodendrum inerme, Derris trifoliata, Suaeda maritima, S. monoica,* and *S. nudiflora* have been examined and interpreted in the light of the related literature available on the studied mangrove associate plant species.

Clerodendrum inerme

Mangrove species are usually categorized as “exclusive” species that are limited to the mangrove environment and “non-exclusive” species that are mainly distributed in a terrestrial or aquatic habitat but also occur in the mangrove ecosystem. These non-exclusive species are referred to as semi-mangrove, back mangrove, or mangrove associate (Lacerda et al., 2002; Parani et al., 1998; Tomlinson, 1986). In case of *C. inerme*, there is a controversy with reference to its status as a constituent of mangrove forests. Parani et al. (1998) reported that it is a fringe species found abundantly both on the landward edge as well as deep inside the mangrove environment. Saenger (2002) considered it as a mangrove, but he has not mentioned whether it is a true mangrove or a mangrove associate. Satyanarayana et al. (2002) did not consider it as a mangrove species. Wang et al. (2011) reported that *C. inerme* behaves like both a true mangrove and a mangrove associate due to its largest salinity tolerance. These different reports indicate that there is no consensus on *C. inerme* to classify it as a component of mangrove species. Nevertheless, in this study, *C. inerme* is considered to be a mangrove associate. It is a perennial shrub that occurs predominantly in the mangrove forests and along the coastlines. It is exposed to a wide range of fluctuations in salinity due to its occurrence in the landward sites as well as in the open sites within the mangrove zonations at the study area. Chethana et al. (2013) stated that it has an advantage over other species that lack strategies to deal with the salt in the soil, and thus, is an excellent competitor in saline environments. Therefore, it plays an important role in the formation and stabilization of forest floor due to its prolific growth.

C. inerme is a rainy season bloomer. It produces typical three-flowered cymes which are quite prominent and displayed well because of its white flowers against bright green foliage. Primack et al. (1981) reported that this species produces two-eight flowers in each cyme and this report does not agree with the present study indicating that the each cyme is three-flowered. Further, these authors noted that the flowers in a cyme generally remain at the same developmental stage, so that the flowers in the same cyme are unlikely to pollinate each other. In the present study, it is found that the flowers within the cyme show different developmental stages; open, whether on the same day or over a period of three days at the most. This difference in developmental stages of flower buds is most likely to pollinate each other if pollinators are available. Further, the cymes of different branches of the same plant also show various developmental stages so that the cymes of the same plant pollinate each other through geitonogamy if there is pollinator activity.

The flowers open during morning hours in *Clerodendrum infortunatum* (Byragi Reddy and Subba Reddi, 1995) and during late evening hours in *C. molle* in which the flowers are fragrant (McMullen, 2011). In *C. inerme*, the flowers are fragrant and open during evening hours as in *C. molle*. Primack et al. (1981) also reported that the flowers are fragrant but they have not mentioned the time of flower-opening. These authors stated that the calyx cup is covered with an irregular series of raised elliptical glands which, apparently, function as extra-floral nectaries and the ants commonly feed at them. In the present study, *C. inerme* does not show such glands on the calyx cup, and also, the ants do not visit the flowers.

Yao-Wu et al. (2010) stated that an unusual pollination syndrome that prevents self-pollination exists in the genus *Clerodendrum*. This pollination syndrome is functional through dichogamy and herkogamy. The usual floral mechanism is that when the flower opens, the stamens stand erect, parallel to the central axis of the flower, while the style bends over holding the stigma beyond the rim of the corolla. After the pollen is shed, the stamens curl up or bend over, and the style straightens out bringing the stigma to the centre of the flower. Such a movement and function of floral sex organs precludes self-pollination. Keng (1990) reported that *C. laevifolium* is pollinated by insects such as bees and butterflies. Byragi Reddy and Subba Reddi (1995) reported that *C. infortunatum*, with morning anthesis, is exclusively pollinated by papilionoid butterflies; the pollination occurs due to striking of anthers and stigma with the wings of butterflies. Such a form of pollination is referred to as pterigotribic pollination. Meera Bai (2014) reported that the typical butterfly pollination in *C. infortunatum* is because of non-promiscuity of floral rewards to other foragers. She also noted that this pollination syndrome is a necessary pre-condition for the rise of floral isolating mechanism. Shamim et al. (2010) reported that *C. viscosum* is exclusively cross-pollinated by ants, butterflies, and hawk-moths. Rohitash and Jain (2010) noted that *C. splendens* is pollinated by *Xylocopa, Eumenes* sp. and *Camponotous campestris*. McMullen (2011) reported that *C. molle* with night/late evening anthesis is pollinated by nocturnal and diurnal visitors. Nocturnal visitors include ants, spiders, hawk moths, and roaches whereas diurnal visitors include carpenter bees and ants. Sakamoto et al. (2012) reported that *C. trichotomum* is pollinated by the carpenter bees, *Xylocopa* species, the butterflies, *Papilio* species, and the hawk moth *Macroglossum*. Primack et al. (1981) reported that *C. inerme* is never visited by daytime visitors but is visited by one large hawk moth during dusk hours.

C. inerme, with evening anthesis, white long corolla with hairy interior to exclude other insects, and strong fragrance, appear to be adaptations for hawk moth pollination (Primack et al., 1981). In the present study, it is visited and pollinated by one large hawk moth, *Macroglossum gyrans*, as soon the flowers are open during evening hours. It is a nectar feeder, but the nectar in just open flowers is almost absent. The new flowers take one to two hours to secrete nectar. In such a situation, this hawk moth is compelled to pay multiple visits to the new as well as old flowers. The flowers opened one or two days before are nectar-rich and serve as the principal nectar source for the visiting hawk moths during evening hours. Further, the same hawk moth was the first visitor to the flowers on the following day during dawn hours by which time the flowers accumulate nectar in considerable amount. The nectar is in considerable volume and sucrose-rich with a sugar concentration of 13-21%. This finding is in agreement with the report of Cruden et al. (1983) that in lepidopteran-pollinated flowers, the nectar is rich in volume and sucrose-rich with the sugar concentration ranging from 15 to 25%. Further, it is a source of certain essential and non-essential amino acids and protein content. In the present study, the hawk moth, being a swift flier, visits numerous flowers on the same day and different plants in quick succession in order to quench its thirst for nectar and, in effect, contributes to both self (geitonogamy) and cross-pollination. Primack et al. (1981) noted that the purple colour of the filament and style presumably make them difficult for the hawk moth to see and avoid. The versatile anthers, with pollen in grooves, allow pollen to be placed precisely on the hawk moth proboscis. In the present study, *M. gyrans* approaches the flowers either laterally or from the front through the stamens and stigma to insert its proboscis into the corolla tube to collect nectar. In this process, its contact with the stamens and stigma are random, but not with certainty, and also there is no precise placement of pollen from the versatile anthers on the proboscis of the moth. The pollen deposition largely occurs on the wings and abdomen. Further, the production of small quantity of pollen in individual flowers of *C. inerme* is another indication that it is adapted for nectar-feeding lepidopteran, in this case *M. gyrans*. Therefore, *M. gyrans* is the appropriate and principal pollinator of *C. inerme*.

In the present study, *C. inerme* is also visited by day-time visitors such as butterflies and bees, but their overall foraging activity is low and is also not consistent throughout the flowering period. The butterflies with their short proboscis are not capable of collecting nectar from the long tubular corolla but they are successful in collecting nectar from the flowers that were previously visited *Xylocopa* bees. Such flowers stay in hanging position, and the nectar is accumulated at the attachment point of staminal filaments covered by internal hairs. The butterflies access this nectar with their proboscis without any difficulty. *Xylocopa* bee bites a hole on the mid-part of the corolla tube where the epipetalous stamens take their origin, and which are covered by short hairs inside. When *Xylocopa* lands on the corolla tube, the flower hangs downward and as a result, the nectar flows to the attached point of stamens, then the bee collects nectar by biting a hole on the corolla tube. *Anthophora* bee also bites a hole to collect nectar, but it does at the base of the corolla tube, this is because its light weight does not bring the flower to hanging position when it lands. Therefore, the two bee species are typical nectar robbers. Both the butterflies and bees, however, contribute to sporadic pollination while approaching the flowers during which their wings and abdomen strike the anthers and style.

Nectar robbing is a behaviour exhibited by some species of bees in which nectar is obtained through holes bitten near the bases of the corolla tubes. Nectar robbers are subdivided into primary nectar robbers, which make the holes and then extract the nectar, and secondary nectar robbers, which obtain nectar by using holes made by primary robbers (Inouye, 1983). Carpenter bees are the most notorious primary nectar robbers (Barrows, 1980), they make perforations with the maxillae (Barrows, 1976) and this method is probably used by all *Xylocopa* bees (van der Pijl, 1954). These bees employ this method when they are unable to access nectar, such a situation exists mostly in tubular flowers (Barrows, 1980). In the present study, *Xylocopa* and *Anthophora* are primary nectar robbers, since they bite holes on the corolla tube of *C. inerme*. Secondary robbers of nectar are absent at the flowers of this plant species.

Nectar robbing is variously interpreted in relation to host fitness. It has positive or neutral or mutualistic effects on host fitness in terms of increase, decrease, or no effect in seed set rate (Zhang et al., 2009). The removal of floral nectar by robbers decreases the standing crop, and in some cases, changes the sugar concentration of nectar available to other pollinators (Pleasants, 1983). Longer pollinator flight distances generally translate into increased pollen flow and increased outcrossing rates (Fenster, 1991). If nectar robbers are the cause of longer flight distances by the legitimate pollinators, they could be increasing the fitness of the robbed plants by promoting outcrossing. The robbers could then be considered as mutualists. Guitian et al. (1994) observed that nectar robbing by carpenter bees had a positive effect on seed set in *Pterocoptis grandiflora*. Zimmerman and Cook (1985), and Castro et al. (2008, 2009) stated that nectar robbing, besides influencing host female fitness, could potentially enhance male fitness and increase the offspring outcrossing rate through forcing legitimate pollinators to fly farther in search of nectar, thus expanding the pollen dispersal distance and neighbourhood size, and reducing geitonogamy. In the present study, nectar robbing by both *Xylocopa* and *Anthophora* could potentially enhance male fitness by driving the legitimate pollinator *M. gyrans* to fly farther and farther in search of nectar. Such a foraging behaviour by this pollinator and expands the pollen dispersal distance and promotes out-crossing rate in *C. inerme*.

Primack et al. (1981) reported that *C. inerme* is strongly protandrous, but did not explain how it works with reference to the movements of stamens and stigma within the flower. They have also not mentioned whether there are different forms of flowers based on the position of stamens and style during the flower life. In this study, three forms of flowers have been distinguished with reference to the position of floral sex organs. The first form is characterized by elongated stamens and style which occur in close proximity to each other just after anthesis, this facilitates contact between the stamens and stigma. The second form is characterized by the scattered position of stamens and style. In the third form, the stamens are fully extended while the style is curved away from them either to the left or to the right, subsequently the stamens curl inward and the style elongates. Interestingly, the three flower forms can be found within a cyme also. Such flower forms have been reported in *C. molle* (McMullen, 2011). These forms of flowers appear to have evolved to prevent autonomous and facilitated selfing but certainly not geitonogamy. The strong protandry in *C. inerme* does not facilitate individual flowers from self-pollinating, but it facilitates different flowers on the same plant to pollinate each other through geitonogamy. This is further substantiated by fruit set in geitonogamous pollinations. Although geitonogamy is self-fertilization, in that the pollen fertilizing the ovules originates from the same parent plant, different parts of branches of the plant may diverge genetically through somatic mutation (Roubik, 1995). Such a genetic divergence was experimentally proved in *Byrsonima crassifolia*, in which one of five trees used in experiments was initially found to be self-incompatible produced fruits through self-pollination when the flowering period was nearly over, and in *Pscidia carthagenensis* in which one-day old artificially self-pollinated flowers did not set fruit but two-days old flowers set some fruits (Baker et al., 1983). In *C. inerme*, the protandry is functional, partially since fruit set occurs through geitonogamy. That the protandry functional in this species is important as an out-breeding mechanism and it is also reflected in the percentage of fruit set recorded through xenogamy. The high fruit set recorded in open-pollinations despite mechanisms which prevent self-pollination in individual flowers, strongly suggests that *C. inerme* is self-compatible. Geitonogamy would allow fruit set in isolated colonizing plants. Initial colonization occurs usually by a single seed floating in tidal water. As a result, certain floral mechanisms which promote out-crossing with its associated genetic advantages can be expected in established populations (Primack et al., 1981). In *C. inerme*, the protandry, together with different positions of stamens and style in different sets of flowers, would allow fruit set in isolated or congregated individuals while totally preventing selfing within individual flowers. Such a dual breeding system is advantageous for *C. inerme* to colonize new areas in mangrove and coastal areas, and also the nearby terrestrial habitats. The prolific growth of *C. inerme* with its extensive root system in these areas is important to control land and beach erosion, and stabilize forest floor.

Wheeler et al. (1992) noted that fruit or seed dispersal in *Clerodendrum* genus through birds. Keng (1990) reported in *C. laevifolium* that birds are probably involved in fruit or seed dispersal. Lorence and Flynn (1997) stated that *C. macrostegium* is spread by fruit eating birds. In *C. inerme*, the fruit is a capsule and breaks into different lobes depending on the number of nutlets produced inside. Each lobe contains a nutlet. Birds such as *Acridotheres tristis* (Indian Myna), *Corvus splendens* (House Crow), *Corvus macrorhynchos* (Jungle Crow), and *Turdoides caudatus* (Common Babbler) disperse nutlets or seeds in the study area. This event occurs during early winter season. Seed germination occurs as soon as monsoon sets in during June; seedlings grow and produce new plants.

A few stated that *Clerodendrum* species serve as larval hosts for lycaenid butterflies. *C. laevifolium* is a larval host for *Zelthus amasa maximinianus* (Keng, 1990), *C. glabrum* for *Hypolycaena philippus philippus* (Ivor, 1994), and *C. indicum* for *Spindasis vulcanus* (Kunte, 2007). Here, field observations show that *C. inerme* is a larval host too for *S. vulcanus*. *Clerodendrum* genus is probably the best larval host plant for lycaenid butterflies. Further studies may provide information on other butterflies that use this plant species as a larval host.

Derris trifoliata

The plant is a deciduous woody climber distributed from oligohaline to polyhaline zones in the mangroves. It displays massive flowering for about a month during rainy season. The acropetal anthesis and the flowers borne in nearly erect racemose inflorescences are quite distinct against the foliage. The floral characteristics, such as small size, pinkish white papilionaceous corolla with explosive pollen release mechanism, and zygomorphic symmetry, indicate that the plant has specialized pollination mechanism adapted for tripping by external agents. Such an explosive pollination mechanism has also been reported in the allied species, *Pongamia pinnata* (Solomon Raju and Rao, 2006), other Fabaceae members (Meeuse, 1961), and also in other plant families such as Lamiaceae (Solomon Raju, 1990), Loranthaceae (Feehan, 1985), Onagraceae (Plitmann et al., 1973), Rhizophoraceae (Davey, 1975; Tomlinson, et al., 1979), Marantaceae (Davis, 1987), Urticaceae (Taylor, 1942), Ericaceae (Marie-Victorin, 1942), Fumariaceae, Musaceae, Acanthaceae (Proctor and Yeo, 1972), Cornaceae (Mosquin, 1985), and Orchidaceae (Proctor and Yeo, 1972; Gottsberger, 1989).

In *D. trifoliata*, the forenoon anthesis and pollen and nectar as rewards, attract daytime foragers. The nectar feeding foragers require strength to depress keel petals in order to collect nectar; only those foragers which have the required strength to do so can collect nectar and in the process trip the floral mechanism and effect pollination. When floral explosion occurs, pollen is somewhat exposed and the pollen feeding foragers then collect it. The small volume of sucrose-dominant nectar with high sugar concentration in the flowers of *D. trifoliata* is an adaptation for pollination by long-tongued bees (Baker and Baker, 1983). But, the present study showed that both long and short-tongued bees trip the flowers, collect nectar, and effect pollination. *Ceratina* and *Nomia* bees are comparatively less efficient than other bees in tripping the flowers and effecting pollination. The butterfly, *Catopsilia pyranthe*, also feeds on this floral nectar and plays a minor role in pollination. The floral nectar of *D. trifoliata* may also provide a few essential and non-essential amino acids for the bees and the butterfly, but nectar analysis for these chemicals is suggested to confirm this. The flowers produce pollen in moderate amounts and it has a small amount of protein. The pollen grains being small in size and with tricolporate exine structure adhere in clumps, and hence, are easy for bees, especially honey bees, to collect and keep them in their pollen baskets (Lakshmi et al., 1997). All the bees, except *Xylocopa* bees, collect pollen from the dehisced anthers which are situated in the keel petals and invariably contact and pollinate the stigma. The specialized explosive floral mechanism is no doubt an important floral adaptation to discourage self-pollination and promote cross-pollination. The flowers close at the end of the day and remain so until they fall off; such a flower function may allow re-mobilization and recycling of structural proteins and nutrients from the flowers back to the plant and serve as an energy-efficient means of enhancing the overall attractiveness of the inflorescences or plant to pollinators (Gori, 1983). Therefore, the pollination system in *D. trifoliata* essentially requires insect pollinators as in *Pongamia pinnata* (Solomon Raju and Rao, 2006). Thrips use the flower buds of *D. trifoliata* for breeding and move out when the buds are open. They exhaust the nectar resource in some flowers and in effect compel insect pollinators to make multiple visits to the same or different plants in search of nectar. Such a foraging behaviour would be advantageous for the plant to maximize cross-pollination in the presence of insect pollinators.

D. trifoliata is weakly protandrous, self-compatible, and self-pollinating. In the keel petals, the stigma slightly exceeds the length of the stamens and contacts the underside of pollinator's body first when the latter visits the flower in quest of nectar and/or pollen. Such a position of stigma appears to be an adaptation for promoting cross-pollination. The pollen-ovule ratio of the plant also favours cross-pollination (Cruden, 1977). Individual flowers that were not tripped by insects set fruit, and hence, it is an indication of autogamy, but fruit set in this mode of pollination is negligible and it is a function of stigma gaining contact with the dehisced anthers within the intact keel petals. In insect-assisted and open-pollination modes, fruit set rate is only up to 30-31% despite the flowers being visited by insect pollinators. This low natural fruit set rate could be primarily due to scarcity of nutrient resources available to the plant. Flower bud abortion is at significant level which may additionally indicate the nutrient status of the plant. Similar situations exist also in the related species, *P. pinnata* (Solomon Raju and Rao, 2006). Therefore, *D. trifoliata*, with mixed mating system, is able to set fruit through self- and cross-pollination; the genetic variation resulting from outcrossing enables it to survive well and colonize the mangrove areas to the extent possible.

Fruits of *D. trifoliata* mature quickly in a month. Each fruit contains one-three seeds against six linearly arranged ovules in the ovary. The regulation of seed set within the fruit may be a character of the plant, or due to the scarcity of nutrient resources. Fruits do not dehisce and seeds also do not germinate while on the parent plant. The fruits are leathery and possess air cavities, the characteristics of which, enable them to float in tidal water. They settle at the parent plant if the site is partly or fully exposed or float to be dispersed if the site is inundated with tidal water. It suggests that the plant uses both self-planting and stranding strategies for dispersal and establishment. Seed release occurs when fruits absorb water and the pericarp breaks. Seeds germinate only when they reach a suitable habitat in mangroves. The importance or significance of this work cannot be highlighted in the absence of information on other species of *Derris*, or other genera of Fabaceae inhabiting the mangroves.

Suaeda maritima, S. monoica* and *S. nudiflora

All the three *Suaeda* species are obligate succulent halophytes and grow well in high and salt marshes in different zonations of mangroves. Their growth, within the interiors of mangroves, is an excellent indicator of their tolerance level to high salinity. However, their growth rates vary depending on the locality, high or low salt marshes. The plants growing in high marshes are taller and more profusely branched than those growing in low marshes. Wetson et al. (2012) reported such plasticity in plant growth pattern in *S. maritima* growing in the upper and lower salt marshes. Further, these authors also reported that plants growing at the extreme tide mark without other species, grow taller with many lateral branches. Ferren and Schenk (2003) reported two varieties, *richii* and *maritima*, in *S. maritima* based on growth habit and seed size. Chapman (1947) also reported three principal varieties, *vulgaris*, *macrocarpa* and *flexilis*, based on growth habit and seed size. Redondo-Gomez et al. (2008) reported that several *Suaeda* species exhibit seed dimorphism and produce both brown and black seeds simultaneously and these varying colorations reflect two different dormancy and germination strategies for survival in saline habitats. Ponnamperuma (1984) explained that occurrence of different growth forms reflect different soil conditions present in high and low salt marshes due to difference in aeration levels. The high salt marshes are well-drained and infrequently inundated by tidal water and hence have stable and good soil aeration due to rapid exchange between air and soil, whereas the low salt marshes with water-logged conditions experience reduced availability of oxygen due to very slow diffusion of gases in water than in air. Further, the exchange of gases would fluctuate in both high and low salt marshes at different times due to variation in the frequency of submergence and quantum of tidal water causing inundation. As a result, the plants growing in the high and low salt marshes show different responses due to variation in soil aeration levels. All the three *Suaeda* species in this study did not show seed dimorphism either in size or in colour, suggesting that the variations in seed morphological characters could be situational depending on the nutrient and water levels, temperature, and other ecological factors present at the time of production of seeds in both annual and perennial *Suaeda* species.

Khan and Weber (2003) reported that in annuals, there is only one reproductive event in a lifetime, and this necessitates the ability to produce seeds with dormancy characteristics; when the seeds reach maturity, the environmental conditions may not be favourable for seedling growth and so germination is postponed until conditions are again more favourable. On the contrary, perennials reproduce by seeds on multiple occasions, which mean that producing genetic variations is not as paramount as it is with annuals; they may reproduce clonally, seeking to reproduce only the most successful genotype. However, as a long-term strategy, they may need to introduce new genetic individuals as and when conditions allow. In the present study, *S. maritima* and *S. monoica* are annuals and produce seeds once in their life with dormancy characteristics because their seeds germinate with a pause of five-six months from seed dispersal to seed germination. In these plants, genetic variation through sexual mode is very essential in order to withstand adverse soil conditions and produce stable populations. *S. nudiflora* is a perennial and produces seeds more than once in its life time, and hence, production of genetic variation is not very important for the production of stable populations. However, introduction of new genetic individuals as and when conditions allow is inevitable if this species is to survive and continuously produce stable populations in inhospitable habitats.

Abeywickrama and Arulgnanam (1993) described floral sex characters in *S. maritima* and *S. nudiflora*. These two species produce male flowers with a small ovary and female flowers with stamens reduced or absent; the styles vary from two to three. In *S. monoica*, each flower cluster consists of a large male flower with rudimentary ovary surrounded by smaller female flowers with or without staminodes. Individual plants produce only female flowers. This study disapproves these, because all the three *Suaeda* species produce only bisexual flowers without styles. *S. maritima* and *S. monoica* flowers produce three sessile stigmas while *S. nudiflora* produces two sessile stigmas. Further, the inflorescences are characteristically axillary in *S. maritima* and *S. monoica*, while they are borne both in the axils and terminally in *S. nudiflora*. The clustered cymes produce varying number of flowers with each *Suaeda* species, they are 9-18 in *S. maritima*, five-eight in *S. monoica*, and two-four in *S. nudiflora*.

Rea (1969) and Kubitzki et al. (1993) show that polygamy occurs in many species of Chenopodiaceae. Gynomonoecy, in combination with protandry or protogyny, occurs in some species. Kubitzki et al. (1993) show that the presence of inconspicuous, minute, frequently perianth-less, and mostly nectar-less flowers are considered as adaptations for anemophily. Typical features of anemophily such as dusting pollen, waving, limp-filaments, or simultaneous flower opening are usually required in order to be uniformly anemophilous. Zandonella (1977) noted that a switch-over from entomophily to anemophily, or reverse, might have occurred in this family. Dalby (1962) stated self-pollination also frequently occurs in various genera. One such genus is *Salicornia* in which the ripe dehiscing anthers stay in contact with the presumably receptive stigmas, and in effect, selfing occurs. Kubitzki et al. (1993) felt that probably various degrees of balance between anemophily and self-pollination can be found in the members of this family. Dem'yanova (1977) reported that *S. microphylla, S. physophora, S. acuminate*, and *S. linifolia* are predominantly anemophilous; entomophilous also exists but it has no significant importance. The flowers receive visits of *Halictus* bees during staminate phase, by which time, the stigma begins to wither and does not accept pollen. Keighery (1979) reported that honey bees and syrphid flies collect pollen from the flowers of *Suaeda australis*, but this author did not state whether they are pollinators or not. Chapman (1947) mentioned that *S. maritima* flowers are homogamous or feebly protandrous, autonomous autogamy is easily possible. The flowers are nectar-less and, hence, insect activity is absent. Bassett and Crompton (2011) recorded that *S. maritima* is wind-pollinated. Naskar and Mandal (1999) reported that *S. maritima* is pollinated by wind, water currents, and flies.

All the three *Suaeda* species are nectariferous and offer nectar in minute to trace amounts. The flowers are dichogamous with protogyny. They are pistillate during mature bud stage and staminate after anthesis, this prevents autonomous or facilitated selfing within the flower. This sexual system is almost typical of temporal dioecy. Cruden and Hermann-Parker (1977) coined the term “temporal dioecism” to describe the pattern of sexual alternation within the individual plants to facilitate outcrossing through the promotion of xenogamy. The sexual system functional in the *Suaeda* species is a type of temporal dioecy. In these species, the strong dichogamy appears to have evolved to promote outcrossing, however, both pistillate and staminate phase flowers are available at any given point within the individual plants facilitating the occurrence of geitonogamy. Therefore, the *Suaeda* species seem to have evolved temporal dioecy to promote outcrossing through xenogamy while keeping the option open for selfing through geitonogamy. The fruit set recorded in open-pollinations substantiates the functionality of such a sexual system. This sexual system is essential for these species to produce seeds in isolated individuals in news areas in order to build up their populations.

Renner and Feil (1993) stated the plants that possess morphological traits fulfilling the aerodynamic requirements of pollen dispersal and capture, favour the evolution of anemophily. Wind pollination evolves when pollinators are scarce, absent, or deliver poor pollen when plants colonize areas with low insect abundance (Weller et al., 1998; Gomez and Zamora, 1996). Anemophilous plants do not invest in resources that attract pollinators, such as showy flowers, nectar, and scent. Instead, they produce a big quantity of light, dry pollen from small, plain flowers that can be carried by wind. Female structures are adapted to capture the passing pollen from the air, but the majority of pollen goes waste. Niklas (1985) stated that plants with small, colourless, odourless, and nectar-less flowers, reduced or no perianth, projecting exserted stamens away from the boundary layer of main flower to higher wind speeds, production of large quantity of light, dry and dusty pollen, permitting the removal of pollen, and exposed large, hairy and feathery stigma to capture pollen, are adapted for anemophily. In all three *Suaeda* species, the flowers have a combination of anemophilous and entomophilous traits. The anemophilous traits are odourless, unattractive flowers with inconspicuous perianth, the exserted stamens projected out of the perianth and light, dry and dusty pollen, while entomophilous traits are production of nectar, dorsi-fixed stamens, production of moderate quantity of pollen, and promiscuity of flower for nectar and pollen collection for insects. Anemophily is effective, especially in high salt marshes, due to the occurrence of moderate to high wind speeds in the mangrove. The pollen deposition by wind on the stigmas can be easily recorded and the leaves also get coated with pollen despite their succulent nature. Insects pollinate the flowers while collecting the forage from pistillate and staminate phase flowers. Bees visit only staminate flowers due to the availability of both nectar and pollen; while approaching these flowers, affect either geitonogamy or xenogamy because of the clustered flowers. Wasps, flies, and ants probe pistillate phase mature buds and staminate phase flowers of the concerned plant species indiscriminately, but the pistillate phase flowers are non-rewarding while the staminate phase flowers are rewarding. As a result, these insects affect geitonogamy and xenogamy. The *Chrysocoris* beetle is a voracious pollen feeder and deprives the flowers of pollen in *S. maritima*, its pollen feeding activity is indirectly compels the bees to collect pollen from different plants and such a foraging behavior results in the promotion of xenogamy. Further, thrips in all the three species and one insect in immature stage in case of *S. nudiflora*, deplete both nectar and pollen considerably and such state of floral rewards drive all the insect species, except ants, to make frequent inter-plant visits within the species and across *Suaeda* species. This leads to the promotion of outcrossing through xenogamy. The occurrence of these species in the same area, and their simultaneous flowering, facilitates the insects to deposit mixed pollen consisting of the pollen of all the three species on their stigmas and this pollen discounting diminishes outcross siring success. In this context, it is to be stated that insect activity is not very intense on these plant species, it is prominent on *S. maritima* and *S. monoica*, while it is not so in *S. nudiflora*, due to the production of very inconspicuous flowers when compared to the other two species. Pollen discounting did not show any affect on seed set rate and it is reflected in the very high fruit set rate in open-pollinations. This could be because of requirement of a few viable pollen grains for stigmas to produce a single seed per flower. Further, water currents also disperse pollen and pollinate flowers within and between plants of all the three species in inundated or submerged localities. In these localities, anemophily or entomophily is not very effective due to wet state of pollen, or flowers, or even plants. These three *Suaeda* species use a combination of pollination by wind, insects and water currents. The function of three pollination syndromes gives flexibility to maximize fruit or seed set rate through outcrossing as well as selfing through geitonogamy (Culley et al., 2002).

Chenopodiaceous seeds are dispersed by wind, water, and animals (Ridley, 1930). Chapman (1947) stated that in *S. maritima*, seed germination occurs from March onwards and fruits disperse from October onwards. Fruit dispersal occurs by tides and they can float for three days and then settle. In the present study also, it is found that in all the three *Suaeda* species, whole plant breaks off and rolls on the floor while shedding its diasporas. Fruits with seeds intact and/or seeds shed from fruits float on water due to their ability for buoyancy. The fruits and seeds thus disperse, settle in the entire extent of salt marshes or coastal areas, and germinate in mid-summer season when salinity is very high in high and low salt marshes.

Jones and Blum (1983) show that pyrrolizidine alkaloids play a key role in host-plant selection and, as a sex pheromone in certain danaid butterflies. These butterflies apply from their proboscides a fluid able of dissolving alkaloids and then re-imbibe it. These butterflies store alkaloids, for defence (Edgar et al., 1976, 1979; Rothschild et al., 1979; Conner et al., 1981). Owen (1971) show that danaine butterflies use withered and damaged plants and floral nectar as sources of alkaloids. *D. chrysippus* uses the pyrrolizidine alkaloids to protect from its predators and synthesize the courtship pheromone. Alkaloids play an important role to protect the most vulnerable stage, the egg (Meinwald, 1990). This butterfly species, and also *D. plexippus*, when equipped with these alkaloids, have been experimentally proved to be unpalatable to their predators by Edgar et al. (1976). Boppre (1983) reported that *Tirumala petiverana* collects sap from *Heliotropium pectinatum* in East Africa. Mathew and Anto (2007) reported that *T. limniace* uses the pyrrolizidine alkaloids to deter its predators, the garden lizards. In the present study, the nymphalid butterflies, *Danaus genutia*, *D. chrysippus*, the lycaenid *Euchrysops cnejus*, and the hesperiid, *Borbo cinnara*, have been found to collect sap from the leaves before flowering and dry fruiting branches of all the three *Suaeda* species. The presence of alkaloids, triterpenoids, sterols, and various other chemicals have been reported in *S. maritima*, *S. monoica*, and *S. nudiflora* (Al-Mohammadi et al., 2005; Ravikumar et al., 2011; Satyavani et al., 2012; Singh et al., 2012; Suganthy et al., 2009; Gurudeeban et al., 2011). Therefore, the *Suaeda* species studied now appear to be an important source of alkaloids for all the recorded butterfly species and the latter use them to deter their predators.

The genus *Suaeda* has both C_3 and C_4 photosynthetic pathways, both categories of species commonly grow side by side; C_4 species are mostly annuals in central Asia (Glagoleva et al., 1990). C_4 pathway is an adaptive mechanism to grow in stressful environment. These species grow abundantly in drier and more saline sites and persist throughout the dry season due to their succulence (Fisher et al., 1997). *S. maritima* is a C_3 species with austrobassioid leaf anatomy and colonizes all areas where perennial species are absent due to sensitivity to competitive interactions (Yeo and Flowers, 1980; Mateu Andres, 1989). *S. monoica* and *S. nudiflora* are C_4 species and grow abundantly in hot, dry, high-light saline environments (Shomer-Ilan et al., 1975; Ehleringer and Monson, 1993; Singh et al., 2004; Patel and Pandey, 2009). In the present study, *S. maritima* and *S. monoica* are annuals while *S. nudiflora* is a perennial; all the three grow side by side in both high and low salt marshes. *S. nudiflora* is dominant particularly in drier, saline areas; its successful growth in such areas could be related to C_4 photosynthetic pathway. Further, *S. maritima* and *S. monoica* have been found to grow mostly in areas where *S. nudiflora* does not grow. Such a growth pattern appears to be related to sensitivity of the first two species to competitive interactions arising from the perennial species, *S. nudiflora*, which is usually available throughout the year and displays extensive mat-forming growth. Nevertheless, C_4 species *S. monoica* and *S. nudiflora*, can be successfully used for eco-restoration in saline areas where other species do not grow.

Manousaki and Kalogerakis (2011) reported that halophytes are more efficient in withstanding and adapting themselves to several abiotic factors due to several inherent basic biochemical tolerance mechanisms when compared to glycophytic plants. They are naturally better adapted to cope with environmental stresses, including heavy metals, compared to salt-sensitive crop plants commonly chosen for phytoremediation purposes for the removal of heavy metals from soils. They are potentially ideal plants for phyto-extraction or phyto-stabilization applications of heavy metal polluted soils, and moreover, of heavy metal polluted soils affected by salinity. Some salt-excreting halophytes use their excretion mechanism in order to remove the excess of toxic metal ions from their sensitive tissues, and hence, act as biological pumps for heavy metals. Phyto-desalination has attracted much interest for the desalination of soils with the use of salt-accumulating halophytes which receive and accumulate high concentrations of salt in their aboveground tissues and consequently saline soils can be improved by harvesting the plants. Cherian and Reddy (2003) stated that salinity is a major problem in irrigated agriculture especially in the arid and semiarid environments. While glycophytes undergo growth inhibition in saline environments either due to a decline in water uptake caused by the increase in external osmotic pressure or due to ionic imbalance in the cytosol, halophytes evolved mechanisms for controlled influx of sodium and chloride ions to be used for their benefit in a saline environment. Reddy et al. (2010) reported that halophytes are widely used due to their high economic values like fodder, oil, fuel, and so forth, and, also for ecological interests like soil desalination, dune fixation, phyto-remediation, landscaping and ornamental purpose. Further, domestication of halophytes as potential crop plants for biomass production, is an emerging field towards rehabilitation of salinized lands in semi-arid and arid areas. Soils adjacent to the coastal areas under irrigation or otherwise get enriched with various materials including hazardous elements from the discharges of industrial effluents, which in turn, pose a great problem for the reclamation of soils and for their use in cultivation. Manousaki and Kalogerakis (2011) reported that *S. maritima* accumulates high concentrations of salt in its aboveground tissues, and consequently, saline soils can be upgraded by harvesting the plants on a regular basis. Ravindran et al. (2007) also reported that *S. maritima* accumulates high concentrations of salts in its tissues and reduces salts in the saline land to a great extent. These authors called it a salt accumulating halophyte and it can be used successfully to accumulate salt in highly salinized areas for crop production after a few repeated cultivations and harvests. Reddy et al. (2010) also mentioned that *S. nudiflora* accumulates and sustains the salinity levels nearby double that of seawater. It could be cultivated for its economic importance, even on highly polluted soils for reclamation. Further, it is also used as a source of biological salt or oil. Singh et al. (2004) reported that the seeds of *S. nudiflora* contain approximately 30-35% oil, and hence, has the potential as a future oil seed crop. It is highly suitable for producing high protein biomass in saline soils with its C_4 photosynthetic pathway. Therefore, the studied *Suaeda* species can be used to extract salt, desalinate saline soils, and use such soils for normal plantation or cultivation. Salinization is a serious problem confronting sustainable agriculture in irrigated production systems in semi-arid and arid regions where plant growth is directly affected by high levels of sodium chloride and other salts (Marschner, 1986). In India, about 30 million ha of coastal land is still barren and uncultivable because of bad soil affected by salinity (Singh and Surendra, 1994). In this context, it is quite appropriate to consider *Suaeda* species as potential desalinating agents for highly saline soils in order to convert bad soils into fertile soils for crop production. Further, they can also be used for the clean-up of polluted soils through phyto-remediation programs.

CONCLUSIONS

Clerodendrum inerme, Derris trifoliata, Suaeda maritima, S. monoica, and *S. nudiflora* are hermaphroditic, self-compatible, and exhibit mixed breeding systems which are primarily adapted for cross-pollination. All these species are vector-dependent for both self- and cross-pollination. *C. inerme* exhibits dichogamy and herkogamy. It is principally pollinated by the hawkmoth, *Macroglossum gyrans*. *D. trifoliata* is feebly protandrous and the flowers close back by the end of the day of anthesis. All three *Suaeda* species are dichogamous and strongly protogynous; the flowers are pistillate during mature bud stage and staminate on the day of anthesis suggesting a type of temporal dioecy. *C. inerme* and *D. trifoliata* are principally entomophilous. The *Suaeda* species are principally anemophilous, followed by entomophily in high salt marshes, while they are primarily pollinated by water currents and also by insects to a lesser degree. All these species are nectariferous and offer pollen and nectar as floral rewards to insect pollinators. The *Suaeda* species do not offer either nectar or pollen during pistillate phase due to closed state of mature buds, but offer both the rewards to insect pollinators during staminate phase, which occurs after anthesis.

In *C. inerme*, birds such as *Acridotheres tristis* (Indian Myna), *Corvus splendens* (House Crow), *Corvus macrorhynchos* (Jungle Crow), and *Turdoides caudatus* (Common Babbler) disperse nutlets or seeds during early winter season. Seed germination occurs in June and seedlings grow gradually to produce new plants. In *D. trifoliata*, the fruits are leathery and possess air cavities which enable them to float in tidal water. They settle at the parent plant if the site is partly or fully exposed, or float for dispersal if the site is inundated with tidal water. Seed release occurs when fruits absorb water and the pericarp breaks. Seeds germinate only when they reach a suitable habitat in mangroves. In the *Suaeda* species, the whole plant breaks off and rolls on the floor while shedding its diaspores. Fruits with seeds intact and/or seeds shed from fruits float on water due to their ability for buoyancy. The fruits and seeds thus disperse, settle in the entire extent of salt marshes or coastal areas, and germinate in mid-summer season when salinity is very high in high and low salt marshes. *S. maritima* is a C_3 species, while *S. monoica* and *S. nudiflora* are C_4 species; the last two species can be successfully used for eco-restoration in saline areas where other species do not grow. All species can also be used to extract salt, desalinate saline soils, and use such soils for normal plantation or cultivation.

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CONSERVATION STATUS OF SOME PEATBOGS IN MARAMUREŞ COUNTY

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ABSTRACT

Peat bogs and specially raised bogs are vulnerable ecosystems all over the world and they create refuges for some rare plant species. The aim of this paper is to provide information regarding the conservation status of five oligotrophic peat bogs situated in the volcanic mountains in the Oriental Chain of Carpathians, in Maramureş County. The studied peat bogs are: Tăul lui Dumitru (Dumitru Pond), Mlaștina Vlășinescu (Vlășinescu Peat bog), Iezeru Mare (Big Tarn), Tăul Chendroaiei (Chendroaiei Pond) and Tăul Negru (Black Pond), all of them have the status of nature reserve and under the IUCN categories they are included in category IV Habitat/Species Management Area (www.iucn.org, 2016). The analysis of the selected peat bogs reveals that all five of them have the vegetation included in the Natura 2000 priority habitat 7110* Active raised bogs. The conservation status of these peat bogs was evaluated and it is variable from moderate to very good conservation status.

ZUSAMMENFASSUNG: Der Erhaltungszustand einiger Torfmoore im Kreis Maramuresch.

Die Torfmoore vor allem die lebenden Hochmoore, sind weltweit gefährdete Ökosysteme, die Rückzugsgebiete für einige seltene Pflanzenarten darstellen. Ziel der vorliegenden Arbeit ist es, Informationen über den Erhaltungszustand von fünf in den vulkanischen Gebirgen der Ostkarpaten im Kreis Maramuresch gelegenen oligotrophen Torfmooren zu liefern. Die untersuchten Moore sind der Tăul lui Dumitru, das Vlășinescu-Moor, der Große Iezer/Iezeru Mare, das Chendroaiei-Moor/Tăul Chendroaiei und das Schwarze Moor/Tăul Negru, die alle den Status eines durch das Gesetz 5/2000 ausgewiesenen Naturschutzgebietes haben. Auch gehören sie laut IUCN Kriterien in die vierte Kategorie der Habitat und Arten Management-Gebiete (***, 2016). Die Analyse der ausgewählten Torfmoore führt zu dem Schluss, dass die Vegetation aller fünf Moore dem prioritären Habitattyp 7110* Naturnahe lebende Hochmoore angehört. Der Erhaltungszustand dieser Torfmoore wurde naturschutzfachlich mit einer Schwankung zwischen mäßig bis sehr gut bewertet.

REZUMAT: Starea de conservare a unor mlaştini de turbă din judeţul Maramureş.

Mlaştinile de turbă, şi în special tinoavele bombate active, sunt ecosisteme vulnerabile la nivel global și constituie refugii pentru specii rare de plante. Scopul acestei lucrări este de a oferi informații referitoare la starea de conservare a cinci mlaștini oligotrofe de turbă, situate în munții vulcanici din lanțul Carpațior Orientali, pe teritoriul Județului Maramureș. Mlaștinile care fac obiectul acestui studiu sunt: Tăul lui Dumitru, Mlaștina Vlășinescu, Iezeru Mare, Tăul Chendroaiei și Tăul Negru, toate încadrate ca rezervații naturale și în categoria IV IUCN. Analiza mlaștinilor de turbă selectate relevă apartenența vegetației lor la habitatul prioritar European 7110* Tinoave bombate active. Starea de conservare a mlaștinilor studiate variază de la medie până la foarte bună, în funcție de impactul antropic manifestat asupra lor.

INTRODUCTION

Peat bogs and especially active raised bogs are both very robust and vulnerable systems (Casparie, 1993). In Europe there are a very low number of active raised bogs unaffected by human impact, except in Finland and Sweden, where active raised bogs are the main bog complex in hemiboreal and south-boreal areas (Gafta, 2008).

The paper present the conservation status of five peat bogs situated in Maramureș County, in the volcanic mountains of Igniș, Gutâi and Țibleș. The studied peat bogs are: Tăul lui Dumitru (Dumitru Pond), Mlaștina Vlăşinescu (Vlășinescu Peat bog), Iezeru Mare (Big Tarn), Tăul Chendroaiei (Chendroaiei Pond) and Tăul Negru (Black Pond), all of them have the status of nature reserve declared by Law 5/2000 and under the IUCN categories they are included in the 4th category IV Habitat/Species Management Area (www.iucn.org, 2016).

Due to the great conservation value of these peat bogs, Tăul lui Dumitru and Iezeru Mare are included in Natura 2000 site ROSCI0092 Igniș and Tăul Chendroaiei is included in Natura 2000 site of community importance ROSCI0089 Gutâi – Creasta Cocoșului, by the Order of the Ministry of Environment and Sustainable Development 1.964/2007.

The pillars of nature conservation policy in Europe are Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora, known as the Habitats Directive, and Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds, known as the Birds Directive (European Commission 1992, 1995, 2007; European Parliament and Council of Europe, 2009). The implementation of these directives leads to the establishment of the Natura 2000 Network.

In Romanian legislation, the Habitats Directive and Birds Directive are enforced by Governmental Emergency Ordinance no. 57/2007 regarding the protected areas regime, conservation of natural habitats and wild flora and fauna, completed and modified by Law 49/2011 and by Governmental Emergency Ordinance no. 31/2014.

Those peat bogs that have the status of nature reserve were studied and the results were published in the 1960’s by Pop and in 2005 by Drăgulescu. The aim of this paper is to provide more data regarding these peat bogs and their conservation status.

MATERIAL AND METHODS

Five of the oligotrophic *Sphagnum* peat bogs situated in the Oriental Chain of Carpathian Mountains in Maramureș County were selected for this study. The selection was made in order to analyze peat bogs with similar conditions of altitude and flora structure.

The data field collecting was conducted in August 2016. For each of the peat bogs data collecting sheets were created for the habitat structures. The plant species were identified in the field using the field guide elaborated by Sârbu et al. (2012) and the other species that were not identified in the field were identified in the office using the Flora Republicii Populare Romîne. (*, 1952-1976, Flora R.P.R.-R.S.R.). The scientific names of the plants were updated using Flora Europaea (**)(http://ww2.bgbm.org/EuroPlusMed/query.asp).

Because no specific data regarding the surface of the peat bog was collected before, it was also necessary to collect GIS data. The centre of each peat bog and the whole area were registered using GPS receptor Garmin Dakota 10. The GIS data were analysed in the laboratory using Arc Map 10.3. Only the surface of the peat bog was mapped, not all the surface of the protected area.

Also, in order to establish the conservation status of the peat bogs, any marks of anthropic impact were registered. Invasive alien species were also registered for each of the peat bogs.

Where necessary, some minimum conservation measures were recommended.

RESULTS AND DISCUSSION

The location of the studied peat bogs in Maramureş County is presented in figure 2. The peat bogs are situated in the volcanic mountains of Igniş, Gutâi and Tibleş, in the mountain layer of vegetation, at altitudes between 881 and 1,153 m (Tab. 1).

Table 1: Geographic information related to the studied peat bogs.

Peat Bog	Altitude and GPS coordinates of the centre	Surface (hectares)	Peat volume (Pop, 1960) (m^3)	Thickness of peat layer (Pop, 1960) (m)
Vlăşinescu	Altitude 881 m N 47°44,817' E 023°43.378'	3.403	50,000	3.5-5.5
Iezerul Mare	Altitude 1,005 m N 47°48.500' E 023°49.526'	10.120	300,000	7
Tăul lui Dumitru	Altitude71,142m N 47°49.458' E 023°41.894'	2.267	180,000	5.5
Tăul Chendroaiei	Altitude 1,053 m N 47°42.589' E 023°50.159'	2.269	Not evaluated	Maximum 8
Tăul Negru	Altitude 1,137 m N 47°39.649' E 023°55.971'	0.566	Not evaluated	Not evaluated

Vlăşinescu Peat Bog

Vlăşinescu Peat Bog (Fig. 1) is situated on Izvoare volcanic plateau, close to the tourist complex of Izvoare, at an altitude of 881 m, and the bog has a surface of about 3.403 hectares. The bog is included in the Nature reserve which has similar name. A detailed map of the bog is presented in figure 2. The peat bog was formed in an ancient volcano crater (Pop, 1960) and it has natural borders that consist of the Vlăşinescu Stream and Alders Stream and it is part of the administrative territory of Deseşti municipality.

The main Natura 2000 habitat is the 7110* Active raised bog, characterised by the plant associations Sphagnetum magellanici and Eriophoro vaginato-Sphagnetum. Also in the area are the associations Empetro-Vaccinietum, Carici rostratae-Sphagnetum, Carici echinatae-Sphagnetum and Carici flavae-Eriophoretum.

The plant list includes the following: *Sphagnum magelanicum, Sphagnum recurvum, Drosera rotundifolia, Andromeda polifolia, Empetrum nigrum, Carex echinata, Carex rostrata, Eriophorum vaginatum, Vaccinium uliginosum, Vaccinium vitis idaea, Vaccinium oxycoccus, Calluna vulgaris, Potentilla erecta,* and *Lycopodium inundatum*, etc.

Vlăşinescu peat bog is surrounded by mesophilous meadows used as pastures and occasionally the sheep use also the area of the peat bog as a pasture, affecting its conservation status. The impact of the pasturing on the vegetation structure is low. Even though the area is situated close to the tourist complex of Izvoare, the anthropic impact generated by tourism is also low, and we can conclude that the conservation status of Vlăşinescu peat bog is favourable.

No invasive alien plant species were identified in the study area. Vlășinescu peat bog Nature Reserve has a custodian and also management plan.

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 1: Vlășinescu peat bog map.

Iezerul Mare

Iezerul Mare peat bog is situated in the administrative territory of Desești municipality, the village of Hărnicești and is also known by the local inhabitants as Hărniceștilor Pond. Iezerul Mare is a protected area declared by Law 5/2000 and it is included in Natura 2000 site ROSCI0092 Igniș. A detailed map of Iezeru Mare is presented in figure 3.

It is a typical raised bog, with a convex shape; the central area is about six-seven metres higher than the periphery of the raised bog. In the centre of the raised bog is a pond that has a surface area of about 250 m^2. Two streams issue from the raised bog – the Iezerului Stream and the Sărita Iezerului Stream.

The main Natura 2000 habitat is the 7110* Active raised bog, characterised by the plant associations Eriophoro vaginato-Sphagnetum, Vaccinietum uliginosi and Empetreto-Vaccinietum.

The main species in the area are: *Sphagnum* sp., *Andromeda polifolia*, *Drosera rotundifolia*, *Empetrum nigrum*, *Vaccinium uliginosum*, *Vaccinium oxycoccus*, *Vaccinium vitis-idaea*, *Molinia coerulea*, and *Scheuchzeria palustris.*

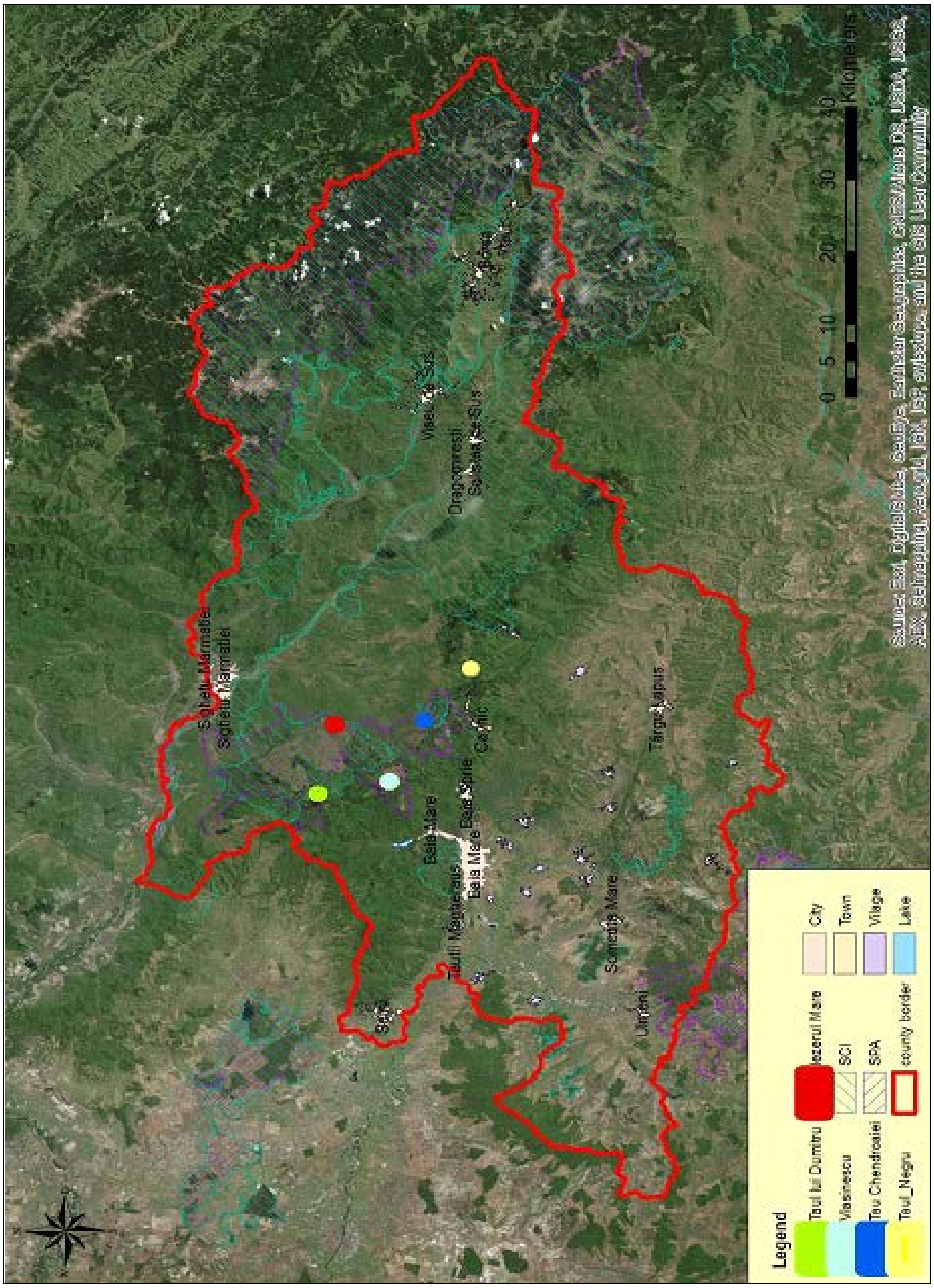
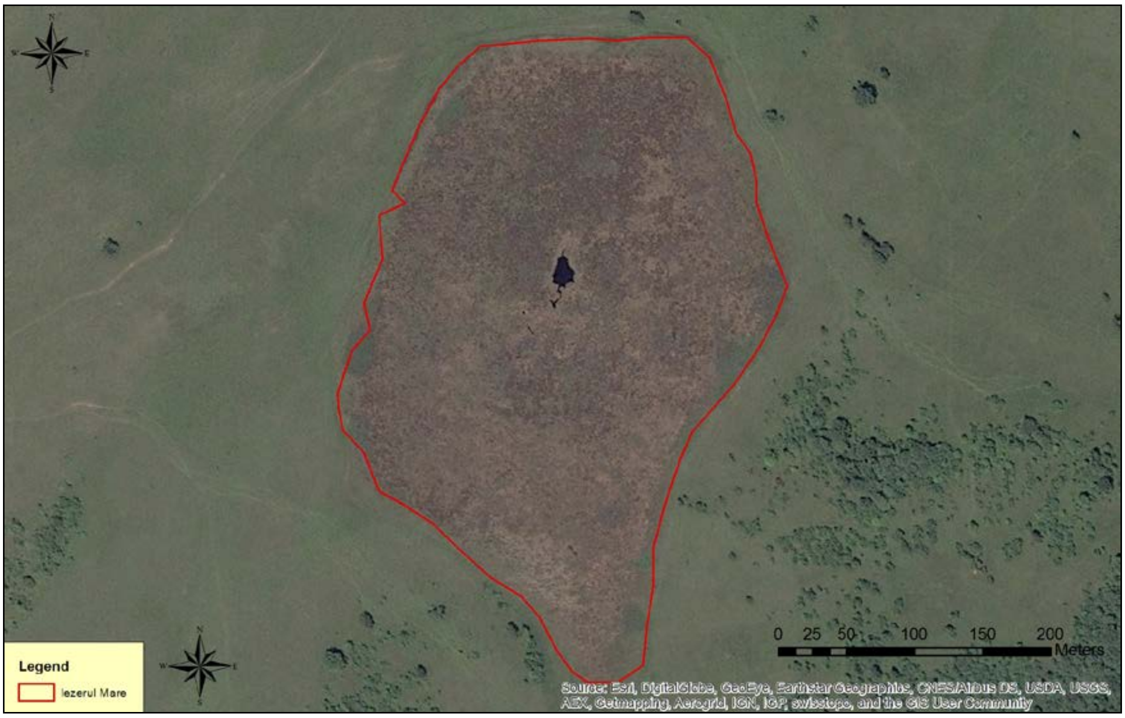


Figure 2: Location of the studied peat bogs in Maramureș County.

From our observations in this area, made in 2012, the central part of the peat bog is being invaded by young saplings of birch (*Betula pendula*) and buckthorn (*Frangula alnus*) that may in time affect the structure of this bog by afforestation. The peat bog is surrounded by mountain pastures, but no impact related to agricultural practices was noticed on the peat bog surface. Also no anthropic drainage affects the peat bog.

The bog and also the protected area are well preserved, and the conservation status of the peat bog is favourable. The custodian of the Iezerul Mare peat bog is Maramureş Mountains Nature Park Administration that also administrates the Natura 2000 site Igniş.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 3: Detailed map of Iezerul Mare peat bog.

In order to maintain the favourable conservation status, ecological rehabilitation measures are needed. One of our recommendations is related to the cutting of the birch and buckthorn saplings on the area.

Restoration of raised bogs in Central Europe influenced by drainage, agricultural use, forest use, afforestation and peat extraction is a common practice. In Switzerland, between 2% and 5% of the former surface of area is still covered by bogs. Starting in the 1980's, efforts have been made to apply restoration measures (Pfadenhauer and Klotzli, 1996).

Tăul lui Dumitru

Tăul lui Dumitru raised bog is situated in Igniş Mountains, at an altitude of 1,142 m, between Brazilor Valley and Sturului Valley in an ancient volcano crater (Pop, 1960). It is located in the administrative territory of Baia Mare and Giuleşti municipalities.

The raised bog is surrounded by spruce forest and at the margins of the raised bog small spruces are growing. In the centre of the raised bog there is a pond 900 m^2. A detailed map of Tăul lui Dumitru raised bog is presented in figure 4.

Tăul lui Dumitru raised bog is a nature reserve declared by Law 5/2000 and it is included in Natura 2000 site ROSCI0092 Igniș.

The main Natura 2000 habitat is the 7110* Active raised bog, characterised by the plant associations Carici rostratae-Sphagnetum, Scheuchzerietum palustris, Empetro-Vaccinietum, Eriophoro vaginato-Sphagnetum and Vaccinietum uliginosi.

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 4: Detailed map of Tăul lui Dumitru raised bog.

The main species in the area are: *Sphagnum* sp., *Andromeda polifolia, Drosera rotundifolia, Empetrum nigrum, Vaccinium uliginosum, Vaccinium oxycoccus, Vaccinium vitis-idaea, Scheuchzeria palustris, Carex rostrata, C. limosa, Eriophorum vaginatum*, and *Picea abies*.

The raised bog is well preserved due to limited access and the conservation status is very good. No management measures are needed supplementary to the applied ones, mentioned in the management plan of the Natura 2000 site ROSCI0092 Igniș.

Tăul Chendroaiei

Tăul Chendroaiei is located on the northern slope of the volcanic Gutâi Mountains, under the Creasta Cocoșului (Cock's Ridge) geographical formation. It is situated at an altitude of 1,153 m and occupies a surface of 2.26 hectares. It is located in the administrative territory of Ocna Şugatag municipality. The raised bog has a typical convex shape, with the centre about six m higher than the margins of the raised bog. In the centre of the raised bog there are two water ponds, as marks of a former lake. A detailed map of Tăul Chendroaiei raised bog is presented in figure 5.

The raised bog is surrounded by mountain pastures in the south and east part and by forest in the northern and west parts. In the eastern part of the raised bog there is an access road. The area has had a status of nature reserve since 2000 and it has been included in the Natura 2000 site ROSCI0092 since 2007. The main Natura 2000 habitat is the 7110* Active raised bog, characterised by the plant associations Empetro-Vaccinietum and Eriophoro vaginato-Sphagnetum. A secondary habitat is 7120 Degraded raised bogs still capable of natural regeneration.

The main species in the are: *Sphagnum recurvum, Sph. magellanicum, Sph. fuscum, Polytrichum strictum, Vaccinium uliginosum, Vaccinium vitis-idaea, Vaccinium oxycoccos, Vaccinium myrtillus, Empetrum nigrum, Eriophorum vaginatum, Drosera rotundifolia, Molinia coerulea, Carex pauciflora, Carex limosa, Lycopodium inundatum, Scheuchzeria palustris,* and *Andromeda polifolia.* Some of the rare species are presented in figures 6 to 9.

Figure 5: Detailed map of Tăul Chendroaiei raised bog.

Tăul Chendroaiei is one of the most visited raised bogs in Maramureș, due to the fact that it is close to the well-known and spectacular volcano formation Creasta Cocoșului. The main anthropic impact in the raised bog area is due to tourism and to pasturing activities. At the time of our visit in the field in August 2016, we observed trails of all-terrain vehicles on the peat surface, close to the two water ponds in the centre. The margins of the water ponds were collapsed into the water. Also in some points, about 5% of the surface of the peat bog was bare, not covered by vegetation.

Considering these aspects, we evaluated the conservation status of Tăul Chendroaiei raised bog at medium to good. Some management measures are necessary. The main one is related to access in the protected area. In order to stop the degradation of this valuable and rare ecosystem some physical measures are needed that will stop access with vehicles in the protected area. Tăul Chendroaiei raised bog has a custodian and a management plan.

Figure 6: *Empetrum nigrum*.

Figure 7: *Drosera rotundifolia*.

Figure 8: *Scheuchzeria palustris*.

Figure 9: *Andromeda polifolia*.

Tăul Negru

Tăul Negru raised bog is situated on the southern slope of Țibleș Mountains, in the administrative territory of Strâmbu Băiuț municipality, at an altitude of 1,137 m. It is surrounded by beech forest on the west, south and east sides and by a mesophilous meadow on the north side. A detailed map of the raised bog Tăul Negru is presented in figure 10.

In the centre of the raised bog there is a small water pond and the water in the raised bog is naturally drained in the Pleșca Stream.

The main Natura 2000 habitat is the 7110* Active raised bog area, is characterised by the specific plant associations Empetro-Vaccinietum and Eriophoro vaginato-Sphagnetum.

The main plant species in the raised bog are: *Sphagnum* sp., *Polytrichum* sp., *Empetrum nigrum, Eriophorum vaginatum, Eriophorum angustifolium, Carex pauciflora, Carex rostrata, Carex canescens, Carex biharica, Nardus stricta, Vaccinium uliginosum, Vaccinium oxycoccus, Vaccinium vitis-idaea,* and *Drosera rotundifolia.*

Figure 10: Detailed map of the Tăul Negru raised bog.

Tăul Negru raised bog has the status of nature reserve and it is declared by Law 5/2000. It has a custodian and a management plan. Due to the difficult access to the raised bog, the area is not affected by any human impact and the conservation status of the area is very good. No supplementary management measures are needed.

CONCLUSIONS

The five studied raised bogs situated in the mountain layer of vegetation of Igniș, Gutâi and Tibleș mountains in the Oriental Carpathians chain have the status of nature reserve; Iezerul Mare and Tăul lui Dumitru are also included in Natura 2000 site ROSCI0092 Igniș and Tăul Chendroaiei is included in Natura 2000 site ROSCI0089 Gutâi.

All five studied areas are characterised by the main priority Natura 2000 habitat 7110* Active raised bog, and occasionally, where anthropic impact is present, there are areas of the habitat 7120 Degraded raised bogs still capable of natural regeneration.

Iezerul Mare is the only raised bog affected by invasive alien plant species, the central area of the peat bog is invaded by young saplings of birch (*Betula pendula*) and buckthorn (*Frangula alnus*) that may in time affect the structure of this bog by afforestation.

Tourist activities and agriculture are the main threats to the conservation status of the studied area. The impact of these threats on the raised bogs determined the conservation status, which varies from medium on Tăul Chendroaiei raised bog to very good in Tăul lui Dumitru and Tăul Negru.

In order to maintain and improve the conservation status, some management measures are needed, especially related to restoration of Iezerul Mare raised bog and tourist access in Tăul Chendroaiei. Public awareness measures are also welcome.

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THE RIVER VALLEYS AS BIODIVERSITY RESERVOIRS FOR LAND SNAILS IN HIGHLY ANTHROPIC AREAS
– THE CASE OF CISNĂDIE RIVER (ROMANIA)

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ABSTRACT

This study focuses on the snail fauna of a river valley passing through two closely located settlements. Thirty six species of terrestrial gastropods were identified. Species such as *Macrogastra borealis*, *Alinda fallax*, *Alinda viridana*, *Bulgarica vetusta*, *Monachoides vicinus*, *Drobacia banatica,* are present along the river and abundant in the sampling stations downstream of Cisnădie town. The high specific diversity and the presence of typical forest species demonstrate the presence of fragments of habitat that can preserve populations of terrestrial gastropods, underlining the importance of river valleys in conservation and dispersion of these species.

RÉSUMÉ: Les vallées fluviales réservoirs de la biodiversité pour les gastéropodes terrestres dans les régions fortes anthropisés – étude de cas le Rivière Cisnădie (Roumanie).

L'étude est axée sur la faune de gastéropodes terrestres de la zone riveraine d'une rivière qui traverse deux établissements sur une distance relativement courte. 36 espèces de gastéropodes terrestres ont été identifiées. Des espèces telles que *Macrogastra borealis, Alinda fallax, Alinda viridana, Bulgarica vetusta, Monachoides vicinus, Drobacia banatica* sont présents le long de la vallée et abondantes en aval de Cisnădie. Une grande diversité spécifique et la présence d'espèces caractéristiques des habitats forestières, démontrent l'existence des fragments d'habitat qui peuvent conserver les populations de gastéropodes terrestres, soulignant l'importance des vallées fluviales pour la conservation et la dispersion de ces espèces.

REZUMAT: Văile râurilor rezervoare de biodiversitate pentru gastropodele terestre în zone puternic antropizate – studiu de caz Râul Cisnădie (România).

Studiul se concentrează pe fauna de gastropode terestre din zona ripariană a unui râu care traversează două aşezări umane pe o distanţă relativ scurtă. Un număr de 36 de specii de gastropode terestre au fost identificate. Specii precum *Macrogastra borealis, Alinda fallax, Alinda viridana, Bulgarica vetusta, Monachoides vicinus, Drobacia banatica,* sunt prezente de-a lungul văii şi abundente în aval de oraşul Cisnădie. Diversitatea specifică ridicată şi prezenţa speciilor caracteristice habitatelor forestiere demonstrează existenţa fragmentelor de habitat care pot conserva populaţiile de gastropode terestre, subliniind importanţa văilor râurilor pentru conservarea şi dispersia acestor specii.

INTRODUCTION

Habitat destruction and fragmentation are among the major threats that affect land snail communities especially in highly anthropic areas, where urbanization, the development of industry and agriculture strongly affect the natural habitats (McKinney, 2002, 2008; Stoll et al., 2009; Douglas et al., 2013). Urbanization impact on land snails has been studied on some European countries (Horsák et al., 2009, 2013; Dedov and Penev, 2000; Gheoca, 2012), but the anthropogenic impact extends beyond the boundaries of the urban system as the human activities or their results are still present in the surrounding areas.

In Southern Transylvania the plateau area landscape is dominated by cultivated lands that, along with the development of urban and rural human settlements, industrial areas and associated infrastructure, are shaping the natural landscape transforming it into a predominantly anthropogenic one. In this landscape few natural habitats remain, especially in the vicinity of the urban areas, where most of the forests were cut down. The closest habitats to their natural state are the river valleys.

The Cisnădie River is one of the tributaries of Cibin River. The source of the river is in the Cibin Mountains, it is 18 km long and after a short course through a deciduous forest, passes through the central areas of a rural (Cisnădioara) and an urban (Cisnădie) settlement. The river is mostly natural in its forest sector, upstream of Cisnădioara, and starts to degrade before entering the village due to deforestation, grazing and tourism. The river banks have been strongly modified and regularized inside both localities. Downstream of Cisnădie, only patches of the former riverine forest remain, with most of the area under construction, including a part in the vicinity of a forest patch.

The aim of the study is to assess the land snail diversity along the river and the impact of anthropogenic modifications on this group as well as on the ability of the river valley to preserve significant snail populations.

MATERIAL AND METHODS

A visual search was used in 11 sampling stations along Cisnădie River valley (Fig. 1).

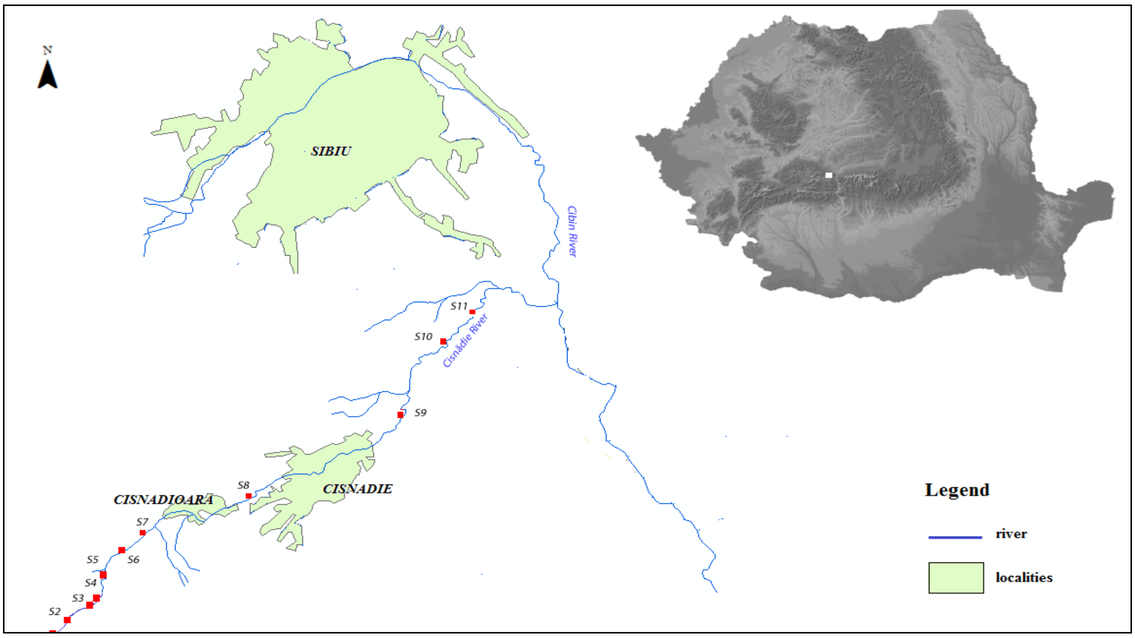

Figure 1: The location of sampling points.

Seven sampling points were located upstream of Cisnădioara (km 2; 3; 3.7; 4.5; 5; 6; 7), one between Cisnădioara and Cisnădie (km 8.8) and three downstream of Cisnădie town (km 13.3; 15; 16.2). The sampling was conducted in the river valley, near the water (Fig. 2). Snails were collected by hand, by two collectors during one hour in each sampling site, and an additional leaf litter sample was taken. About 20 l of leaf litter were sieved and the material was sorted and identified in the laboratory (Pokryszko and Cameron, 1995). The key-book of Grossu (1981, 1983, 1987) and Welter-Schultes (2012) were used for species identification. The taxonomic list follows the Fauna Europaea (Bank, 2013). Species relative abundance and the Margalef diversity index were calculated and used to assess the land snail communities. The relative abundance was also used to build the affinity diagram of the sampling stations (single linkage method, Euclidean distance).

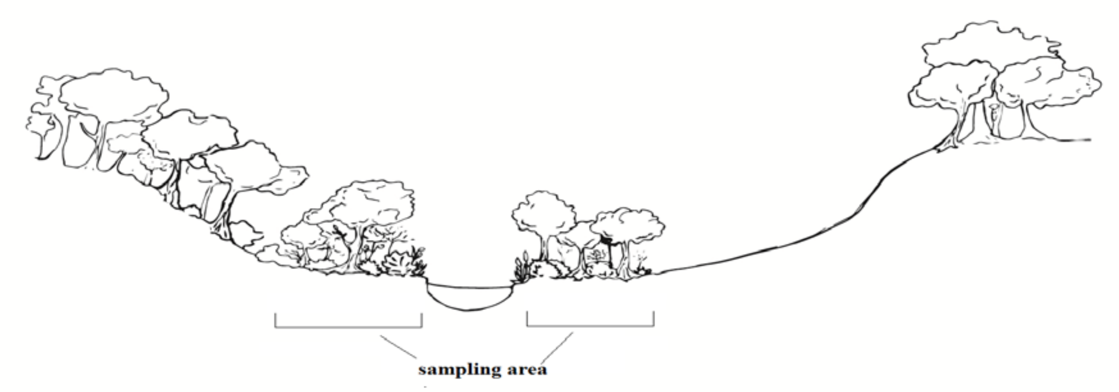

Figure 2: General cross-section of the valley, showing the location of the sampling area.

RESULTS AND DISCUSSION

Thirty six land snail species were identified in the area. The systematic list is presented in table 1. The 11 sampling points were located in the forest area, upstream of Cisnădioara, S1-S7, between Cisnădioara and Cisnădie S8 and downstream of Cisnădie S9-S11. The number of species ranges between seven, for the most degraded sampling point (S6) and 20 at the last station downstream of Cisnădie (S11). Table 2 presents the number of individuals, species and the Margalef diversity index for each sampling station.

For the entire area, the most common species are *Helix pomatia* (highest frequency and relative abundance), and *Vestia elata*. In the forest area, upstream of Cisnădioara the most abundant species are *Perforatella dibotrion, Monachoides vicinus, Discus perspectivus, Drobacia banatica, Vestia elata* and *Helix pomatia* (Fig. 3). The first three species, along with other less abundant species such as *Isognomostoma isognomostomos, Morlina depressa, Vitrea contracta, Vitrea transsylvanica* and *Alinda viridana*, were found exclusively in the sampling stations upstream of the first locality.

Generally, their abundance decreases as the village is approached, with a high diversity (Margalef Index value) at sampling stations S1, S2 and S4 (Tab. 2). The sampling stations located near the localities have the lowest diversity values. The most degraded habitat was found in S6, an area with intensive pastoral activities, like sheep grazing and watering, located in the vicinity of a camping site. In this sector, the most abundant species are *Helix pomatia, Vestia elata, Euomphalia strigella* and *Bulgarica vetusta*.

Table 1: The systematic list of land snail species found along the Cisnădie River valley (number of individuals, frequency (F%), relative abundance (A%) and the sampling points where each species was found).

Species	**Ind.**	**F%**	**A%**	**Sampling stations**
Carychiidae				
Carychium (Carychium) minimum Müller O. F. 1774	2	18.18	0.12	S2, S3
Succineidae				
Succinea putris (Linnaeus, 1758)	13	36.36	0.81	S2, S9, S10, S11
Cochlicopidae				
Cochlicopa lubrica (Müller O. F., 1774)	10	36.36	0.62	S2, S3, S7, S11
Orculidae				
Sphyradium doliolum (Bruguière, 1792)	3	9.09	0.19	S5
Valloniidae				
Vallonia pulchella (Müller O. F., 1774)	1	9.09	0.06	S10
Acanthinula aculeata (Müller O. F., 1774)	1	9.09	0.06	S4
Enidae				
Merdigera obscura (Müller O. F., 1774)	2	9.09	0.12	S10
Chondrula tridens (Müller O. F., 1774)	3	18.18	0.19	S10, S11
Clausiliidae				
Cochlodina (Cochlodina) laminata (Montagu, 1803)	46	63.63	2.86	S1, S2, S3, S4, S8, S10, S11
Macrogastra (Pyrostoma) borealis (Boettger O., 1878)	52	18.18	3.23	S10, S11
Clausilia (Andraea) dubia Draparnaud, 1805	18	4.45	1.12	S5, S7, S8, S10, S11
Alinda (Pseudalinda) fallax (Rossmässler, 1836)	96	72.72	5.97	S2, S3, S4, S5, S6, S7, S10, S11
Alinda (Pseudalinda) viridana (Rossmässler, 1836)	11	27.27	0.68	S1, S2, S5
Vestia (Vestia) gulo (Bielz E. A., 1859)	31	45.45	1.93	S1, S2, S4, S5, S11
Vestia (Vestia) elata (Rossmassler, 1836)	217	72.72	13.49	S4, S5, S6, S7, S8, S9, S10, S11
Bulgarica (Strigilecula) vetusta (Rossmässler, 1836)	127	8.81	7.89	S1, S3, S4, S5, S6, S7, S8, S10, S11
Patulidae				
Discus perspectivus (Megerle von Mühlfeld, 1816)	66	4.45	4.10	S1, S2, S4, S5, S7
Pristilomatidae				
Vitrea transsylvanica (Clessin, 1877)	12	36.36	0.75	S1, S2, S3, S4
Vitrea contracta (Westerlund, 1871)	20	2.27	1.24	S1, S2, S3
Oxychilidae				
Oxychilus (Oxychilus) draparnaudi (Beck, 1837)	18	27.27	1.12	S9, S10, S11
Mediterranea depressa (Sterki, 1880)	12	36.36	0.75	S1, S2, S4, S5, S7
Aegopinella epipedostoma (Fagot, 1879)	69	63.63	4.29	S1, S2, S4, S5, S9, S10, S11
Aegopinella pura (Alder, 1830)	10	36.36	0.62	S1, S2, S3, S4, S5
Nesovitrea (Perpolita) hammonis (Strøm, 1765)	2	9.09	0.12	S3
Vitrinidae				
Vitrina pellucida (Müller O. F., 1774)	3	27.27	0.19	S1, S2, S3

Table 1 (continued): The systematic list of land snail species found along the Cisnădie River valley (number of individuals, frequency (F%), relative abundance (A%) and the sampling points where each species was found).

Bradybaenidae				
Fruticicola fruticum (Müller O. F., 1774)	108	54.54	6.71	S4, S5, S7, S8, S10, S11
Hygromiidae				
Euomphalia strigella (Draparnaud, 1801)	110	4.45	6.84	S6, S8, S9, S10, S11
Pseudotrichia rubiginosa (Rossmässler, 1838)	4	18.18	0.25	S9, S11
Monachoides vicinus (Rossmässler, 1842)	58	72.72	3.60	S1, S2, S3, S4, S5, S6, S7, S8
Perforatella dibothrion (Kimakowicz M., 1884)	12	2.27	0.75	S1, S2, S7
Helicidae				
Drobacia banatica (Rossmässler, 1838)	64	9.91	3.98	S1, S2, S3, S4, S6, S7, S8, S9, S10, S11
Faustina faustina (Rossmässler, 1835)	18	27.27	1.12	S2, S3, S7
Isognomostoma isognomostomos (Schröter, 1784)	5	27.27	0.31	S1, S3, S4
Cepaea (Austrotachea) vindobonensis (Pfeiffer C., 1828)	11	3.36	0.68	S8, S9, S10, S11
Helix (Helix) pomatia Linnaeus, 1758	353	100	21.94	S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11
Helix (Helix) lutescens Rossmässler, 1837	21	27.27	1.31	S9, S10, S11

Table 2: Number of individuals, species and the value of Margalef diversity index in each sampling station.

Sampling station	Nomber of specimens	Nomber of species	Margalef Index
S1	90	16	12.46
S2	94	19	9.12
S3	86	15	6.62
S4	91	16	7.66
S5	146	14	5.54
S6	60	7	3.37
S7	198	13	5.27
S8	167	9	3.60
S9	113	10	4.38
S10	248	18	7.10
S11	365	20	7.42

The two sampling stations located more than two km from Cisnădie, have a totally different land snail community, dominated by *Fruticicola fruticum*, *Alinda fallax*, *Aegopinella epipedostoma*, *Macrogastra borealis* and *Vestia elata*. Despite the high values in species number (18 and 20 respectively), the specific diversity remains below the values registered in the upstream sector.

The dendrogram built of species abundance (Fig. 4) shows the similarity between the sampling stations located upstream (S2, S3, S1, and S4). A second cluster is formed by S5 and S7, still upstream but closer to the first locality. The rest of the sampling stations from the proximity of localities do not form a group or discriminate from each other, but are close to the upstream stations, while the last two sampling points are totally distinctive as the land snail communities in these stations are largely different from the rest.

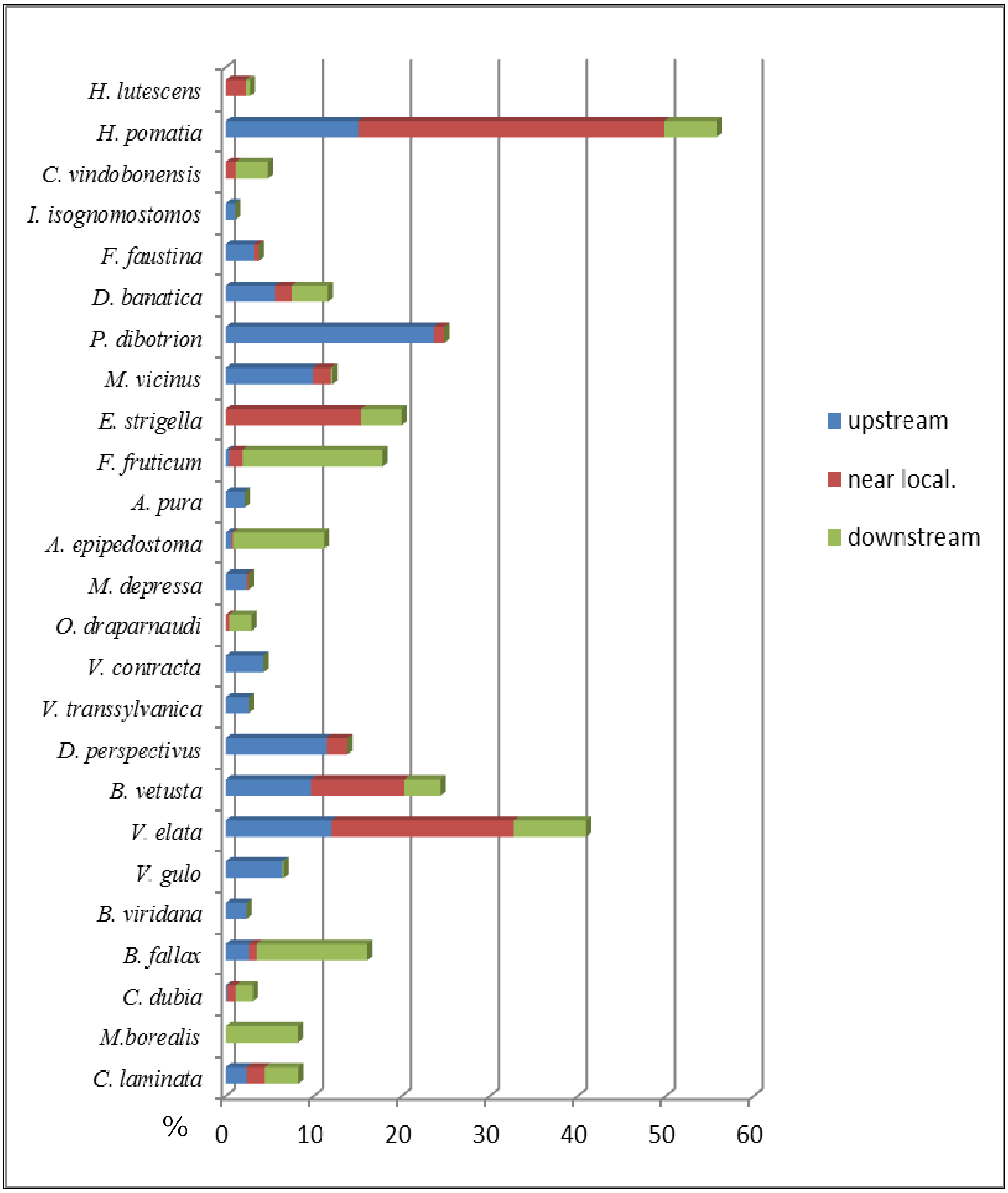

Figure 3: The relative abundance of the most common land snail species in the sampling stations split in three categories S1-S5, upstream; S6-S9, near localities; S10-S11, downstream.

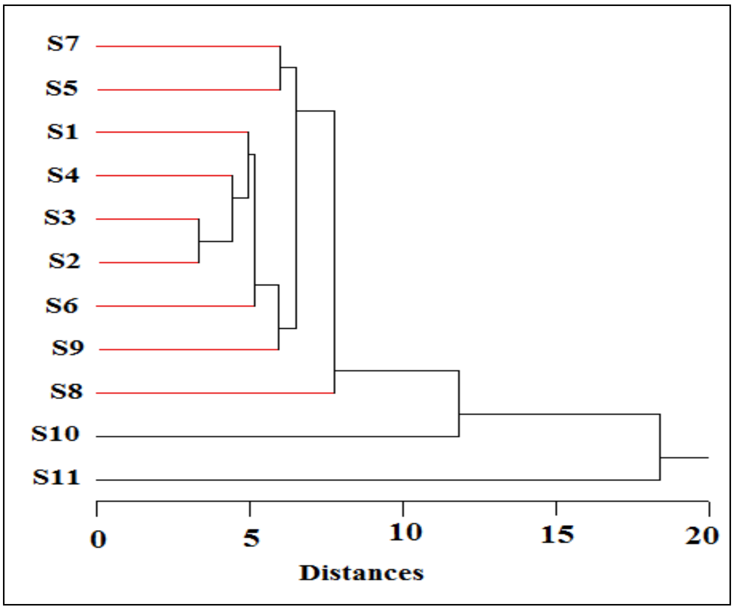

Figure 4: Dendrogram showing the affinity among the sampling stations S1-S11. The relative abundance of land snail species in each sampling station was used. The linkage method is single linkage, and Euclidean distance.

CONCLUSIONS

Land snail communities from the Cisnădie River valley are shaped by their habitat. The forest areas have a rich land snail fauna with valuable elements including the endemic species *Alinda viridana* and *Drobacia banatica*, the only species from the Annex II of the Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora (Habitats Directive).

D. banatica was found in ten of the eleven sampling stations, and is more abundant in the upstream sector. As a result of degradation by human activities, the species diversity decreases and, in the proximity of human settlements the communities are based upon ubiquitous species such as *Helix pomatia* and *Euomphalia strigella*, or on those species that find favourable conditions for their particular requirements such as *Vestia elata* and *Helix lutescens.* These particular conditions may be very different between adjacent locations. As the pressure generated by human activities decreases, land snail communities are re-established, but their structure depends on the dimensions of habitat fragments, previous structure of the habitat and the potential connection with other natural habitats that can supply the species richness. In the case of the Cisnădie River, the sampling points located downstream have particular land snail communities, inhabiting natural habitat patches that are in contact with a remnant forest. Unfortunately the regularization works conducted along the river have separated the upstream land snail populations from those downstream. It is still possible that some individuals are transported downstream during floods, but it is less probable that they contribute substantially to the land snail community of this sector. Despite the high level of human disturbance, these habitat fragments are still able to preserve a high diversity and function as biodiversity reservoirs in a highly anthropic landscape, sheltering species with conservation value. The future of land snail species in this type of habitat largely depends on how these river valleys are managed.

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