

AN APPRAISAL OF BIODIVERSITY MONITORING IN TURKEY WITHIN
THE FRAMEWORK OF ESSENTIAL BIODIVERSITY VARIABLES

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ABSTRACT

AN APPRAISAL OF BIODIVERSITY MONITORING IN TURKEY WITHIN THE FRAMEWORK OF ESSENTIAL BIODIVERSITY VARIABLES

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The survival of species, habitats, ecosystems and thus the welfare of humankind are increasingly under threat due to adverse effects of land use change, overexploitation, pollution, invasive species and climate change. Monitoring biodiversity, understanding environmental responses and analyzing trends enable us to develop urgent actions for combatting biodiversity decline, and to improve policies to cope with these global challenges.

Biodiversity observation has a long history. However the dispersed structure of knowledge, uneven distribution of existing data, and the lack of coordination between nations hamper effective harmonization. Furthermore, promising technological improvements and open source resources extend the biodiversity data landscape. Essential Biodiversity Variables (EBVs) which are a set of indicators for the standardized surveillance of biodiversity change, were developed by the Group on Earth Observations Biodiversity Observation Network in 2013 for interoperability of data.

In this study, I explored the suitability of EBVs, considering the accumulated academic knowledge and the existing monitoring expertise in Turkey. By assessing the status of biodiversity monitoring, I identify spatial, temporal, taxonomic gaps. Then, a feasibility methodology was developed to prioritize the EBVs. Remote sensing plays a significant role in ecosystem monitoring globally as it is cheap, easily

accessible, highly accurate and provides long term data delivery. However the utilization of this technology is not yet sufficient at the national level. I also demonstrate an example of using remotely sensed data in habitat mapping for monitoring purposes. I executed this study in sparse Mediterranean forests where several anthropogenic factors together with fires and droughts are shaping the ecosystem structure and composition.

Keywords: Biodiversity monitoring, Essential Biodiversity Variables (EBVs), Remote Sensing, Random Forest, Biological diversity



ÖZ

TÜRKİYE’DE BİYOÇEŞİTLİLİK İZLEME ÇALIŞMALARININ TEMEL BİYOÇEŞİTLİLİK DEĞİŞKENLERİ ÇERÇEVESİNDE DEĞERLENDİRİLMESİ

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Türlerin, habitatların, ekosistemlerin varlığı ve buna bağlı insanlığın refahı; arazi kullanım şekillerinin değişmesi, aşırı tüketim, kirlilik, istilacı türler ve iklim değişikliği nedeniyle giderek daha fazla tehdit edilmektedir. Biyoçeşitliliğin izlenmesi, çevresel tepkileri anlamayı ve eğilimleri analiz etmeyi, biyoçeşitlilik kaybıyla mücadele etmek için acil eylemler geliştirmemizi ve bu küresel zorluklarla başa çıkmak için politikaları iyileştirmemize olanak tanır.

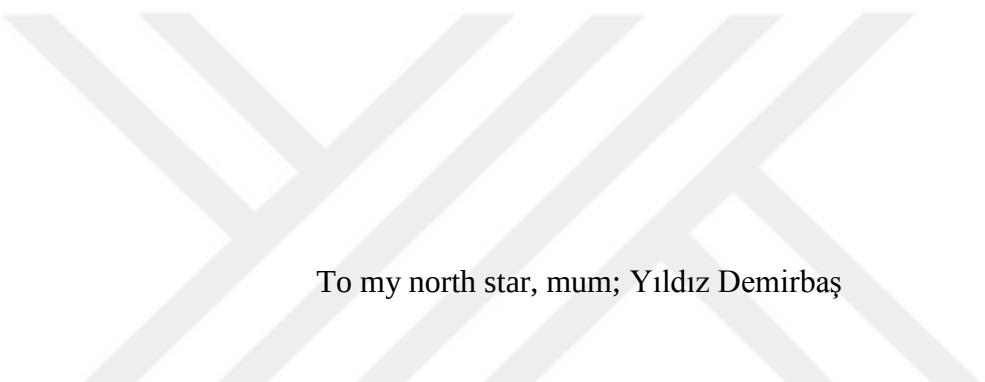
Biyoçeşitliliği izlemenin uzun bir tarihi vardır. Ancak, mevcut bilginin dağınık yapısı, verilerin adil olmayan dağılımı ve ülkeler arasındaki koordinasyon eksikliği, bu bilgilerin etkili bir şekilde uyumlaştırılmasını engellemektedir. Ayrıca, gelecek vaat eden teknolojik gelişmeler ve açık kaynaklar, biyoçeşitlilik veri ortamını genişletmektedir. Temel Biyoçeşitlilik Değişkenleri (TBD), biyoçeşitlilik gözlemlerinin standartlaştırılması ve verininin işlevliliğini sağlamak için 2013 yılında Yeryüzü Gözlem Grubu Biyoçeşitlilik Gözlem Ağı tarafından geliştirilmiştir.

Bu araştırmada, Türkiye'deki akademik bilgi birikimi ve mevcut izleme uzmanlığını göz önünde bulundurarak TBD'lerin uygunluğu araştırılmıştır. Biyoçeşitlilik izlemenin durumunu değerlendirmiş; mekansal, zamansal, taksonomik boşluklar belirlenmiştir. Ardından, TBD'lere öncelik vermek için bir fizibilite metodolojisi geliştirilmiştir. Uzaktan algılama; ucuz, kolay erişilebilir, son derece doğru ve uzun vadeli veri dağıtımını sağladığı için küresel düzeyde ekosistem izlemede önemli bir rol

oynamaktadır. Ancak bu teknolojinin ulusal düzeyde kullanımı henüz yeterli değildir. Bu nedenle ayrıca, uzaktan algılama verilerinin habitat haritalamasında izleme amaçlı kullanımına bir örnek sunulmuştur. Örnek çalışma çeşitli antropojenik faktörlerin yanı sıra yangın ve kuraklığın ekosistem yapısını ve kompozisyonunu şekillendirdiği seyrek Akdeniz ormanlarında gerçekleştirmiştir.

Anahtar Kelimeler: Biyoçeşitlilik izleme, Temel Biyoçeşitlilik Değişkenleri (TBD), Uzaktan Algılama, Rastgele değişkenler, Biyolojik çeşitlilik





To my north star, mum; Yıldız Demirbaş

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LIST OF ABBREVIATIONS

ABBREVIATIONS

CBD	United Nations Convention on Biological Diversity
COPs	Conference of the Parties
EBVs	Essential Biodiversity Variables
ECV	Essential Climate Variables
ESDGVs	Essential Sustainable Development Goal Variables
ESA	European Space Agency
EU	European Union
FAO	Food and Agriculture Organization
GDNCNP	General Directorate of Nature Conservation and National Parks
GBIF	Global Biodiversity Information Facility
GCOS	Global Climate Observing System
GEOSS	Global Earth Observation System of Systems
GFOI	Global Forest Observation Initiative
GDP	Gross Domestic Product
IPCC	Intergovernmental Panel on Climate Change
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
ICP Forests	International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests Network

IUCN	International Union for Conservation of Nature
LTER	Long-Term Ecological Research
MAF	Ministry of Agriculture and Forestry
MoL	Map of Life
MEA	Millennium Ecosystem Assessment
UBENIS	National Biodiversity Inventory and Monitoring Project
NGO	Non-Governmental Organisation
SPA	Special Protection Areas
SAP	Species Action Plan
SDG	Sustainable Development Goals
BIP	The Biodiversity Indicators Partnership
GEO BON	The Global Earth Observation Biodiversity Observation Network
NASA	The National Aeronautics and Space Administration
NBDSAP	The National Biological Diversity Strategy and Action Plans
UNFCCC	United Nations Framework Convention on Climate Change
UNEP	United Nations Environment Programme
UNCED	United Nations Conference on Environment and Development
UNCCD	United Nations Convention to Combat Desertification
UNESCO	United Nations Education Scientific and Cultural Organization
UNEP	United Nations Environment Programme
WCMC	World Conservation Monitoring Centre
WMO	World Meteorological Organization

WRI

World Resources Institute



CHAPTER 1

INTRODUCTION

1.1. Problem Definition

Increasing magnitude and extent of anthropogenic activities has been changing global biodiversity detrimentally (Butchart et al., 2010, Tittensor et al., 2014, Visconti et al., 2016). Direct pressures mainly driven by human population growth and resource use and they can be listed as land cover change, overexploitation, invasive alien species, pollution and climate change (Pereira et al., 2012). Degradation of natural ecosystems reduced biodiversity intactness (Newbold et al., 2016) and rapid depletion in "natural capital" reveal the loss of ecosystem services which human wellbeing depends upon strongly (MEA, 2005). A growing literature in the last twenty years provides evidence with the substantial connection with nature and its essential contributions to people (Costanza et al., 1998, Costanza et al., 2014, Diaz et al., 2018). Thus, it is vital to conserve biodiversity to ensure the continuation of the services that biodiversity provides not only for sustaining the variety of life itself, but also securing the human welfare.

In scientific perspective “how bad is the biodiversity crises?” (McGill et al., 2014), “how urgent the actions to prevent biodiversity loss?”, “do we have time to develop more and exhaust natural capital?”. These questions can only be answered by understanding the status and trends in biodiversity globally. But monitoring is a scalable question. McGill et al. (2014) argued about the distinction between alpha diversity and beta diversity. Measuring different components of biodiversity at different scales cannot be comparable, and misguide the decision takers. To an extent this discussion, Pereira et al. (2012) introduced the two components of biodiversity change as biodiversity loss and biodiversity alterations (Figure 1.1). Simply

biodiversity loss is defined as the extinction of an allele or species locally or globally and biodiversity alteration is the response of biodiversity by shifting species distribution or modifying the structure of a community. For example species would most likely react ecosystem disturbances by shifting locally and colonizing new ecosystems. Thus a local scale monitoring might not reflect this change. So in that regard monitoring biodiversity change at various aspects are needed to track to the response of environmental change on genes, species, communities and ecosystems. From remote sensing to in situ techniques, any monitoring effort will develop our skills to better interpret the complex interactions (e.g. traits) and feedbacks (e.g. ecosystem functions) and matching various temporal, spatial and biodiversity scales (Scholes et al., 2012).

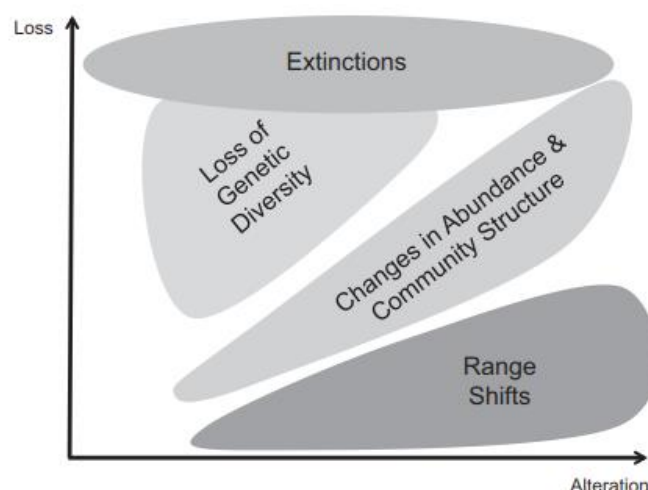


Figure 1.1. Components of biodiversity change in loss and alteration dimensions (Pereira et al., 2012)

Observation of nature has the most plentiful and longest records in human history (Scholes et al., 2012). However measuring something in nature, merely does not mean monitoring. Monitoring needs some essential ingredients; “a question, an experimental design, a conceptual framework, and data integrity through the

repeatable application of appropriate field protocols” (Lindenmayer and Likens, 2010). Yoccoz et al. (2001), define monitoring as the process of collecting information about some system state variables at different points in time to evaluate the system state and draw conclusions about changes of these variables over time. And they criticized the concurrent programs as most of them are lack of answers of these fundamental questions “why to monitor?, what to monitor? and how to monitor?”

Monitoring can be science, management, policy-oriented. The policy decisions related with a) prioritization of conservation efforts and managing vulnerable areas, b) evaluation of the success of conservation management, c) reporting international obligations with solid parameters can be achieved. Monitoring is not an option for nations anymore, it is an obligation to increase ecosystem integrity and resilience against catastrophes such as climate change and pandemics.

In addition to these conservation-oriented concerns, today’s agenda of sustainability (i.e. Sustainable Development Goals) also pushes monitoring by means of effective management of natural resources. Ultimately, monitoring the earth’s life support systems is directly linked with biological diversity.

Convention on Biological Diversity (CBD) is the most important political instrument in terms of conserving biodiversity, globally. Since its development at the Rio Earth Summit in 1992, several targets have been imposed on countries for preventing biodiversity loss. Measuring biodiversity ‘globally’ is an ambitious goal and is a must for to track the target: “reduce the rate of loss of biodiversity by 2010” taken by CBD and approved by 190 countries (Balmford et al., 2005). However, there was not broadly agreed and globally available set of measures for the evaluation of the biodiversity. In seven topics of CBD, 40 measures present the situation in 22 major indicators. A consistent message could not be delivered to policymakers from these enormous set (Scholes et al., 2008). In Nagoya CBD conference of the parties (2010) Aichi Targets were approved for the period of 2011-2020. Similar to previous targets, the Aichi Targets have been facing the same problems. Scholes et. al (2012) updated

the situation such that (1) some proposed indicators were not functional in reliability, (2) compared to some local achievements, some of the 21 sub-targets were not achieved globally, (3) broader analysis conducted with 31 indicators revealed that biodiversity was declining and the pressures behind this decline are increased (Butchart et al., 2010). Pereira et al. (2013) highlighted that the indicator problem continued such that although almost a hundred indicators were proposed, two-thirds of the submitted reports had presented inefficient information about biodiversity change and the information cannot be integrated to a global assessment.

Two major reasons are behind this obstacle. The first one is the intrinsic structure of existing data such that the diversity, disorganized and scattered character imposes a barrier in harmonization. The second one is the spatially, temporally and taxonomically data gaps (Scholes et al., 2008; Butchart et al., 2010). Up to now, biodiversity is monitored where ecologists exist and work (Jongman, 2013). The studies are intensified in the temperate climate, developed countries, although the biodiversity is more concentrated in tropical, developing countries (Scholes et al., 2012). Also the biased distribution is evident in taxonomic perspective. Bonnet et al. (2002) called this syndrome as “taxonomic chauvinism”. Tydeck et al. (2018) has conducted a comprehensive analysis covering 134,321 publications. Their results highlighted in terrestrial ecosystems among realms and plants among species groups are the most studied in Europe and Asia (Figure 1.2). Globally, publications distributed 47.9% genetics, 68.4% species, 15.8 % ecosystem and 8.1% phylogenetic level.

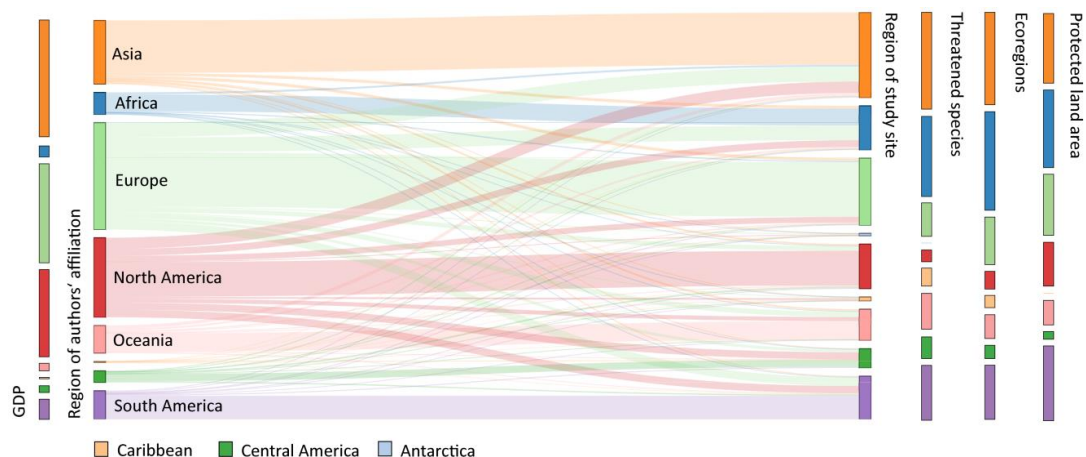


Figure 1.2. Analysis of imbalance in biodiversity research (Tydeck et al., 2018)

In accordance with CBD requirements, Turkey had prepared its National Biodiversity Strategy and Action Plan and submitted to the CBD secretariat in 2001, and updated the strategy in 2007 and lastly in 2018. These national strategies have guided policy and actions. In addition to several legislations and conservation actions, the fundamental achievements in monitoring perspective are;

- National Biodiversity Inventory and Monitoring Project (UBENIS) (2013-2019): The project aimed the generation of biodiversity inventory countrywide. Occurrence data of vascular plants, mammals, birds, freshwater fish, reptiles and amphibians were acquired by field surveys and literature reviews and cryptogamic plants and invertebrates were reported by literature review only. In each province inventory report the areas to be monitored were identified.
- Species Action Plans (2013-...): The Ministry of Forestry and Water Affairs set a target to accomplish 100 Species Action Plans by 2023. Almost all of the SAPs action plans highlight the importance of the monitoring of species.
- Noah's Ark National Biological Diversity Database (2007-...): Biological data especially species records collected by UBENIS project and Species Action Plans have been stored in Noah's Ark National Biological Diversity Database. Currently the database includes 852.813 point records from 14.334 taxon in 81

provinces. The dispersed biodiversity data has now compiled in this database. However, the data share policy and accessibility problems which will be discussed in the following chapters create a barrier for other users (universities, NGOs, citizens).

In Turkey, non-governmental organisations also act as important agents in biodiversity monitoring. Although their efforts particularly focus on endangered charismatic species (i.e. Mediterranean Monk Seal (*Monachus monachus*), sea turtles (*Caretta caretta* and *Chelonia mydas*) and flamingos (*Phoenicopterus roseus*)) their role in providing expertise and ambition to sustain monitoring are indispensable. However their limited budget and human resources and frequent shifts in the topic areas of international financial supports, risk the continuity of monitoring activities.

Similar to other nations, monitoring activities are very much limited by financial constraints. Figure 1.3 shows the annual budget of The Ministry of Forestry and Water Affairs, General Directorate of Nature Conservation and National Parks (GDNCNP) which was presented in the yearly Status Reports on Nature Conservation (GDNCNP, 2020). Although we do not know the share of monitoring investments, it is visible that the annual budget fluctuates a lot over the years with steep cuts from time to time. Most recently the ministry decreased the budget around 45% in 2019. At its current state, the annual budget is below 2014 levels. Furthermore, in USD terms the budget is even below 2012 levels. Turkish Lira's depreciation against USD also imposes an additional financial constraint as most of the monitoring activities have expenses in foreign currency. As of today USD to TL exchange rate is above 7, while it was 1.79 in 2012. The graph also shows that the national Gross Domestic Product (GDP) in USD terms (green line), it is evident the budget allocations are insensitive to the GDP. Thus, it is necessary to develop a national biodiversity monitoring program which is globally applicable and financially feasible.

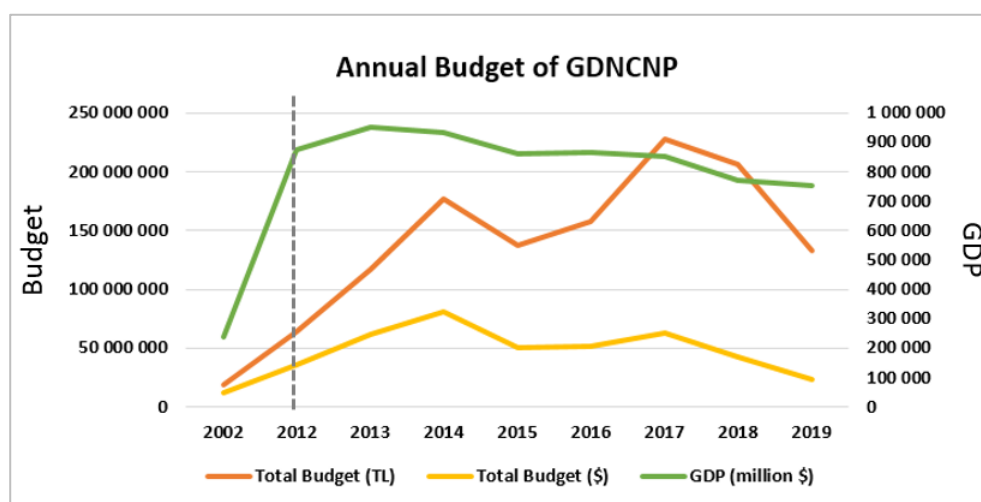


Figure 1.3. The annual budget of General Directorate of Nature Conservation and National Parks

To tackle the above-mentioned challenges on a global scale, clear priorities need to be set to guide the development of biodiversity monitoring systems worldwide. Essential Biodiversity Variables (EBVs) focus on a limited number of measurements that are crucial for characterizing global changes in biodiversity. EBVs also facilitate the harmonization of existing observation systems and guide the deployment of new monitoring schemes, especially in areas where biodiversity is still very limited.

1.2. Essential Biodiversity Variables Approach

The Global Earth Observation Biodiversity Observation Network (GEO BON) was established under GEO umbrella in 2008 to improve the coordination for biodiversity monitoring. GEO BON has generated the list of EBVs. These are similar to Essential Climate Variables (ECVs) that successfully deliver Global Climate Observing System (GCOS) and thus used in the reporting of the UN Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC) as a primary observation level.

As aforementioned before, indicator-based approaches are not successful neither in reporting nor managing global challenges. Problems arise in two pillars; (1) to fill missing data, (2) to manage existing data (Scholes et al., 2008).

To generate the effective minimal set of variables, following criteria were set as follows (Scholes et al., 2012, Pereira et al., 2013);

- Meeting the operational requirements of Aichi targets
- Repeatable and applicable for current and future user needs
- Scalable, from local to global
- Complement to various biodiversity aspects
- Not raw data and not an indicator, intermediate information between these two levels
- Sensitive to temporal changes
- Comprehensive for different taxa and different realms (terrestrial, freshwater, and marine)
- Feasible

EBVs identify a condensed set of primary observations necessary to support the long-term, multi-purpose data for biodiversity monitoring at various levels (Pereira et al., 2013).

The EBV framework (Figure 1.4) stand on the primary observation data derived from in-situ or remote sensing systems. EBVs are combined from primary observations and bridges towards indicators. EBVs covers all aspects of biodiversity and serve to assess Aichi Targets. The EBV products together with ancillary information such as drivers and pressures, management and policy responses serve the generation of future scenarios for policy and management decisions (UNEP/CBD/SBSTTA/17/INF/7, 2013).

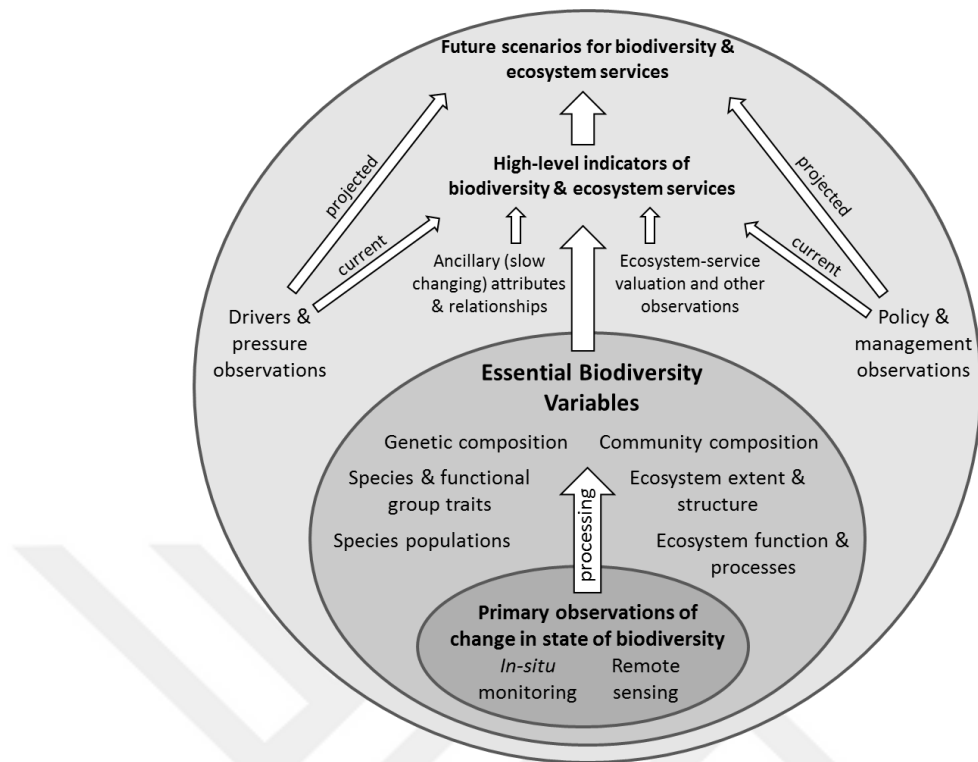


Figure 1.4. EBV framework (Source: UNEP/CBD/SBSTTA/17/INF/7, 2013)

EBVs, the details about measurement and scalability and their temporal sensitivity and global feasibility are presented in Table 1.1. EBVs most instrumental attribute is their relations with an international target such as Aichi Targets and Sustainable Development Goals (SDGs). This information are also added to the table. The links were already mentioned by Pereira et al., (2013), GEOBON (2013 and 2017) and Kissling et al. (2018a). However, the SDG links in species traits and genetic composition were missing thus I linked the associated goal and marked it with red.

Table 1.1. Essential Biodiversity Variables (GEO BON, 2013)

	EBV	Measurement and scalability	Temporal sensitivity	Feasibility	Link with Aichi Targets	Link with SDGs
Genetic composition	Co-ancestry	Pairwise relatedness among individuals or inbreeding coefficient of selected species, within and among populations of each species.	Generation time	Available for many species but few populations, and little systematic sampling over time.	12	12, 14, 15
	Allelic diversity	Allelic richness from genotypes of selected species (e.g. endangered species and domesticated species) at multiple locations (statistically representative of the species distribution).	Generation time	Data available for several species and for several locations, but little global systematic sampling.	12, 13	12, 14, 15
	Population genetic differentiation	Gene frequency differentiation (Fst and other measures) among populations or of a subpopulation compared to the meta-population of selected species.	Generation time	Data available for many species but often for a limited number of populations. Easy to augment datasets.	12, 13, 15	12, 14, 15
Species populations	Breed and variety diversity	Number of animals of each livestock breed and proportion of farmed area under each local crop variety, at multiple locations.	5 to 10 years	Large datasets have been compiled by national organizations and FAO for livestock breeds, but there is insufficient systematic sampling for coverage of local crop varieties.	13	12
	Species distribution	Presence surveys for groups of species easy to monitor, over an extensive network of sites with geographic representativeness. Potential role for incidental data from any spatial location.	1 to >10 years	Presence surveys are available for a larger number of species than population counts and can make use of existing distribution atlas. Some efforts for data compilation and integration exist (GBIF, IUCN, Map of Life). There is an increasing trend for data contributed by citizen scientists (Observado, iNaturalist).	4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15	3, 6, 14, 15

Table 1.1. Essential Biodiversity Variables (GEO BON, 2013) (continued)

	EBV	Measurement and scalability	Temporal sensitivity	Feasibility	Link with Aichi Targets	Link with SDGs
Species populations	Population abundance	Population counts for groups of species easy to monitor and/or important for ecosystem services, over an extensive network of sites with geographic representativeness.	1 year	Population counts underway for a significant number of species in each of the following groups: birds, butterflies, mammals, plankton, important fisheries, coral reef fishes. Most of these extensive networks are geographically restricted. Much of the data are currently being collected by citizen science networks.	4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15	3, 6, 14, 15
	Population structure by age/size class	Number of individuals or biomass of a given demographic class of a given taxon or functional group at a given location.	1 year	Available for some managed species (hunting and fisheries), usually geographically restricted.	4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15	3, 6, 14, 15
Species traits	Phenology	Timing of periodic biological events for selected taxa/phenomena at defined locations. Examples include: timing of breeding, leaf coloration, flowering, migration, oceans flow pattern shifts, intermittent flows in rivers, extant of wetlands.	1 year	Several ongoing initiatives (Phenological Eyes Network, PhenoCam, ClimateWatch, etc.), some making use of citizen science contributions.	10, 15	13, 15
	Body mass	Body mass (mean and variance) of selected species (e.g. under harvest pressure), at selected sites (e.g. exploitation sites).	1-5 year	Data available for many important marine fisheries, but little data available for bushmeat and other exploited species groups.	6, 7	2, 14
	Natal dispersal distance	Record median/frequency distribution of dispersal distances of a sample of selected taxa. In marine species larval lifetime it may be a useful surrogate.	>10 years	Banding/markings and observation data available for some birds, mammals, turtles, fish, temperate trees	5, 6, 9, 10, 11, 12, 15	-

Table 1.1. Essential Biodiversity Variables (GEO BON, 2013) (continued)

	EBV	Measurement and scalability	Temporal sensitivity	Feasibility	Link with Aichi Targets	Link with SDGs
Species traits	Migratory behaviour	Presence/ absence/ destinations/ pathways of selected migrant taxa.	1 to >10 years	Banding/ marking/ tagging and observation data available some birds, mammals, turtles, fish and butterflies.	5, 6, 10, 11, 12	-
	Demographic traits	Effective reproductive rate (e.g. by age/size class) and survival rate (e.g. by age/size class) for selected taxa at selected locations.	1 to >10 years	Data available for some fisheries, birds, mammals, reptiles, plants, and other taxa, but little trend data available.	4, 6, 8, 9, 12, 15	14, 15
	Physiological traits	For instance, measurement of thermal tolerance or metabolic rate. Assess for selected taxa at selected locations expected to be affected by a specific driver.	1 to >10 years	Some data available for corals, lizards, amphibians and insects.	4, 6, 8, 9, 12, 15	-
Community composition	Taxonomic diversity	Multi-taxa surveys (including by morphospecies) and metagenomics at selected in situ locations at consistent sampling scales over time. Hyper-spectral remote sensing over large ecosystems.	5-10 years	Many intensive long-term research sites have excellent but uncoordinated data, and there are abundant baseline data for many locations in the terrestrial, marine and freshwater realms. Metagenomics and the possibilities of remote sensing are emerging fields.	8, 10, 14	14, 15
	Species interactions	Studies of important interactions or interaction networks in selected communities, such as plant-bird seed dispersal systems.	5-25 years	Some studies have monitored the structure of species interaction networks such as mutualistic networks (pollination and seed dispersal), soil food webs, host-parasite and herbivore-plant interactions. There is a lack of global or regional representativeness of these studies.	7, 9, 14, 15	14, 15

Table 1.1.Essential Biodiversity Variables (GEO BON, 2013) (continued)

	EBV	Measurement and scalability	Temporal sensitivity	Feasibility	Link with Aichi Targets	Link with SDGs
Ecosystem function	Net primary productivity	Global mapping with modelling from remote sensing observations (FAPAR, ocean greenness) and selected in situ locations (eddy covariance).	<=1 year	A network of regional networks of in situ measurements exists (FLUXNET), and some global maps based on models and remote sensing are available. GCOS is also addressing this EBV.	5, 8, 14	2, 6, 14, 15
	Secondary productivity	Measurement of secondary productivity for selected functional groups, combining in situ , remote sensing, and models. Example functional groups include: fisheries, livestock, krill, and herbivorous birds.	1 year	FAO and national statistics on fish and livestock production.	6, 7, 14	2, 6, 14, 15
	Nutrient retention	Ratio of nutrient output from the system to nutrient input, measured at selected in situ locations. Can be combined with models and remote sensing to extrapolate regionally.	1 year	Some intensive monitoring sites have nitrogen saturation monitoring in some acid-deposition areas; phosphorus retention monitoring in some impacted rivers and estuaries.	5, 8, 14	2, 6, 14, 15
	Disturbance regime	Type, seasonal timing, intensity and frequency of event-based external disruptions to ecosystem processes and structure. Examples: sea surface temperature and salinity (RS), scatterometry for winds (RS), trawling pressure (in situ), flood regimes (in situ), fire frequency (in situ , RS), cultivation/ harvest (RS), windthrow and pests (in situ).	1 year	Abundant data is available for several perturbations, sometimes at the global scale, although harmonization and integration is needed.	5, 7, 9, 10, 11, 14, 15	2, 6, 14, 15

Table 1.1. Essential Biodiversity Variables (GEO BON, 2013) (continued)

	EBV	Measurement and scalability	Temporal sensitivity	Feasibility	Link with Aichi Targets	Link with SDGs
Ecosystem structure	Habitat structure	Remote sensing measurements of cover (or biomass) by height (or depth) classes globally or regionally, to provide a 3-dimensional description of habitats.	<=1 year	Global terrestrial maps available with RS (e.g., LIDAR). Marine and freshwater habitats mapped by combining RS and in situ data.	5, 11, 14, 15	2, 6, 11, 14, 15
	Ecosystem extent and fragmentation	Local (aerial photo and in situ monitoring) to global mapping (satellite observations) of natural/semi-natural forests, wetlands, free running rivers, coral reef live cover, benthos cover, etc.	1-5 years	Global maps of forests, assessment of fragmentation for major river basins, and local to regional maps of coral reefs already exist, but comparable observations over time are limited and a distinction between natural and modified ecosystems (e.g. natural forests versus plantations) is often not made.	5, 7, 10, 14, 15	2, 6, 11, 14, 15
	Ecosystem composition by functional type	Functional types can be directly inferred from morphology (in situ) or from remote sensing.	5 years	Implicitly part of current ecosystem maps. Some models (e.g. DGVMs, marine ecosystem models) are based on functional groups.	5, 14, 15	2, 6, 11, 14, 15

1.3. The Objective and Scope of the Thesis

Turkey has remarkable biodiversity however this diversity is exposed to detrimental damages. Biodiversity monitoring is an urgent action for combatting biodiversity decline, managing policies and actions, coping with global challenges (climate change, poverty, etc.) and providing sustainable development. Major progress has been achieved in biodiversity monitoring at a national scale in recent years. Turkey is now in the phase of transition from 'little biodiversity knowledge' to 'baseline inventory accomplished'. At this point, EBVs approach serves as a smart tool for us.

Today, high quality and reliable biodiversity measurements are not enough to understand and prevent biodiversity loss. Monitoring needs to be consistent in space and time, it should reflect the major dimensions of biodiversity and the outputs should be exchangeable between data providers and users. Cost-effectiveness can only be assured by strong coordination between agencies, governments and NGOs. The focus of this dissertation is guiding the terrestrial biodiversity monitoring in Turkey using the Essential Biodiversity Variables (EBVs) which stand at the core of this study. The objectives of this thesis are:

- 1) to collate the distributed information of biodiversity monitoring generated by various agents in Turkey,
- 2) to assess the status of biodiversity monitoring with empirical data and highlight the spatial, temporal and taxonomic gaps in accordance with EBVs,
- 3) to present opportunities for future actions in data acquisition, data integration and data delivery phases of monitoring, considering the technical skills already in Turkey,
- 4) to generate a framework for querying the feasibility of EBVs in Turkey, considering the political, technical and economic dimensions of monitoring,
- 5) to test the feasibility of remote sensing in monitoring ecosystems with a case study.

1.4. Thesis Outline

This dissertation is organized into six chapters. Following problem definition and objectives of the thesis, Chapter 2 provides a comprehensive review based on the relevant literature. After a brief information about the definition and importance of biodiversity, I present the monitoring topic and categorize the information in three pillars of biodiversity: gene, species and ecosystem. I summarize the considerable empirical literature from a global perspective and also I highlight any remarks for Turkey, if they exist. Several policy instruments and recommendations guide the monitoring effort together with several contributors. Hence, I have summarized this vast topic by calling them “agents” and compiled the information in accordance with policy perspective at three scales: international, regional and national. Moreover, I introduced the complicated issues related with biodiversity monitoring addressed by several authors. This section is followed by “What makes monitoring efficient?” section and comprises the subtitles focusing on the questions “What to monitor?” and “How to monitor?” by choosing optimal sampling method, efficient targets, increasing cooperation between users, engaging citizen science and adopting technological improvements. The last section gives some successful examples of large scale national monitoring programs.

Chapter 3 introduces the current situation of terrestrial biodiversity monitoring in countrywide perspective, covering ongoing efforts, potential programs and the academic research. Here I focused on active monitoring programs which have been executed by NGOs or governmental organizations that can be regarded as “long-term monitoring”. Since the monitoring data is highly dispersed and have different ontologies, I had generated a questionnaire and derived necessary metadata information from respondents. Apart from these active programs, there are other potential programs such as Species Action Plans that were generated by General Directorate of Nature Conservation and National Parks. The national policy interest in these species presents a great opportunity for extending future monitoring practices. Although the academic studies cannot be named as monitoring they constitute a

baseline. Once the study would be repeated in the same location with the same methodology, they can be easily linked to a monitoring program. The major limitation in biodiversity monitoring is availability of human resources, namely the expertise in a particular taxonomic group. Some of the EBVs require specific skills that are not readily available. In this regard, academic studies were used as a measure of the available technical expertise. By querying active and potential monitoring programs and academic studies “the biodiversity monitoring portfolio of Turkey” was generated. Further analyses were done by using this portfolio in order to highlight the gaps taxonomically, spatially and temporally in accordance with essential biodiversity variables. This chapter touches on the gaps, challenges and strong attributes of accumulated knowledge. Lastly, I focused on guiding the future of biodiversity monitoring with an emphasis on potential opportunities and the current state-of-the-art.

Chapter 4, addresses the feasibility of EBVs for Turkey and developed a framework by identifying a number of criteria focusing on the political, technical and economic aspects of monitoring activities. In this simple assessment, scoring relied on the findings of Chapter 3 and literature reviews. However this framework is not limited to specific circumstances such as particular ecosystems or cases, so anyone can use this framework to choose between EBVs and identify priorities for future studies. The development in certain criteria, for example including citizen scientists or the reduced cost of a survey method can make an option feasible in future. Here, my motive is not to offer a set of EBVs, but rather to present a basin for vision change. Current tendencies are often constricted by customary practices and habits. Monitoring is an inherently expensive and resource demanding activity. By assessing their usefulness (as benefits) and feasibility (as a derivative of cost), future monitoring actions can be wisely selected.

Biodiversity monitoring is highly resource-demanding. Remote sensing is a promising tool in monitoring since its data accessibility, affordability and continuity attributes. The vast majority of literature highlighted the great opportunity of remote sensing

with enhanced technical qualifications of recently settled orbit satellites. Several global scale (such as Forest Watch) analyses prove its capability. Also, many national biodiversity monitoring programmes acknowledge remote sensing, especially in ecosystem level monitoring. However, it is hard to say that remote sensing is adequately used for monitoring purposes in Turkey. For this reason in Chapter 5, I present a sample to generate a baseline by using machine learning technology and the Sentinel 2 image gallery. Sentinel 2's enhanced spatial and temporal resolution increases the accuracy and develops the nomenclature compared to earlier free satellite image galleries. I chose Mediterranean sparse forests due to their complexity and less appreciated diversity. The main objective of this chapter is to show how to map the compositional diversity in a complex Mediterranean maquis ecosystem and generate a baseline for ecosystem monitoring. This monitoring approach is not only useful for conservation practices but also applicable to fire recovery, landscape restoration and forest management practices.

Lastly, in Chapter 6, I present a brief conclusion and recommendations for future work. With this dissertation, I draw a snapshot of biodiversity monitoring in Turkey and suggest novel ways to improve it: in design and implementation, data management and storage, analysis and reporting phases of monitoring.

CHAPTER 2

BACKGROUND OF BIODIVERSITY MONITORING

2.1. Biodiversity

Life on earth is everywhere, from the deepest point of ocean to the highest point of mountains, from the coldest polar region to the driest deserts, from bacteria to the large mammals. This diversity of life is a consequence of 4.5 billion year evolution comprising the process of speciation and response to the major extinctions. The variety of life forms, adaptation skills and measures in response to geological and environmental factors create a boundless spectrum of life. Thus, covering all aspects of this variety in an exact definition is a hard and evolving process (Boenigk et al., 2015).

“Why are there so many kinds?”, “What is the relation of a kind to its individual representatives?”, “Why is there an order in nature?”, “Are these kinds arranged systematic ways?”. These are questions were arisen by The Greek philosophers and they are still topical. Plato was the first one who defended that “life tends to manifest itself in the greatest diversity” as “principle of plenitude” expression. Although Plato was not centrally nature-oriented, Aristotle put living world to the object of his studies. He is generally acknowledged as a founder of biological sciences since he had developed biological descriptions and classifications. He emphasized to consider any living organism (from the creepiest to the most spectacular) in the same way, with his saying “in all natural things there is something marvellous” (Borghini and Casetta, 2009).

Swedish botanist Carl Linnaeus introduced a systematic classification for living organisms in the 1700s. This classification includes hierarchical levels stating from the most inclusive “species-level” to the most exclusive “kingdom level”. He also

developed a binomial nomenclature system for naming species. However, this classification includes taxa from the species (least inclusive) to the kingdom (most inclusive). Linnaeus's classification is based on morphological differences of organisms. Additionally, after Darwin's evolution theory in the 1800s, the taxonomists directed towards phylogeny which reflects the evolutionary history of the organisms.

Wilcox (1985) defines biodiversity as: "the variety of life forms, the ecological roles they perform, and the genetic diversity they contain."

During the Earth Summit (United Nations Conference on Environment and Development (UNCED)) of Rio 1992, where 150 states signed the Convention on Biological Diversity (United Nations Convention on Biological Diversity, CBD), the term "biodiversity" term gain recognition in the political arena. This definition by CBD (UNEP, 1992) is still the most acknowledged one and states that "biodiversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species (1), between species (2) and of ecosystems (3)." The Global Biodiversity Strategy (1992) developed by World Resources Institute (WRI), International Union for Conservation of Nature (IUCN), United Nations Environment Programme (UNEP), the Food and Agriculture Organization (FAO) and the United Nations Education Scientific and Cultural Organization (UNESCO) (WRI/IUCN/UNEP, 1992), adopted these three aspects of diversity levels as below;

1. Genetic, or alpha, diversity refers to the variation of genes within species.
2. Species, or beta, diversity refers to the variety of species within a region, while species diversity can be measured in many ways; the number of species in an area or species richness is often used. Species diversity is also considered in terms of taxonomic diversity, which considers the relationship of one species to another.

3. Ecosystems, or gamma, diversity refers to numbers of species in a particular location, the ecological functions of the species, the manner in which the composition of the species varies within a region, the associations of species in particular areas, and the process within and between ecosystems. Ecosystem diversity extends to the landscape and biome level.

Noss and Cooperrider (1994) extended the definition, “Biodiversity is the variety of life and its processes. It includes the variety of living organisms, the genetic differences among them, the communities and ecosystems in which they occur, and the ecological and evolutionary processes that keep them functioning, yet ever changing and adapting.” With this definition, the ecological and evolutionary processes are also highlighted.

2.1.1. Biodiversity Decline in Anthropocene

Human civilization was developed by the modification of nature, invading wilder areas and consuming natural resources. Vitousek et al. (1997), stated 30-50% of the land surface had been transformed by humans. However, over two centuries this occupancy has pushed its limits and has accelerated tremendously and now this era is named as ‘Anthropocene’ (Mausser, 2006). This new definition marks the human interference to nature whose metabolism is impacting by the dominant force as humankind. Millennium Ecosystem Assessment (MEA, 2005) named the global challenges that threats biodiversity as “big five”. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) report (2019), ranked these impacts in their magnitude as (1) changes in land and sea use; (2) direct exploitation of organisms; (3) climate change; (4) pollution and (5) invasive alien species. Consequences of ‘global change’ include changes in the climate system, alteration of natural cycles, and also socio-economic systems. Some important indicators of change related to human activities within the last century are shown in Table 2.1.

Table 2.1. Some indicators of change caused by human activities (Crutzen, 2006)

Indicator	Increase/ Decrease	Change Factor (1800s-1900s)
World Population	+	4
Urban Population	+	13
Global Economy	+	14
Industrial Output	+	40
Energy Use	+	16
Coal Production	+	7
Carbon dioxide emissions	+	17
Sulphur dioxide emissions	+	13
Water use	+	9
Marine fish catch	+	35
Cattle population	+	4
Irrigated area	+	5
Cropland	+	2
Forest area	-	20%
Blue whale population (Southern Ocean)	-	99.75%
Bird and mammal species	-	1%

Due to the decline in biodiversity and ecosystems, ecological processes on which the survival of humankind depends on via the goods and services, disappear globally (Walpole et al., 2009; Tittensor et al., 2014). The direct loss of biodiversity in local, regional and global extents, and simplification of diverse habitats into lesser diverse habitats with more dominant species occupancies are seen many places globally (Pereira et al., 2012). However, the speed, intensity and selectivity of biodiversity loss varies spatially and temporally (Edie, 2018). Not only the importance, magnitude and

severity of the change among ecosystems and regions but also the interactions and the feedbacks changes and limit the resilience of ecosystems.

The exceptional loss of biodiversity over the last few centuries has been highlighted as “sixth mass extinction” (Ceballos et al., 2015). Mass extinction events were concluded with almost 75% of species loss within a geologically short period of time. Considering the previous five extinctions throughout earth’s five billion years of history, mass extinctions had triggered new formations or dominance such as from anaerobic bacteria through oxygen-generating algae. This innovation of life forms enabled recovery. Also, some abrupt changes such as an asteroid crash stimulated various organisms to evolve. Somehow earth overcame these mass extinctions. However, today the loss rate is higher than ever. Examples are listed by Ceballos et al. (2015) as follows (by using IUCN vertebrate data since 1500); 338 species have gone extinct (EX) and 279 species have gone extinct in the wild (EW). And most extinctions had occurred in the last century. And biodiversity loss is connected with global change as mentioned before as ‘Anthropocene’. The globalization, modernization, and economic development are major socio-economic drivers which cause the land cover changes, expansion of urban and agricultural areas, deforestation, over-harvesting, pollution and alteration of ecosystems which cause invasion and infection. These changes not only responsible for biodiversity crises but also for climate change. These global crises are connected and trigger each other. Biodiversity change is both a cause and an important indicator of threat. Another catastrophe is losing the information of billions of years of mutations and adaptations embedded in evolution. Development in biotechnology is still far away to catch and understand the knowledge of the past. Losing diversity means losing billions of years’ knowledge on evolution history that has a great opportunity for future (Scholes et al., 2017).

Humans are interested in biodiversity whether ethical, aesthetic, or utilitarian reasons. Ethical reasons comprise the rights of other organisms to live and also for the consideration of future generation legitimacy. Aesthetic reasons comprise the conservation of beauty and variety of nature for admiration. And lastly, human’s

survival and well-being depend on nature. In the following title, this utilitarian approach is explained further as “ecosystem services” title.

2.1.2. Human Dependence on Ecosystem Services

Biodiversity is vital for human survival. Agriculture and fisheries, medicine, pharmaceuticals are examples of ecosystem goods; these directly harvested goods are components of biodiversity. Also, various ecosystem mechanism and processes at different scales regulates the state, provide stability of the service and thus human well-being (Mace et al., 2012; Cardinale et al., 2012). Water regulation, carbon sequestration, and waste assimilation are fundamental samples of ecosystem services that humans benefit from nature (MEA, 2005). Beside these examples, intangible benefits such as cultural values are also provided by nature.

Ecosystem services can be categorized into four groups (Figure 2.1). Provisioning services are goods that are harvested and directly used by humans. They often have market values. Since they are tangible, the provisioning services are the most acknowledged. Regulating services are byproducts of fundamental ecosystem processes and functions; climate regulation, water quality, soil fertility, flood protection are some examples. The regulating services do not have a market value, indirect calculations are used. Cultural services are related with experiencing the nature; spending time, developing a sense of place and identity, attaching spiritual and aesthetics values are intangible benefits to humans (Balvanera et al., 2017). In general recreation and tourism have market values but other services in this category are valued by cognitive approaches. The last category is the supporting services that are composed of the indispensable process of ecosystems such as nutrient retention, primary production etc. These are crucial for the delivery of the other services and thus the existence of life on earth. Any service is provided by a particular ecosystem depends on specific components of biodiversity and its interaction with society. For example, the capacity of provisioning services and partly cultural services depend on

the abundance of species (non-forest timber products, area of a national park as a recreation opportunity). However, species richness and composition are also effecting mainly supporting and regulating services (Tilman et al., 2001; Pereira and Cooper, 2006).

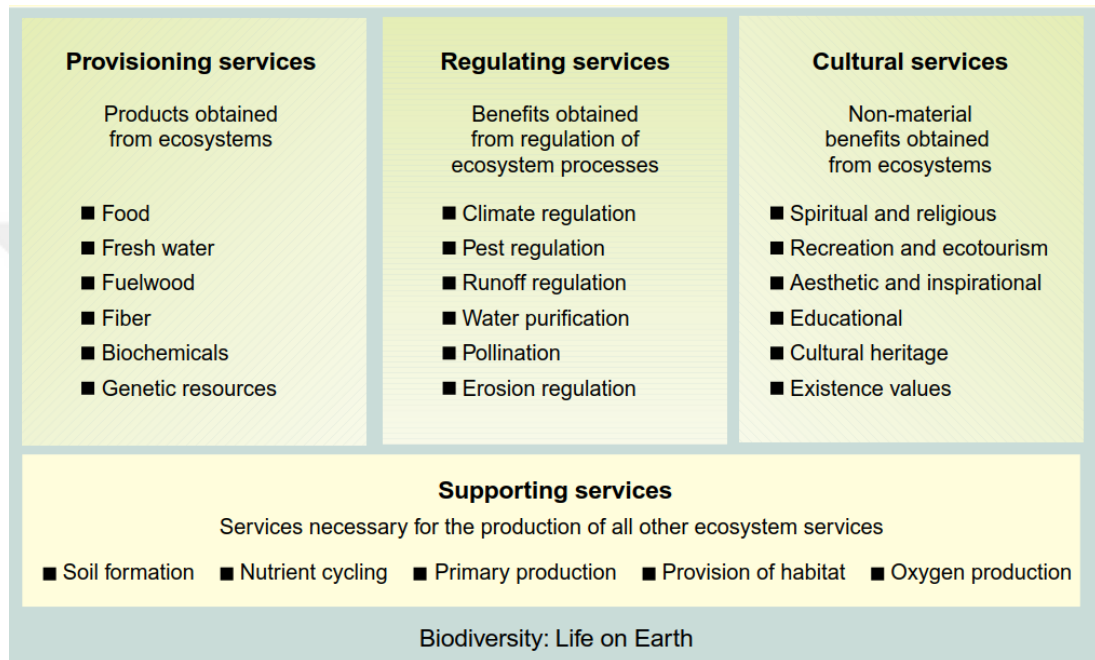


Figure 2.1. Classification of Ecosystem Services (Pereira and Cooper, 2006)

2.2. Biodiversity of Turkey

Turkey has high levels of biodiversity. Elevation ranges that start from sea level and exceed 5000 meters, had enabled speciation and intraspecific diversity during the last glacial maximum (Médail and Diadema 2009; Bilgin, 2011). Mediterranean basin, Caucasus and Irano-Anatolian hotspots meet in Turkey (Mittermeier et al., 2011) and Turkey is the only country where nearly its entire area is covered by three hotspots (Şekercioğlu et al., 2010) (Figure 2.2).

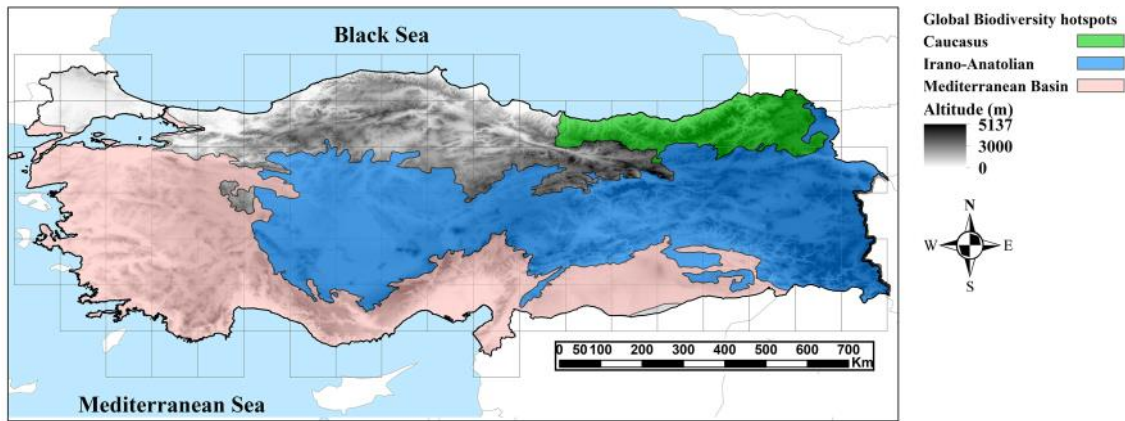


Figure 2.2. Biodiversity hotspots of Turkey (Noroozi et al., 2019)

In Turkey, 168 mammals (Şekercioglu et al., 2011), 502 birds (Kiziroğlu, 2008), 236 fish (Kuru, 2004), 11 turtles, 63 lizards, 55 snakes (129 reptiles) and 28 amphibians (Baran et al., 2012) exist. The numbers are updated with ongoing efforts. The updated taxon numbers are presented in Table 2.2 (Zeydanlı et al., 2020).

Table 2.2. Taxon numbers (Zeydanlı et al., 2020)

Species Group	Approximate number
Vascular plants	11.840
Birds	551
Freshwater fish	389
Mammals	176
Reptiles	149
Amphibians	35
Butterflies	377

Plant richness and abundance of endemic plants has been an interesting topic when considering biodiversity of Turkey. New plants are discovered approximately at a rate of more than one species per week (Özhatay and Byfield, 2003). The distribution of plants associated with the IUCN Red List is presented in Table 2.3.

Table 2.3. The distribution of plans according to IUCN red list categories (Ekim and Gür, 2017)

	EX	CR	EN	VU	LC- NT	DD	NE	Total
Red List of Plants (Ekim et al., 2000)	10	422	774	705	1541	223	3	3678
Updated version (Ananoymus, 2017)	3	1328	675	624	1264	130	28	4052

Turkey is located at the intersection of two major Vavilovian gene centers – the Mediterranean and the Near Eastern gene centers, both of which had a key role in the emergence of cereals and horticultural crops from such genera as lint (*Linum*), onion and garlic (*Allium*), barley (*Hordeum*), wheat (*Triticum*), oat (*Avena*), chickpea (*Cicer*), lentil (*Lens*), pea (*Pisum*), grape (*Vitis*), almond (*Amygdalus*), plum (*Prunus*), and sugarbeet (*Beta*). There are five micro-gene-centers in which more than 100 species display wide variation and which are the origin or center of many important crops and other economically important plant species such as medicinal plants and fruit tree species. These micro-gene-centers offer very important genetic resources for the future sustainability of many plant species cultivated across the world. These centers are (1) Thracian and Aegean area, (2) Southern and Southeastern Anatolia, (3) Samsun, Tokat, and Amasya provinces, (4) Kayseri Province and its surroundings, (5) Ağrı Province and its surroundings (FAO, 2018).

In addition to species richness ecosystem richness is also an enormous value for diversity. The wilderness areas and old-growth forests contributes to the functional and composition diversity of Turkey (Zeydanlı et al., 2020). Forests, steppes, arable lands, wetlands, inland waters as well as mountain, coastal and marine ecosystems diversify Turkey. CORINE land cover map (2018) which was showed in Figure 2.3 reflects the diversity of various land cover types in Turkey.

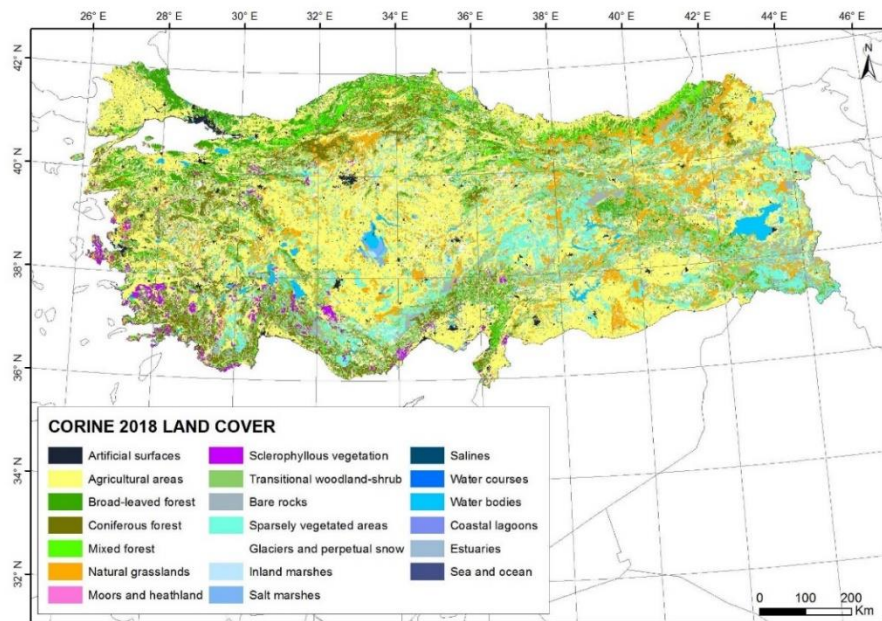


Figure 2.3. CORINE 2018 Land Cover Map of Turkey

Another schematization of ecosystem diversity is presented in Figure 2.4. This map which was produced by Olson et al. (2001) distributed by WWF, reflects the terrestrial ecoregions of Turkey.

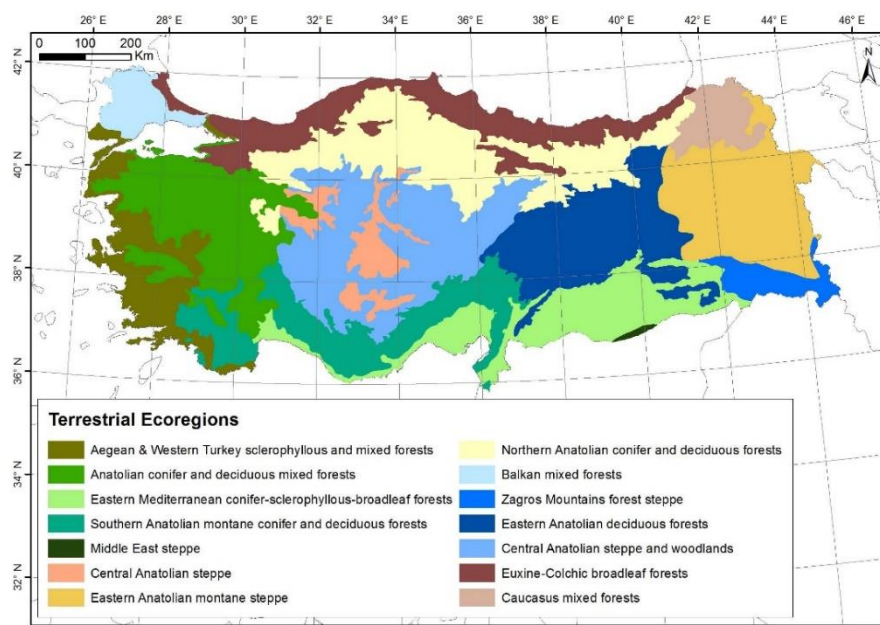


Figure 2.4. Terrestrial Ecoregions of Turkey (Olson et al., 2001)

Another contribution was done by Atalay et al. (2014) for assessing the ecoregions of Turkey (Figure 2.5).

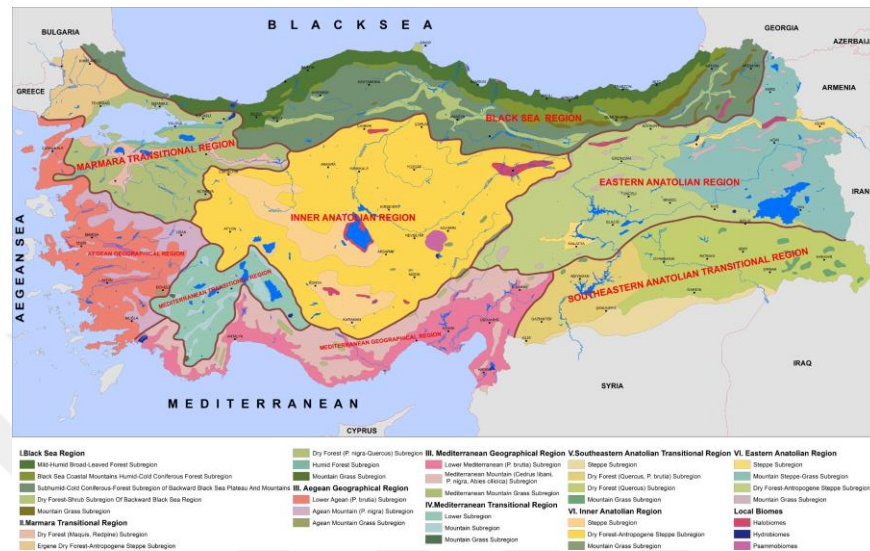


Figure 2.5. Ecoregions of Turkey (Atalay et al., 2014)

However, this astonishing diversity is threatened by several factors and the negative impacts over biodiversity is accelerating day by day. Population rise, developmentalist obsession, and interest in the rapid growth of economy exhaust the natural capital of Turkey. Energy consumption and demand toward hydro-electric power plants together with irrigation projects cause huge destructions in freshwater ecosystems and wetlands. Overgrazing and erosion degrade steppes and rangelands. Forest fires, deforestation and timber production threat the forests. Habitat loss occurs in coastal areas and maquis and phrygana shrublands due to construction of summer houses and tourism facilities (Evrendirek and Doygun, 2000; Şekercioğlu et al., 2011). Kahraman et al. (2012) listed the major activities threatening the gene pool of Turkey as over-grazing of meadow and grassland, erosion, stubble burning, agricultural practices by machine, irregular and excessive use of pesticides in agriculture, drying

of wetlands, dams, urbanization, industrialization, household and industrial waste, global warming, excessive hunting and collection and climate change.

2.3. Agents of Biodiversity Monitoring

Scholes et al. (2012) listed the main stakeholders of biodiversity monitoring community as; national biodiversity and natural resource communities; nature conservation and management agencies; national government departments responsible for biodiversity-related international treaty obligations; the treaty secretariats and United Nations organisations; non-governmental organisations (both national and international), and a variety of mostly science institution-based biodiversity information centers involved with the monitoring and conservation of biodiversity. In this section, the agents are grouped in international, regional and national levels and some political remarks have been presented for each level.

2.3.1. International Policies and Organizations

Turkey is a party to thirty international treaties and conventions on the environmental aspect¹. Table 2.4, shows the international conventions and protocols that require biodiversity monitoring directly or indirectly. Convention on Biological Diversity (CBD) is mentioned frequently in previous sections since its particular focus on biodiversity. However other conventions for instance UNFCCC (United Nations Framework Convention on Climate Change) and UNCCD (United Nations Convention to Combat Desertification) mandate environmental monitoring and suggest standardized monitoring terminology at ecosystem level for monitoring mitigating greenhouse gasses or desertification. Among these treaties, biodiversity monitoring politically and also scientifically are significantly mentioned in CBD. The COPs (Conference of the Parties) are triggering the topic and enables the generation of many other international organizations. Thus, CBD's success and failures in

¹ <http://www.mfa.gov.tr/ulkemizin-taraf-oldugu-baslica-cevre-anlasmalari.tr.mfa>

achieving its targets are given in detail. Additionally, Sustainable Development Goals (SDGs) as another mainstreaming global agenda are discussed further.

Table 2.4. International treaties that Turkey has been ratified

Annotation	Name	Year	Place	Year of ratification
Ramsar •	Convention on Wetlands	1971	Ramsar	1994
CITES •*	Convention on International Trade in Endangered Species of Wild Fauna and Flora	1973	Washington	1996
Bern •*	Convention on the Conservation of European Wildlife and Natural Habitats	1976	Bern	1984
UNFCCC °	United Nations Framework Convention on Climate Change	1992	Rio de Janeiro	2004
Kyoto °	The Kyoto Protocol on the United Nations Framework Convention on Climate Change	1997	Kyoto	2009
CBD *	Convention on Biological Diversity	1992	Rio de Janeiro	1996
Cartagena •	The Cartagena Protocol on Biosafety to the Convention on Biological Diversity	2000	Cartagena	2004
UNCCD °	United Nations Convention to Combat Desertification	1994	Paris	1998
Barcelona •*	Mediterranean Action Plan-Barcelona Convention	1995	Barcelona	2002
ELC	The European Landscape Convention	2000	Florence	2003
UNESCO	Convention concerning the Protection of World Cultural and Natural Heritage	1972	Stockholm	1983
• Monitoring of biodiversity is required/proposed ° Monitoring of land cover/ land use is required/proposed * Monitoring targets have been set in particular lists (species, ecosystems, etc.)				

2.3.1.1. Convention on Biological Diversity (CBD) and Aichi Targets

Convention on Biological Diversity (CBD) is the most important political instrument in terms of conserving biodiversity, globally. Since its development at the Rio Earth Summit in 1992, several targets have been imposed on countries for preventing biodiversity loss. In 2002, UNEP (2002) set the target as “to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth”. Similarly, twenty targets to be met by 2020 were defined under five strategic goals as Aichi Targets in 2011. These goals are;

- Strategic Goal A: Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society
- Strategic Goal B: Reduce the direct pressures on biodiversity and promote sustainable use
- Strategic Goal C: To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity
- Strategic Goal D: Enhance the benefits to all from biodiversity and ecosystem services
- Strategic Goal E: Enhance implementation through participatory planning, knowledge management and capacity building

Unfortunately, these ambitious goals were not achieved as they planned. Many authors highlighted several reasons behind this failure. The voluntarily reporting on selected indicators creates confusion for comparison and harmonization. Setting a list of biodiversity indicators list distracts monitoring focal from providing biodiversity data for certain aspects and minimum standards, and it may cause the unclear delivery of messages to decision-makers (Scholes et al., 2008; Pereira et al., 2013). Many developing countries choose their reporting indicators according to the available substantial data. The reporting mostly rely on data gathered for other purposes and

generally covers short time spans. Coverage of protected areas together with the extent of forest and forest types indicators are the most common reported indicators (Walpole et al., 2009; Butchart et al., 2010; Collen and Nicholson 2014). Tittensor et al. (2014) highlighted that only a few indicators are capable on reflecting accurate trend information. Most of them are difficult to interpret thus sometimes misguide the policies, especially on a global scale based on their temporal and spatial coverages. Only sixteen Aichi Targets have reliable metrics for monitoring progress.

Even so, the agenda mandated by CBD with global coordination is a great success. The creation of the national biological diversity strategy and action plans, shape the biodiversity strategies and policies in many countries, and push them to monitor measures and report ecological, evaluative and performative indicators.

Governments are in the process of developing a post-2020 global biodiversity framework that will guide actions in the decades to come (CBD, 2020).

Turkey had prepared “The National Biological Diversity Strategy and Action Plan 2018-2028” and contributed the Aichi Target 17. Recently 6th National Report² was presented to CBD secretariat. The report section in achieving Aichi targets (Section IV) left empty.

2.3.1.2. Sustainable Development Goals (SDGs)

United Nations is the key organization in defining the global agenda in sustainability perspective, it aims to bring together the nations with its decadal meetings. The first stimulated effort is the 1972 The United Nations Conference on the Human Environment namely as Stockholm conference. In 1982 Kenya summit was not successful because of the enmity during the cold war period. But afterwards, a remarkable report was published and guided the sustainability debates. Our Common Future report (Brundtland et al., 1987), emphasizing the environmental and development concerns and formulated a new way of thinking in policy and action

² <https://chm.cbd.int/database/record?documentID=249347>

related to sustainability concept. In 1992 at the Rio Earth Summit, the nations built a global partnership for sustainable development and parties adopted Agenda 21. In that conference three important conventions were opened to signature: (1) The Convention on Biological Diversity, (2) United Nations Framework Convention on Climate Change, (3) United Nations Convention to Combat Desertification. The Millennium Development Goals (2000-2015) were the results of these Earth Summits. In 2015 the United Nations General Assembly adopted the 2030 Agenda for Sustainable Development, along with a set of seventeen goals (2015-2030) (Figure 2.6) to end poverty, improve health and education, reduce inequality, and develop economic growth and ensure prosperity for all while tackling climate change and preserve the oceans and forests. The UN Sustainable Development Goals constitute a universal, integrated and transformative vision for the world.



Figure 2.6. Sustainable Development Goals

To achieve the 17 SDGs, 169 targets have been identified. However, these targets are qualitative and offer space to governments in interpreting and implementing the goals (Biermann et al., 2017). Biermann (2017) also criticized unless quantitative and

clearly defined, appropriate indicators would be defined, the weak implementation and governance might cause struggles in achieving goals. At this point, Reyers et al. (2017) present a similar approach to EBVs or ECVs, namely Essential Sustainable Development Goal Variables (ESDGVs) and a condensed sectoral set core ESDGVs for monitoring purposes and for a common standard reporting. ESDGVs comprise a system approach and integrates biophysical, social, economic subsystem models.

Reyers and Selig (2020) highlighted the link between the decline of ecosystem services and biodiversity and their negative impacts on SDGs. They used IPBES assessment in their analyses and revealed that only 35 targets can be evaluated among 150 targets. And all of the 35 targets demonstrate negative or insufficient progress. The other finding is data and knowledge gap limits our ability to monitor achievement and to link the target with biodiversity and ecosystem services.

2.3.1.3. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)

IPBES was established in 2012 by more than a hundred governments for to strengthen knowledge foundations for a better policy through science, for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development (<https://ipbes.net/history-establishment>). It rooted from Busan outcome that declared “an intergovernmental science-policy platform for biodiversity and ecosystem services should be established” in UNEP’s Third ad hoc intergovernmental and multi-stakeholder meeting on an intergovernmental science-policy platform on biodiversity and ecosystem services in 2010. The Platform’s conceptual framework includes six interlinked elements constituting a social-ecological system that operates at various scales in time and space:

- Nature
- Nature’s benefits to people
- Anthropogenic assets;

- Institutions and governance systems and other indirect drivers of change;
- Direct drivers of change
- Good quality of life.

Up to now several reports, assessments and decisions have been published by IPBES, guide the policy globally. IPBES 2030 work programme³ focuses on three topics, six objectives and fourteen sub-objectives. The three topics are;

1. Understanding the importance of biodiversity in achieving the 2030 Agenda for Sustainable Development
2. Understanding the underlying causes of biodiversity loss and determinants of transformative change and options for achieving the 2050 Vision for Biodiversity
3. Measuring business impact and dependence on biodiversity and nature's contributions to people

2.3.1.4. The International Union for Conservation of Nature (IUCN)

IUCN is a membership union composed of both government and civil society organisations. It was established in 1948. It harnesses the experience, resources and reaches of its more than 1,400 Member organisations and the input of more than 15,000 experts. This diversity and vast expertise make IUCN the global authority on the status of the natural world and the measures needed to safeguard it (<https://www.iucn.org/about>). The six commissions focusing on diverse topics of conservation and sustainable development.

- CEC – Commission on Education and Communication: promoting ecosystem-based approaches for the management of landscapes and seascapes,

³ <https://ipbes.net/work-programme>

- CEESP- Commission on Environmental, Economic and Social Policy: harmonizing nature conservation and the critical social, cultural, environmental, and economic justice concerns of human societies.
- SSC – Species Survival Commission: influencing, encouraging and assisting societies to conserve biodiversity by building knowledge on the status and threats to species
- WCEL – World Commission on Environmental Law: advancing environmental law to strengthen the legal foundations of conservation of nature and sustainable development
- WCPA – World Commission on Protected Areas: developing knowledge-based policy, advice and guidance on the full suite of issues surrounding protected areas

The most acknowledged product of IUCN is the Red List of Threatened Species (<https://www.iucnredlist.org/>). It was generated in 1964 and updated regularly. It is the most comprehensive data source on the global extinction risk of species.

IUCN also played a fundamental role in the creation of key international conventions, including the Ramsar Convention on Wetlands (1971), the World Heritage Convention (1972), the Convention on International Trade in Endangered Species, (1974) and the Convention on Biological Diversity (1992). Later in the 2000s, IUCN pioneered ‘nature-based solutions’ – actions to conserve nature which also address global challenges, such as food and water security, climate change and poverty reduction.

2.3.1.5. World Conservation Monitoring Centre (UNEP-WCMC)

UNEP- WCMC is a partnership organization and established under UN umbrella. Their partners are UN agencies and other inter-governmental organizations, national governments, secretariats of multilateral environmental agreements, international and national non-governmental organizations (NGOs), the private sector, and academic

and research institutions. Its mission is defined as “to provide authoritative information about biodiversity and ecosystem services in a way that is useful to decision-makers who are driving change in environment and development policy”. Specifically, they collaborate with data access, data management, data processing with biodiversity information systems. Apart from several online tools and reports, they share global spatial data and maps such as: world database on protected areas, global wetlands, global wilderness, world dryland areas, centers of plant diversity, etc. (<https://www.unep-wcmc.org/>).

2.3.1.6. Group on Earth Observations (GEO)

The Johannesburg Declaration on Sustainable Development and the Plan of Implementation, adopted at the World Summit on Sustainable Development in South Africa in 2002, the global and accurate data deficit was highlighted and underlined the urgency of filling data gap. Later, a voluntary organization composed of 111 governments and 129 participating international organizations has formed the GEO in 2005. GEO’s global priorities include supporting the UN 2030 Agenda for Sustainable Development, the Paris Climate Agreement, and the Sendai Framework for Disaster Risk Reduction. In addition to over 70 Work Programme activities and initiatives that address global needs, coordination and knowledge gaps. The GEO community generated the Global Earth Observation System of Systems (GEOSS) and has already made more than 400 million data and information resources accessible online (www.geoportal.org). The national and regional providers such as The National Aeronautics and Space Administration (NASA) and European Space Agency (ESA); international organizations such as World Meteorological Organization (WMO) and the commercial sector such as Digital Globe contribute the open-source data portal. Two flagships (GEO Biodiversity Observation Network (GEO BON), Global Forest Observation Initiative (GFOI)); eight initiatives and five community activities are actively working in GEO umbrella. The Essential Biodiversity Variables which are in the core of this dissertation was produced by GEO BON community.

2.3.1.7. The Biodiversity Indicators Partnership (BIP)

The Biodiversity Indicators Partnership (BIP) was established in 2007 in response to monitor progress towards intergovernmental targets. It is a global initiative to promote and coordinate the development and delivery of biodiversity indicators for use by several international conventions and treaties such as CBD, SDG, and IPBES. They guide the indicator development and selection by setting standards. BIP also ease to indicator match by categorizing the policy context (Aichi Targets, SDGs) and also themes: Terrestrial, marine & freshwater habitats, policy & conservation actions, species, pollution, sustainable use of natural resources and land, finance, research and knowledge, agriculture (<https://www.bipindicators.net/>).

2.3.2. Regional Policies and Organizations

2.3.2.1. European Union Legislation

European Union has developed strong legal tools to protect biodiversity across the continent. The main pillars are Birds and Habitat Directives. Birds Directive aims to protect wild birds of Europe. The Directive prohibits activities that directly threaten birds. Furthermore, it prohibits activities that directly threaten birds. It also designates almost 200 bird species as particularly threatened and requires Member States to establish Special Protection Areas (SPAs) to ensure that the most suitable areas are protected for the conservation of these bird species and migratory birds that occur in the EU. These Special Protection Areas are part of the Natura 2000 ecological network established under the Habitats Directive. Similar to the Birds Directive, the Habitat Directive Annex highlights almost 1200 particular species mostly endangered or vulnerable and habitat types. The most important outcome of the directives is Natura 2000 sites. Natura 2000 network composed of outstanding natural areas where the typical and most threatened habitats and species of Europe are protected and restored. Monitoring and reporting the status of sites are done territorially in six years intervals.

Although Turkey is not a member state yet, establishing a network of protected areas by using Natura 2000 concept is under the focus of General Directorate of Nature Conservation and National Parks. Recently “Technical Assistance for Strengthening the National Nature Protection System for Implementation of Natura 2000 Requirements” project has been executed by GDNCNP, in which Central Anatolian Region is studied (<http://natura2000.ormansu.gov.tr/>).

The 2030 Biodiversity Strategy of EU⁴, defines key commitments in the following elements;

- Establishing a larger EU-wide network of protected areas on land and at sea, building upon existing Natura 2000 areas, with strict protection for areas of very high biodiversity and climate value.
- An EU Nature Restoration Plan - a series of concrete commitments and actions to restore degraded ecosystems across the EU by 2030, and manage them sustainably, addressing the key drivers of biodiversity loss.
- A set of measures to enable the necessary transformative change: setting in motion a new, strengthened governance framework to ensure better implementation and track progress, improving knowledge, financing and investments and better-respecting nature in public and business decision-making.
- Measures to tackle the global biodiversity challenge, demonstrating that the EU is ready to lead by example towards the successful adoption of an ambitious global biodiversity framework under the Convention on Biological Diversity.

⁴ https://ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm

2.3.2.2. New Agenda: European Green Deal

European Green Deal⁵ is an action plan developed sequentially with “EU Biodiversity Strategy for 2030”, “EU strategies for energy system integration and hydrogen” and “EU Climate law”. It focuses “to boost the efficient use of resources by moving to a clean, circular economy” and “to restore biodiversity and cut pollution” and put an ambitious goal as making the Europe climate neutral by 2050. It has nine policy areas: biodiversity, from farm to fork, sustainable agriculture, clean energy, sustainable industry, building and renovating, sustainable mobility, eliminating pollution and climate action.

2.3.2.3. Barcelona Convention

In 1995, the Action Plan for the Protection of the Marine Environment and the Sustainable Development of the Coastal Areas of the Mediterranean was adopted by the Contracting Parties to replace the Mediterranean Action Plan of 1975. Turkey has ratified the convention in 2002. Although this convention focuses the marine realm, it has a particular impact on the development of a protected area network of Turkey by introducing a new category “Special Environmental Protection Areas”. Today, these areas occupy 35% of the total protected area coverage (calculated from

Table 2.7).

2.3.3. National Policies and Organizations

2.3.3.1. Governmental Organisations

The eldest institution is General Directorate of Forestry and rooted back to the Ottoman Empire. It was established in 1839 under the “Trade and Agriculture

⁵ https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/actions-being-taken-eu_en

Ministry” as the name of “Forest Directorate” (GDF, 2020). The environmental crimes such as pollution and illegal constructions were dealt by “Soubashi” who was an Ottoman gubernatorial title used to describe different positions within Ottoman hierarchy. The term was also used for the commander of the town or castle in the Ottoman Empire, an ancient version of the chief of police (Wikipedia, 2020).

After the republic was established in 1923, as a consequence of the parliamentary system, ministries became notable structures that have arranged policies, legislations and management. Until now there were several changes such as separations when the public services need diversification and particular attention or assembling when the legislative force needs to strengthen the responsibilities need to be unified (Lamba et al., 2014). As a consequence of these frequent changes nature protection and use of natural resources cannot gain a well-established character and a strong basis in national policies.

The Ministry of Forestry was established in 1969 and had continued its activities until 1981. In that year the Ministry of Forestry had joined with Ministry of Agriculture. In 1991, it was divided again as a separate ministry. Until 2003, the forestry and agriculture issues are evaluated as parallel topics and subject to rural services. In 2003, The Ministry of Environment and Forestry was joined. Later in 2011, a major change in structural organization occurred. The Environment section was joined with the former Ministry of Public Works and Settlement and the Forestry section was joined with the General Directorate for State Hydraulic Works (Figure 2.7).

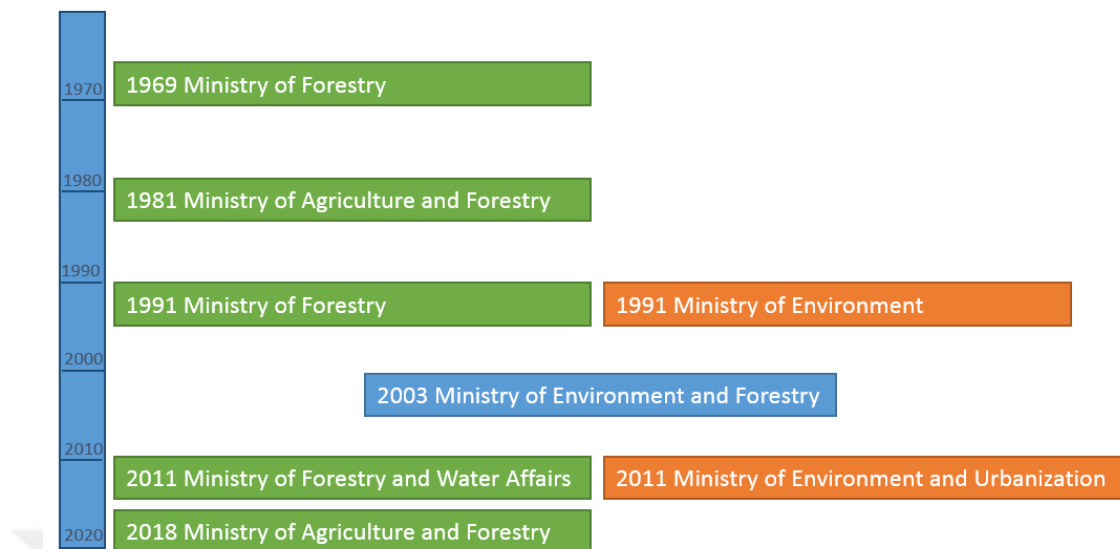


Figure 2.7. The arrangements in Ministries throughout the republic

The protection of nature has been issued by several arts and legislations were governed by several departments up to 1970. The first independent and relevant structure was established in 1973 as the "Environmental Problems Coordination Board".

In order to determine the basic policies for environmental protection, to prepare plans and projects related to the subject, and to ensure coordination between the relevant ministries and institutions in their implementation, the "Prime Ministry Environment Organization" was established in 1978. Environment Law No. 2872 dated 09.08.1983 has entered into force to address environmental issues in an integrated manner. With the Decree Law No. 222 dated 08.06.1984, the General Directorate of Environment was established as an institution with a legal personality, with an added budget and is responsible for implementing the Environmental Law.

With the Decree Law No. 383 of 19.10.1989, as another institution related to environmental protection, the Presidency of the Special Environmental Protection Agency with legal personality was established under the Prime Ministry. Then, it was

closed in 2011 and the General Directorate of Protection of Natural Assets was established under the Ministry of Environment and Urbanization.

The constitution of ministries and structural changes are linked with national acts and international conventions. The Figure 2.7 has been updated by adding these milestones. In Figure 2.8 the right hand side shows the international conventions and treaties starting with Bern Convention and accelerated in the 90s with several treaties; Ramsar Convention, CITES, CBD and UNCCD. The first decade of 2000 is another golden era considering the international relations such as Barcelona Convention, European Landscape Convention, Cartagena Protocol, UNFCCC and Kyoto Protocol. These conventions and agreements form an important backdrop to the issues surrounding biodiversity. And they are a significant pressure driving the development of a strong basin for biodiversity conservation.

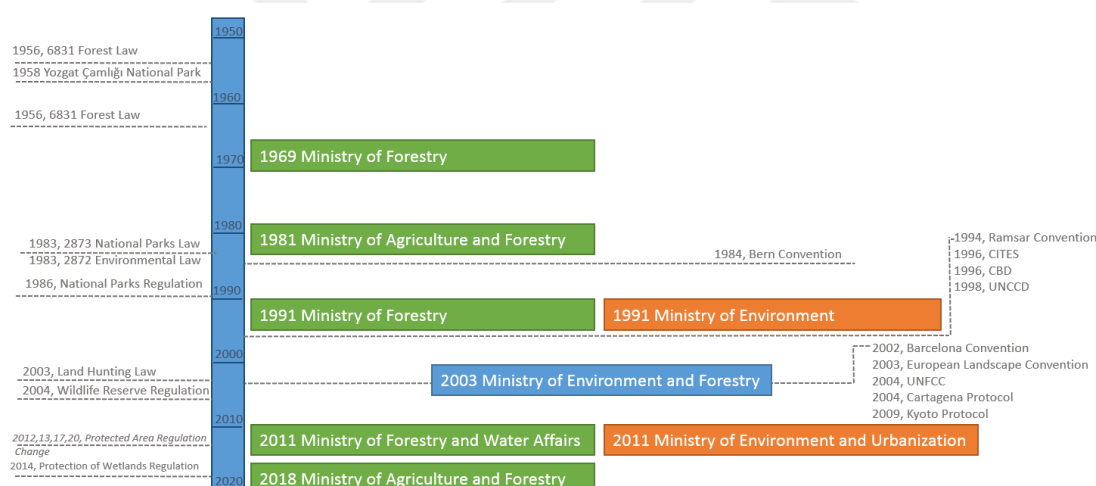


Figure 2.8. Milestones in biodiversity conservation and management

The important developments in national policy perspective have been listed on the left side of the Figure 2.8 also presented in Table 2.5. The 2873 National Parks Law become prominent among 35 laws, 3 decree laws, 23 regulations and 10 circulars for the conservation of the environment (Birben, 2019). The frequency of changes in recent years, particularly in the regulation of protected areas, is appalling.

Table 2.5. Milestones in National acts and regulations

Year	Act/ development
1956	6831 Forest Law
1958	Declaration of 1 st protected area; Yozgat Çamlığı National Park
1983	2873 National Parks Law
1983	2863 Conservation of Cultural and Natural Assets Law
1986	National Parks Regulation
1989	Agency for the Protection of Special Area
2003	Land Hunting Law
2004	Wildlife Reserve Regulation
2004	5199 Animals Protection Law
2010	General Directorate for Protection of Natural Assets
2012	Protected Area Regulation Change
2013	Protected Area Regulation Change
2017	Protected Area Regulation Change
2020	Protected Area Regulation Change

The major departments responsible for the protection of biodiversity is presented in Table 2.6. Two types of protection *in-situ* and *ex-situ* have been established

2.3.3.1.1. Ex-situ conservation

Ex-situ conservation is achieved through establishing gene banks, seed banks, zoos etc. and in general, the genetic material is preserved. Early studies had begun in 1933 for agricultural seeds (covering almost 50.000 seed samples) by Ministry of Agriculture and Ankara University. Atatürk and Çukurova Universities have seed banks and Istanbul University and Aegean University have arboretums and botanical gardens. Then, the National Seed Bank was established in 1972 in İzmir. There were 13 institutes which had gene banks in 1998 (NBDSAP, 1998) and raised to 16 in 2007

(NBDSAP, 2007). The seeds of endemic plants collected under the “Turkish Endemic Plants Project” between 1992 and 1997 are also preserved in the National Gene Bank.

Ex-situ conservation of forest trees (seed gardens, origin trials, progeny trials) were executed by the Ministry of the Environment and Forestry, especially by the Directorate of Forest Trees and Seeds Improvement and Research. A total of 169 seed gardens in 8 species, a total of 35 seed plantations in 19 species and a total of 13 clone parks in 5 species had been established to date (NBDSAP, 2007).

2.3.3.1.2. In-situ conservation

The protected areas are under the responsibility of the matching directorates. Only the biodiversity related departments are placed in the Table 2.6.

Table 2.6. The protected areas and responsible general directorates

Ministry	Departments	Protected Areas
Ministry of Agriculture and Forestry	GENERAL DIRECTORATE OF NATURE CONSERVATION AND NATIONAL PARKS Department of National Parks Department of Vulnerable Areas Department of Biological Diversity Department of Hunting Management Department of Nature Conservation Department of Wildlife Management	National Parks Nature Parks Nature Conservation Areas Nature Monuments Wildlife Conservation Areas Ramsar Areas Nationally Important Wetlands Wetland of Local Importance
	GENERAL DIRECTORATE OF FORESTRY Department of Non-timber Forest Products and Services Department Department of Forest Management and Planning	Protection Forests Gene Conservation Forests (in-situ) Seed Stands
Ministry of Environment and Urbanization	GENERAL DIRECTORATE OF CONSERVATION OF NATURAL HERITAGE Department of Research and Registration Department of Conservation and Monitoring	Special Environmental Protection Areas Natural Sites Natural Assets

Table 2.6. The protected areas and responsible general directorates (continued)

Ministry	Departments	Protected Areas
Ministry of Culture and Tourism	GENERAL DIRECTORATE OF CULTURAL HERITAGE AND MUSEUMS Headquarters Provincial Organizations Constant Scientific Committees	UNESCO World Heritage Sites Archaeological Sites Urban Sites Historical Sites Urban Archeological Sites

Protected areas provide shelter areas to biodiversity and secure the survival of organisms. They are important tools to conserve biodiversity and also improves the wellbeing of the local community (Stolton et al., 2015). The benefits through ecosystem services were presented in Figure 2.9.



Figure 2.9. Ecosystem services of protected areas (Stolton et al., 2015).

The distribution and coverage of protection status are presented in

Table 2.7. These numbers are used in CBD reporting. When we match the global IUCN categorization for protection status, 70 % of them has no equivalents in the

global assessment. Şekercioğlu et al., (2011) questioned the designation attributes of protected areas (mostly steep mountains, remote areas and not consider the habitat needs of wide range species), their isolated distribution and their position in the highly human occupied landscapes. For example, considering the negative impacts of climate change, organisms survival is highly dependent upon the individual capability of movement in this fragmented network. Their distribution among several organisations complicates the management. Also, the distribution of protected areas among ecosystems types is not distributed fairly. Especially the grasslands, river valleys and Mediterranean shrublands are undervalued (Eken et al., 2016; Ambarlı et al., 2016). Also, Atmış (2018) criticized the current utilisation policy within protected areas. Many public interest projects such as mining, tourism investments etc. get permissions even by changing the protected area status from one another.

Table 2.7. The statistics of Protected Areas as 31.12.2019 (MAF, 2020)

Ministry of Agriculture and Forestry Protected Areas	Number	Area (he)	IUCN categorization**
National Parks	44	868.428	Category II
Nature Parks	247	106.836	Category V
Strict Nature Reserve	30	46.726	Category Ia
Nature Monuments	116	9.389	Category III
Wildlife Conservation Areas	82	1.159.480	Category IV
Ramsar Areas	14	184.487	No equivalent
Nationally Important Wetlands	56	800.588	Category IV
Wetland of Local Importance	12	13.719	Category IV
Protection Forests	55	251.493	No equivalent
City Forests	134	10.198	No equivalent
Gene Conservation Forests (<i>in-situ</i>)	325	43.016	Category Ia
Seed Stands (<i>in-situ</i>)	315	41.567	No equivalent

Table 2.7. The statistics of Protected Areas as 31.12.2019 (MAF, 2020) (continued)

Ministry of Agriculture and Forestry Protected Areas	Number	Area (he)	IUCN categorization**
Seed Orchard (ex-situ)	202	1.457	No equivalent
SUB-TOTAL*	1.632	3.407.566	
Ministry of Environment and Urbanization Protected Areas	Number	Area (ha)	
Special Environmental Protection Areas	18	2.586.774	No equivalent
Natural Sites	2.574	1.784.071	No equivalent
TOTAL*	4.224	6.777.346	

* The intersections are eliminated. ** Derived from Zeydanlı et al. (2020)

2.3.3.2. Strategical Documents

2.3.3.2.1. The National Biological Diversity Strategy and Action Plans (NBDSAP)

The General Directorate of Nature Conservation and National Parks (GDNCNP) had prepared the national biological diversity strategy and action plan firstly in 1998 and updated the strategy in 2007 and 2018. These strategies were delivered to CBD secretariat to discharge the responsibility in the sixth article.

The main goals defined in each NBDSAP presented below;

1998 NBDSAP;

- Conservation and Sustainable Use
- Ecological Management
- Education and Awareness
- Incentives and Legislation

- International Cupertino
- Implementation

2007 NBDSAP;

- GOAL 1: To identify, protect and monitor biological diversity components which have importance for Turkey
- GOAL 2: To use biological diversity components in a sustainable manner by applying the methods and at a level fitting to their renewal capacity by taking the future generations' needs into account
- GOAL 3: To identify, protect and benefit the components of genetic diversity, including the traditional knowledge, which have importance for Turkey
- GOAL 4: To identify, protect and monitor the components of biological diversity which have importance for agricultural biological diversity; to protect genetic resources which have actual and potential values for food and agriculture, and to ensure the sustainable use of such resources; and to ensure the fair and equitable sharing of the benefits arising out of the utilization of genetic resources
- GOAL 5: To protect steppe biological diversity, to ensure the sustainable use of its components, as well as to ensure the fair and equitable sharing of the benefits from the utilization of genetic resources; and to combat against the loss of steppe biological diversity and the socio-economic results of that
- GOAL 6: To establish an effective monitoring, management and coordination system for the conservation of forest biological diversity and the sustainable use of its components
- GOAL 7: To establish an effective monitoring, management and coordination system for the conservation and sustainable use of mountain biological diversity, together with its different ecosystems, pursuing a holistic approach
- GOAL 8: To develop and implement effective methods for the conservation of inland waters biological diversity, the maintenance of ecological functions of inland waters ecosystems, and the sustainable use of these ecosystems

- GOAL 9: To develop and implement effective methods for the conservation of coastal and marine biological diversity, the maintenance of ecological functions provided by coastal and marine ecosystems, and the sustainable use of these ecosystems
- GOAL 10: To establish a mechanism for the implementation of the Biological Diversity Strategy and Action Plan and the follow-up of implementation and reporting

2018 NBDSAP;

- NATIONAL OBJECTIVE 1: Pressures and threats on biodiversity and ecosystems will be determined, reduced to the possible lowest level or removed totally
- NATIONAL OBJECTIVE 2: Biological diversity components (ecosystem, species and genetic variability) will be determined, monitored, and species-specific and ecosystem-based conservation approaches (traditional and modern) will be developed by determining the current condition of biodiversity
- NATIONAL OBJECTIVE 3: Conservation and sustainable management of biodiversity of areas exposed to agriculture, forestry and fishing activities in the country will be ensured
- NATIONAL OBJECTIVE 4: Awareness of the public and administrators on ecosystem services will be raised, benefits from ecosystem services will be increased and sustainable biodiversity management will be ensured
- NATIONAL OBJECTIVE 5: Rehabilitation and restoration of ecosystems damaged due to different reasons will be ensured, measures to prevent damage to healthy ecosystems will be developed and legislative gaps thereon will be fulfilled
- NATIONAL OBJECTIVE 6: In order to develop high added value products based on knowledge and technology concerning conservation and sustainable use of biological resources, coordination mechanisms among universities,

public and private sectors will be established, and long-term plans and programmes will be prepared

- NATIONAL OBJECTIVE 7: National legislation will be prepared considering the international conventions on access to genetic resources and fair and equitable sharing of the benefits arising from their utilization, and the necessary technical infrastructure will be established

Each NBDSAP differs in content (Table 2.8). Early efforts (1998 and 2007) more focused on the identification of biodiversity values and highlighting threats among them. It is evident from the documents that the institutional capacity has risen throughout these years. One major distinction is the major shift in stakeholders composition while preparing the NBDSAPs. In 1998 and 2007 NBDSAPs, major universities and NGOs included in the preparation also, the documents had featured the projects accomplished by non-governmental institutions. However in the last NBDSAP, the other agents' participation into preparation was ignored, only governmental organisations had contributed the plan. Only the projects of the governmental organization took place in it although several large scale projects executed by NGOs have contributed to the conservation of biodiversity.

The last NBDSAP (2018) had a section where the Aichi targets directly linked with NBDSAP 2007 and 2018. This linkage enables to highlight the gaps such that the foreseen activities in 2007 NBDSAP contributed to 19 targets among 20 Aichi targets, on the other hand, 2018 NBDSAP' activities are planned to serve 18 targets. However, it is recognized that a number of foreseen activities have these linkages. Also, the criteria used for evaluating the performance of NBDSAP does not match with the index and indicators suggested for monitoring purposes by BIP. As long as the objectives are not SMART (Specific, Measurable, Assignable, Realistic and Time-related) (Doran, 1981) the success or failure cannot be quantified directly. For example, the indicators in management activities are defined as the number of projects or pilot studies. However, no threshold was identified.

Table 2.8. Contents of The National Biological Diversity Strategy and Action Plans (NBDSAP)

1998	2007	2018
• Overview of Turkey's Biodiversity • Presentation of biodiversity and threats in accordance with ecosystems • Identification of Priority Issues • Strategy and Goals	• Overview of Turkey's Biodiversity • Presentation of biodiversity and threats in accordance with ecosystems • Cross-cutting issues • Strategic goals, priorities and actions • National Biodiversity Action Plan • Implementation Mechanism • Success criteria and the outcomes expected in the first five years	• Implementation status of NBDSAP (2007-2017) • National Legislation • National Biodiversity Action Plan, Objectives and Actions • Monitoring Mechanism

The previous NBDSAPs (1998 and 2007) had considered the threats over biodiversity. Also in 2007 NBDSAP a synthesis was done about the gaps and challenges, that were listed thereon; *“the lack of sufficient coordination between institutions regarding biological diversity studies, the non-completion of inventory studies, the non-completion of the setting up of a national database and monitoring unit yet, the insufficient number of experts and technical staff in the relevant institutions, the insufficient number of academic researches, the lack of experience and technology transfer, the poor level of staff and technical facilities for monitoring, the lack of accessible available information, and the most important of all, the lack of resources.”*

This GAP analysis was categorized into four groups: Human resources, financial resources, infrastructure, legislation and institutional structure (Figure 2.10).

TARGET	HUMAN RESOURCES				FINANCIAL RES.			INFRASTRUCTURE				LEGISLATION				INSTITUTIONAL STR			
	NUMBER OF PERSONNEL	QUALITY OF PERSONNEL	TRAINING OF PERSONNEL	EMPLOYMENT POLICIES	LACK OF RESOURCES	INEFFECTIVE UTILIZATION	APPLICATION DIFFICULTY OF BIDDING PROCEDURES *	LABORATORIES	EQUIPMENTS AND CHEMICALS FOR ANALYSIS	EQUIPMENTS FOR FIELD STUDIES	INFORMATION SYSTEMS	INCONSISTENCIES IN LEGISLATION	LACK OF LEGISLATION	LACK OF ENFORCEMENT	LACK OF PUNISHMENT	LACK OF COMMUNICATION AND COORDINATION	LACK OF RELEVANT INSTITUTION	DUBLICATED OR UNCERTAIN TORs	LACK OF CAPACITY
INVENTORY		X		X	X	X	X			X	X					X		X	
MONITORING	X	X		X	X	X				X	X			X		X		X	
RESEARCH & DEVELOPMENT		X		X	X	X		X	X							X			
INFORMATION MANAGEMENT		X	X	X		X					X		X			X			

Figure 2.10. Gap analysis conducted in NBDSAP (2007)

Currently, the species inventories have been completed. Another improvement is the setting up of a national database and monitoring unit completed. Yet, the other limitations are still valid. The 2007 NBDSAP, with its well-structured content, detailed activity descriptions and time tables was the most comprehensive compared to the other NBDSAP.

2.3.3.2.2. XI. Development Plan (2019-2023)

The Presidency of the Republic of Turkey, Directorate of Strategy and Budget has prepared the 11th Development Plan (2019) with the participation of various stakeholders, governmental, non-governmental organisations and academia. The plan highlighted the biodiversity and ecosystem integrity with the targets presented in Table 2.9.

Table 2.9. *The biodiversity linked targets in the 11th Development Plan (2019-2023)*

Goal	Definition
364.3.	The infrastructure will be developed for production of chemical, floral, biological and radiopharmaceutical (nuclear) raw material
412	Our biological diversity will be preserved in the field of local animal breeds and seeds in agricultural production and thus the production would be sustainable
412.1.	Biodiversity inventory will be completed, important species and special areas will be monitored, sharing the benefits derived from genetic resources and related traditional knowledge mechanism will be established for the purpose of recording traditional information based on biodiversity, and it will be made available for R&D purposes
416.2	Studies carried out with priority in the fields of protection of biodiversity, animal and plant breeding, biotechnology will be supported within the framework of cooperation of research institutes, public, university and private sector
666	To ensure the sustainable development of cities; ... In this context, prevention of environmental pollution, biodiversity and natural resources conservation and sustainable usage is given priority
716	Biodiversity and genetic resources detection, registration, protection, sustainable use, development, monitoring and prevention of trafficking will be ensured, Benefits obtained from genetic sources and related traditional knowledge will be sustained at national level
716.1	The national biodiversity inventory is updated regularly conducted through research and monitoring studies, traditional knowledge based on biological diversity is recorded and will be made available
716.2	Conservation and sustainable use of biological diversity and genetic resources, legislation to prevent smuggling will be developed
716.3	A mechanism for equal and fair sharing of benefits will be established for to access to genetic resources and obtained from these resources and traditional knowledge
717	Ecosystems and ecosystem services will be protected, restored and used sustainably by increasing the number of protected areas on land and sea and the effective management of protected areas will be realized
717.1	By increasing the number of protected areas on land and sea, effective management of these areas will be carried out by generating green corridors, planning and infrastructure works
415	The contribution of forests to the economy will be increased by sustainable forest management
415.1	National Forest Inventory study will be completed
415.2	Capacity to combat diseases, pests and fires in forestry will be strengthened.

2.3.3.3. Major Developments in Biodiversity Monitoring

Under this title, major developments accomplished by the General Directorate of Nature Conservation and National Parks (GDNCNP) which is the top responsible organization in the biodiversity monitoring topic is presented and assessed.

2.3.3.3.1. National Biodiversity Inventory and Monitoring Project (UBENIS)

Biodiversity inventories are more than simple lists of names. Inventories comprise surveys, catalogues, quantifications and maps of biological entities that can be genes, species, populations, habitats, ecosystems and landscapes. Inventories are “snapshots of the state of biodiversity” and they provide necessary baseline information to analyze the change. After defining inventory as it, Stork et al. (1996) identify monitoring as “recording change” and continues definition as “intermittent surveillance to ascertain the extent of compliance with a predetermined standard or degree of deviation from an expected norm”.

National Biodiversity Inventory and Monitoring project (UBENIS) has been initiated in 2013 by the monetary support of the Ministry of Development and executed by Ministry of Agriculture and Forestry General Directorate of Nature Conservation and National Parks. Currently, all of the 81 provinces’ inventories have been completed by literature review and field surveys for the following species groups;

- Vascular plants, mammals, birds, freshwater fish, reptiles and amphibians.

And only literature reviews for the followings;

- Cryptogamic plants and invertebrate animals.

The project progress report was prepared in 2019 and covers statistics of 74 provinces except seven provinces (Manisa, Muğla, Muş, Mardin, Siirt, Şırnak, Hakkari)⁶. Below statistics are presented in this progress report. Totally, 423.357 fauna and, 334.342 flora points were recorded from 13.231 taxon out of 11.815 were plants. 539 local endemic and 4305 endemic taxon were identified (Figure 2.11).

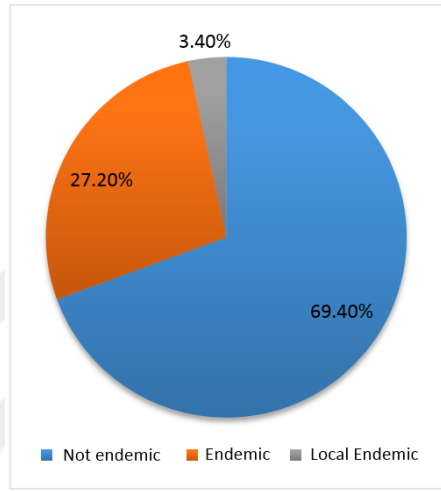


Figure 2.11. Distribution of endemism (Source: UBENIS progress report)

Distribution of species according to IUCN Red list categories are presented in Figure 2.12 for flora and Figure 2.13 for fauna. However, compared with Figure 2.23. IUCN Red List Categories of species (Source: Noah's Ark) almost 3000 species were assessed as CR. And it is surprising not to see any CR species in this assessment. Some corrections might have done within the last two years.

⁶ <http://www.nuhungemisi.gov.tr/Content/Documents/Projects/ubenis.docx>

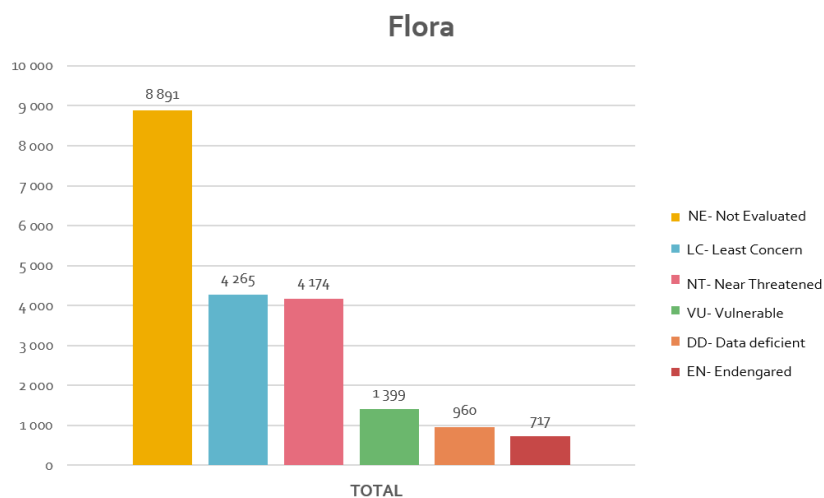


Figure 2.12. IUCN Red List Categories of flora records (Source: UBENIS progress report)

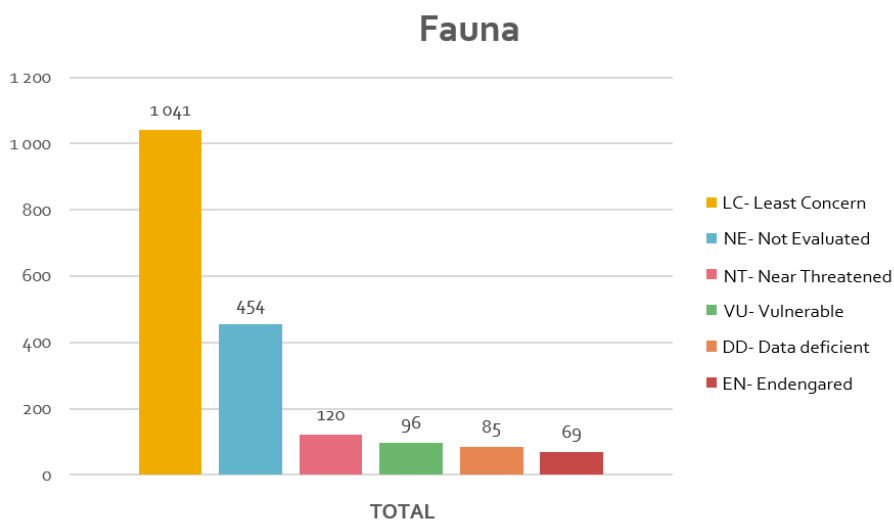


Figure 2.13. IUCN Red List Categories of fauna records (Source: UBENIS progress report)

The most influential outcome of the project is the identification of monitoring sites at species/population, habitat/ecosystems and regional level (Figure 2.14).

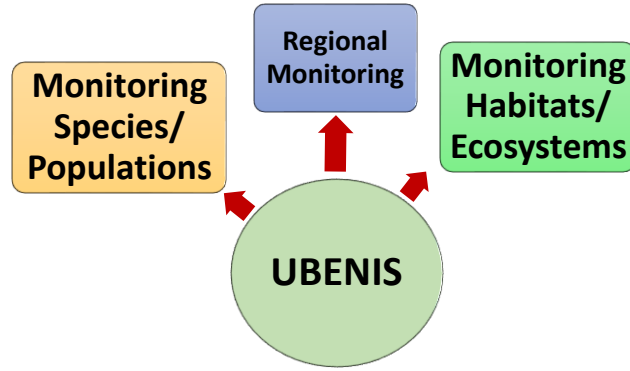


Figure 2.14. Proposed monitoring scheme

Monitoring sites for flora and fauna are presented for the 65 provinces in Figure 2.15 and Figure 2.16 accordingly. And also the map of special sites for monitoring is given in Figure 2.17. For these 65 provinces; 262 flora, 208 fauna and 236 special sites are identified for monitoring. The proposed regional monitoring sites which are supposed to be done by remote sensing, are not presented in the progress report. Even though these maps are incomplete, the characteristics of the monitoring can be inferred from them.

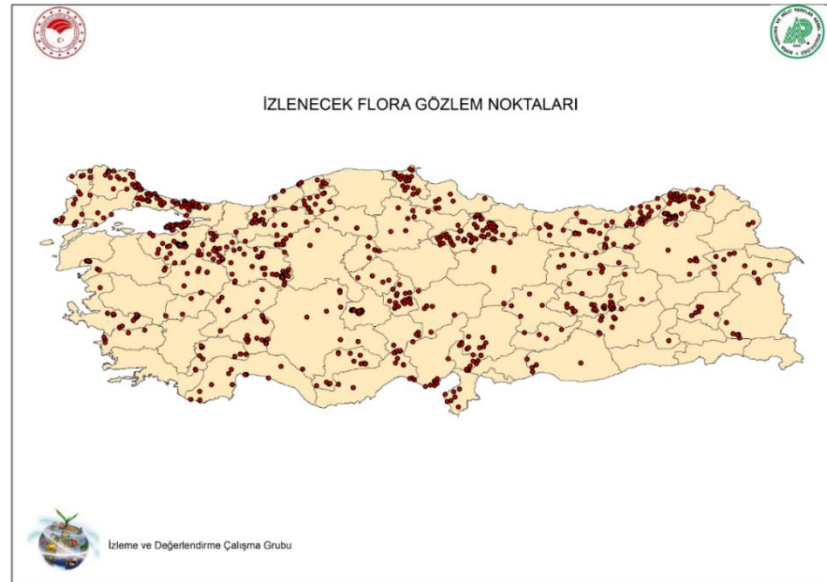


Figure 2.15. Map of monitoring sites for flora (Source: UBENIS progress report)

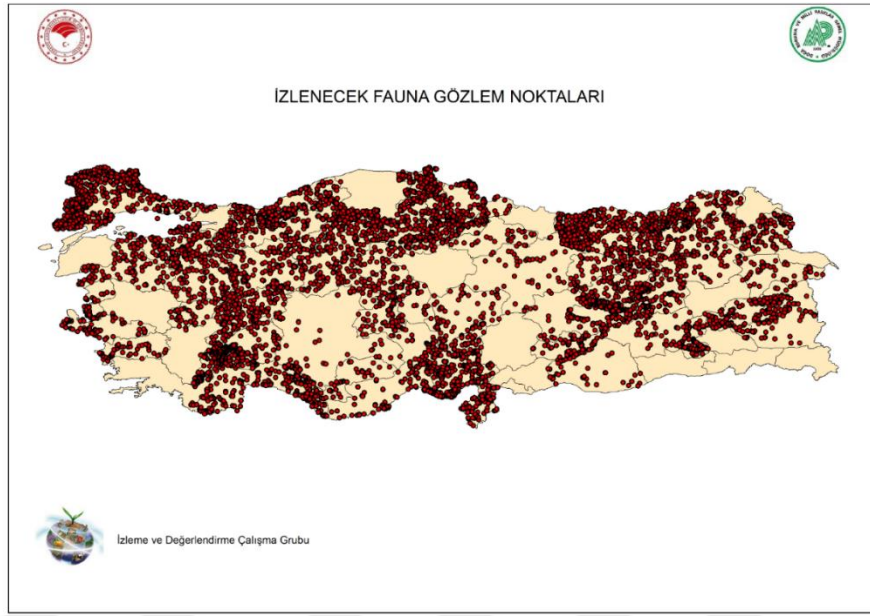


Figure 2.16. Map of monitoring sites for fauna (Source: UBENIS progress report)

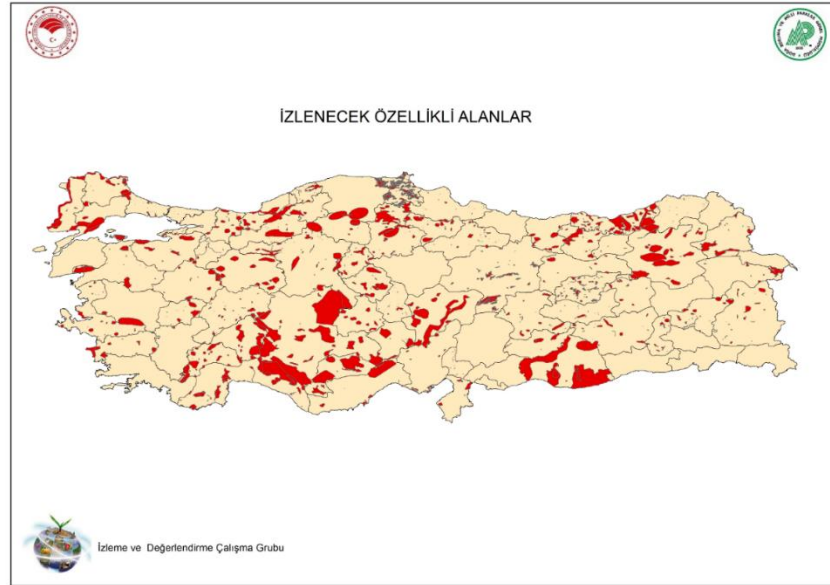


Figure 2.17. Map of special monitoring sites (Source: UBENIS progress report)

I overlapped these maps in PhotoShop software to understand the intersections with special sites with flora and fauna sites (Figure 2.18). These maps showing enormous variances for the areal coverage and distributions of monitoring sites. One reason for

this is the tender process applied through the project execution. Probably, each province inventory and assessment has been completed by different teams with different approaches. The other question is the link between monitoring sites and protected areas. The progress report does not present a clue about this issue.

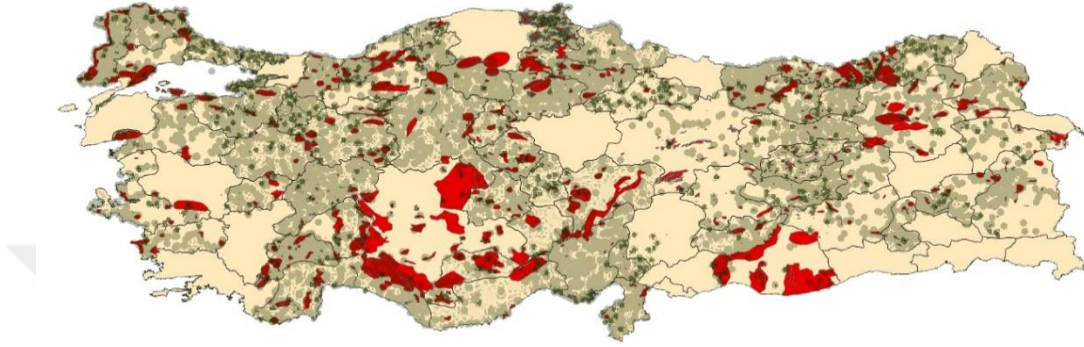


Figure 2.18. Map of proposed monitoring sites (overlapped in Photoshop)

This project contributes to the comprehensive surveillance of biodiversity and generation of species lists. In the progress report, it is also mentioned that the ecosystem mapping has been done by EUNIS nomenclature, however no output has been shared up to now related with habitat mapping section. A particular section has been prepared related with non-wood plant and animal products and taxon with economic values such as medical plants, grassland plants, food production, genetic material, landscaping and ornamental plants, bee plants, herbal plants etc. but conservation and management effectiveness cannot find a place in the report.

2.3.3.3.2. Species Action Plans

The Species Survival Commission of IUCN has promoted Species Action Plans since 1986 (McGowan et al., 1998). It is defined as a prescriptive plan for a species, aiming to maintain the species status in a favorable conservation or restoring it. A Species

Action Plan (SAP) is a scientifically authoritative and a strategic document which includes specific, measurable objectives and actions for conserving priority species (Sande et al., 2005). The Ministry of Forestry and Water Affairs put a target to accomplish 100 Species Action Plans by 2023 (DAD, 2013). Three birds (*Grus grus archibaldii*, *Otis tarda*, *Tetrao mlokosiewiczi*), three fish (*Alburnus nasreddini*, *Capoeta mauricii*, *Salmo coruhensis*), five herpetofauna (*Acanthodactylus schreiberi*, *Darevskia Sapphirina*, *Rafetus euphraticus*, *Vipera anatolica*, *Vipera kaznakovi*), one invertebrate (*Formica pratensis*), eight mammals (*Dama dama*, *Felis chaus*, *Hyaena hyaena*, *Meriones dahli*, *Monachuys monachus*, *Monachuys monachus*, *Myomimus roachi*, *Myotis brandtii*) and nineteen plants (*Iberis halophila*, *Ajuga xylorrhiza*, *Alyssum nezaketia*, *Astragalus beypazaricus*, *Crocus speciosus subsp. Xantholaimos*, *Erodium hendrikii*, *Ferula mervynii*, *Fritillaria baskilensis*, *Iris peshmeniana*, *Ornithogalum malatyanum*, *Hypericum malatyanum*, *Lilium candidum*, *Polygonum samsunicum*, *Pseudodelphinium turcicum*, *Rhodothamnus sessilifolius*, *Salvia siirtica*, *Scilla mesopotomica*, *Thermopsis turcica*, *Tulipa orphanidea*, *Verbascum eskisehirensis*, *Verbascum yurtkuranianum*) in total thirty nine SAPs had been prepared and published between 2013 and 2016. The reports of these action plans were accessed from the former Ministry of Forestry and Water Affairs in 2017 May via weblink⁷. The SAP reports cannot be available online after the ministry's structure has changed.

Demirbas-Caglayan and Bilgin (2018) have evaluated the performance of SAPs according to the various criteria presented by several authors (McGowan et al., 1998; Fuller et al., 2003; Sande et al., 2005; AEWA, 2005; Nagy, 2009; Kovács and Williams, 2012; DAD, 2013; IUCN, 2016). The SAPs condensed on plants and endangered species (Figure 2.19).

⁷ <http://www.milliparklar.gov.tr/yabanhayati/turkorumasube/>

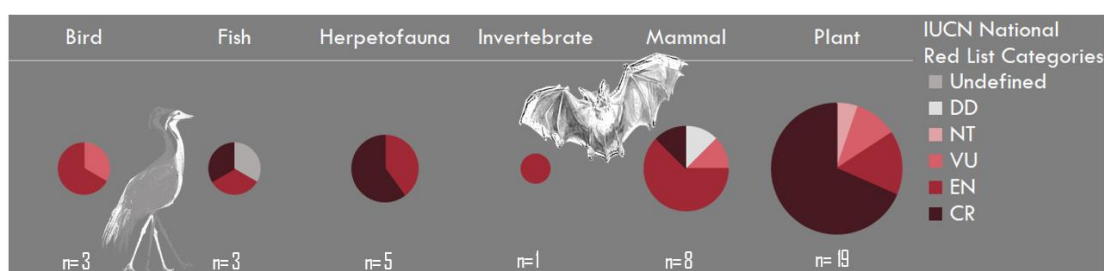


Figure 2.19. Distribution of species among IUCN Red List Categories (The proposed categories in the SPAs are evaluated) (Demirbas-Caglayan and Bilgin, 2018)

Each SAP includes background information with the current status and a threat analysis and proposed conservation actions in detail. A SAP must have a vision for the long term desired state of the species as well as aims that outline the plan's specific contributions during its life span. SMART (specific, measurable, achievable, realistic and timely) objectives are statements that provide details to reach those aims. The activity package is the core of a SAP. Each activity should answer who, when, how frequent, how urgent, at how much cost an activity is to be performed and what is needed for it. An evaluation strategy at mid-term and the end of a SAP is also recommended. Totally 33 criteria have been used and scored to each SAP as a binary matrix to provide a comparative assessment. In Table 2.10, colours represent the percentage of SAPs which meet the criteria in that species group. These 39 plans provide very detailed information on the life history of the target species and have largely met the defined criteria in the fields of taxonomy, morphology, habitat requirement, life cycle, global and local distributions, and laws and regulations. However, population size is often given only as the number of individuals observed during site studies, and a population estimate is only reported in a few SAPs. Only one SAP included a population viability analysis (*Polygonum samsunicum*, 2015). 64% of SAPs rank the threats and 66% provide stakeholder analysis. Most (87%) do not include indicators for objectives. Almost all define the responsible organization, site, and time of the activity while only 33% define costs or required technical expertise or equipment, and only 35% rank urgency of the activities. None of the SAPs meet all of

the defined criteria. 58% placed an evaluation of SAP activities in the plan but only 12% describes a means of verification of success. Monitoring of the target species is not recommended as an action in a single SAP (*Salmo coruhensis*, 2013). Other SAPs define monitoring activities on genetic (10%), species (100%), population (82%), community (25%) and habitat (50%) levels.

Table 2.10. Evaluation table of 39 SPAs according to the criterions

	Invertebrate	Bird	Fish	Herpetofauna	Mammal	Plant
Population size						
Population viability analysis						
Ranking of threats						
Measures related with threats						
Stakeholder analysis						
Clarity of location						
Requirements or cost of the activity						
Priority of the activity						
Monitoring of SAP						
Means of verification						
Defined thresholds						
Indicators for monitoring						
Monitoring population						
Monitoring habitat						
Monitoring interactions with other species						
Monitoring life cycle/ life history						
Monitoring breeding success						
Monitoring genetic diversity						

0-20%	21-40%	41-60%	61-80%	81-100%

General limitations apparent in the SAPs are listed as follows (Demirbas-Caglayan and Bilgin, 2018);

- The duration of preparation the action plan is limited with tender generally expected to finalize within a year. However, it is rarely possible to understand the population dynamics, compositional interactions or ecosystem-level dynamics.
- Monitoring and evaluation of a SAP is an essential component to assess its progress towards achieving the aims. Clear definitions, indicators and means of verification are needed to ensure SAPs are more than academic exercises.
- Monitoring actions are often described without detail. Well-defined sampling schemes, monitoring requirements, or inclusion of population thresholds are needed.
- High endemism rates in plants unsurprisingly lead to a strong emphasis on them. However, it is important to include other indicator and threatened organism groups as well.
- Most SAPs propose new sites for the protection of the target species. Existing protected area network should not be ignored.
- About half of the target species range wider than their SAP's coverage. It is important to cover the whole range of the species within Turkey to develop conservation actions.

2.3.3.3.3. Noah's Ark National Biological Diversity Database

The most important development is the generation of "Noah's Ark National Biological Diversity Database" (Akgündüz et al., 2009). Biological data especially species records collected by UBENIS project and Species Action Plans have been stored in Noah's Ark National Biological Diversity Database. Although the database was

generated in 2007, the data entry has been shifted with national effort after the UBENIS project was initiated in 2013 (Figure 2.20).

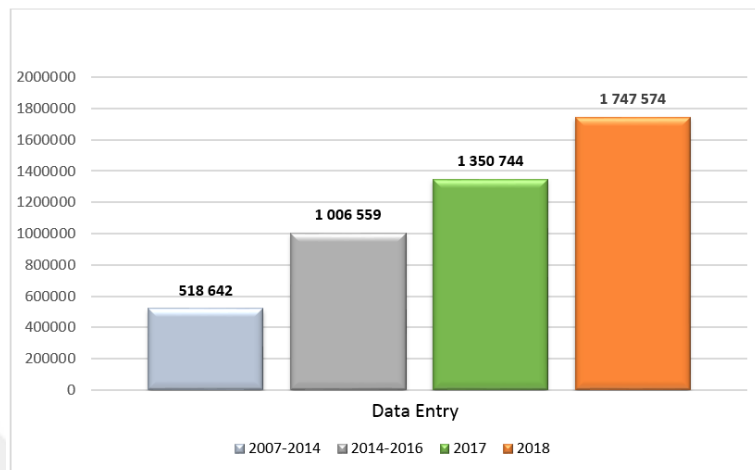


Figure 2.20. Progress of data entry in Noah's Ark (Source: UBENIS progress report)

The database includes 852.813 point records (Figure 2.21) from 14.334 taxon (Figure 2.22) for 81 provinces (<http://www.nuhungemisi.gov.tr/public/>). The distribution of species according to the IUCN Red List Categories is given in Figure 2.23. The database is under the responsibility of GDNCNP, due to strict restrictions, no data has been shared even with the data collectors. For to collate the database's accessibility information, I have searched the Scopus and Google Scholar search engines with the following keywords: [*“nuhun gemisi” OR “veritabanı” OR “biyolojik çeşitlilik” / “noah's ark” OR “database” OR “biodiversity”*]. The results (33) only mention the existence of the database but none of the studies presents its data or an analysis by use of the biological data. Similarly, none of the NGOs could acquire data from the database for conservation projects or site management projects (personal communication through survey respondents).

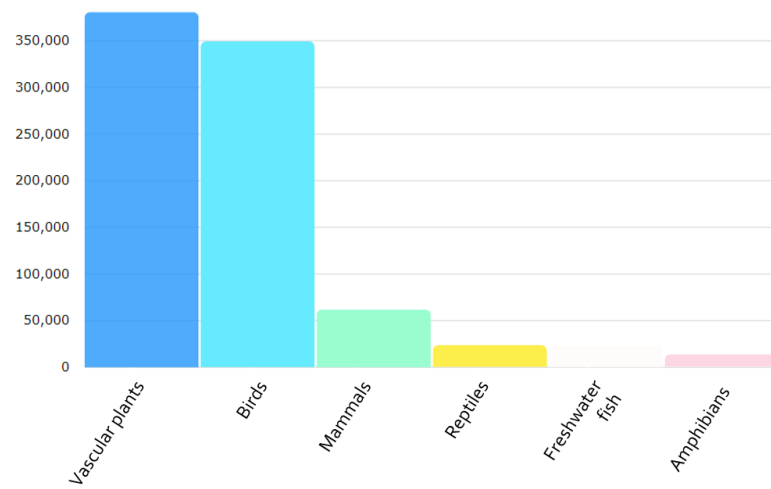


Figure 2.21. Number of points on species group (Source: Noah's Ark)

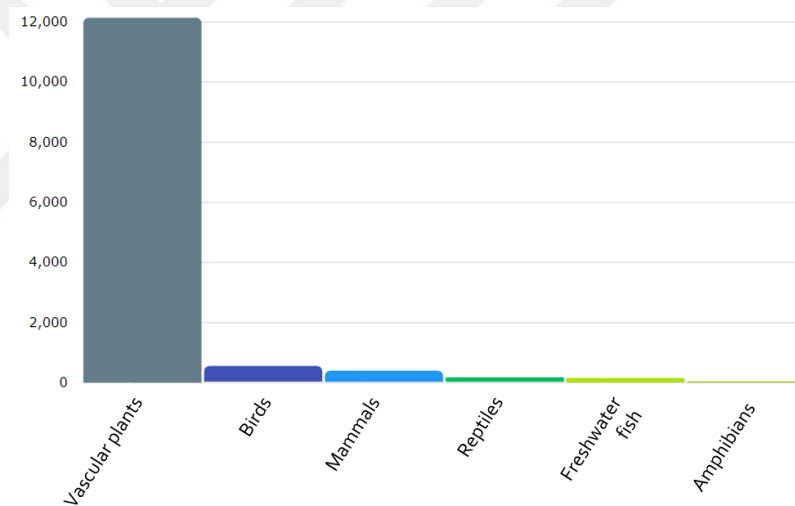


Figure 2.22. Number of taxon according to species group (Source: Noah's Ark)

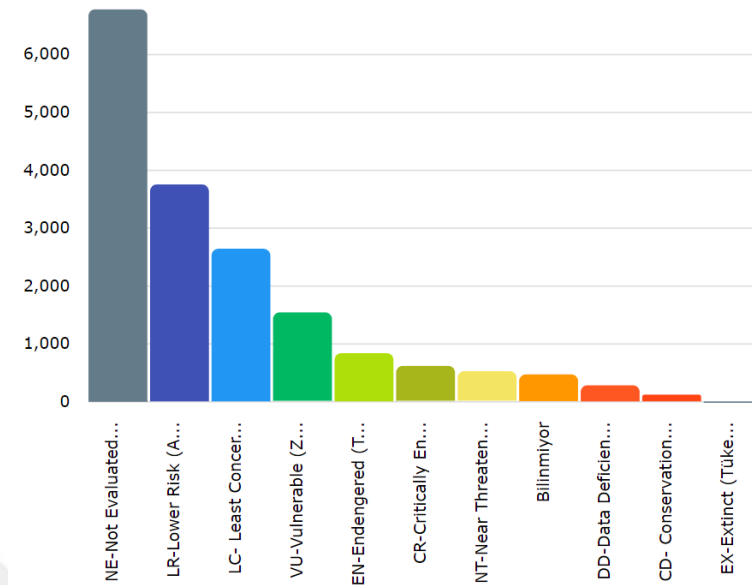


Figure 2.23. IUCN Red List Categories of species (Source: Noah's Ark)

The above numbers are presented in the official web site of the Noah's Ark National Biological Diversity Database and only summary statistics are accessible no further information is shared even with the data contributors.

2.3.3.4. Non-Governmental Organizations (NGOs)

In Turkey, there are many national and local non-governmental organizations contributing on a voluntary basis to the conservation and sustainable use of biological diversity, including public awareness-raising and education in particular (NBDSAP, 2007). This section presents, partial number of works accomplished by NGOs with a brief history.

The eldest society was established in 1955 with the name of "Turkish Society of Nature Protection". Its main focus was combatting erosion and other environmental problems. Their early efforts together with IUCN support had included protection of wetlands (i.e. Bird Paradise National Park). And in 1975, the Society for Nature

Conservation (DHKD) and WWF- Turkey were established. Up to 1995 the NGOs expertise mostly had rooted in forestry and biological science. After Habitat Congress the number of NGOs has risen and also their envelope has extended. (Kesmez et al., 2016). Also, the international support has shifted the biodiversity conservation, for example, BirdLife, RSBP and WWF are international institutions in this perspective. Also several funds GEF, UN and EU have contributed the NGO's efforts. It is necessary to mention the share of the private sector in supporting NGOs in recent years especially the biodiversity offset projects of large scale investments and social responsibility projects. Several volunteers ranging from various age groups, bird watchers and nature photographers were contributed to the civil movement.

The status of NGOs was summarized in NBDSAP (1998) with these exact words: *“Concepts of environment and biodiversity were introduced to Turkey by Government but became very popular through activities of NGOs, as is the case elsewhere. There are no clear provisions in Turkish legislation for NGOs and in their potential input to general environmental and specifically, biodiversity conservation activities which, are therefore severely hampered. Legal impediments related to financing mechanisms available to NGOs, their ability to collect donations or raise funds, as well as regulatory constraints regarding Cupertino with international NGOs are major problems. In spite of the existing problems facing NGOs, a number of internationally important flora and fauna species and their habitats have been put under protection through their efforts in collaboration with international organisations and many activities that have adverse effects on the species and their habitats were stopped”*. Their role was evolved from raising public awareness and execution body of conservation and also they present necessary technical expertise in sophisticated analyses. Some of these works were mentioned in NBDSAP (1998 and 2007) and the rest of them were scientifically credible and acknowledged regularly (such as important plant areas, key biodiversity areas etc.).

Marine Turtle Monitoring: In 1998, 17 important marine turtle breeding areas (*Caretta caretta* and *Chelonia mydas*, according to IUCN redlist VU and EN status

accordingly) had identified by the Society for Nature Conservation (DHKD), WWF and Dokuz Eylül University. In accordance with Barcelona Convention and its annexed protocols, “Marine Turtle Monitoring and Assessment Commission” had been formed in 1990. Until then the sea turtles are the species whose monitoring has been done regularly.

Mediterranean Monk Seal: Mediterranean Monk Seal (*Monachus monachus*) is one of the species that take particular attention through the nature conservation history. It was considered to be one of the 12 most endangered species in the world by IUCN. Strong international and national policy and legislations exist upon this charismatic species. Barcelona, Bern and CITES conventions mention the species in their annex. Also, the monk seal enjoys conservation at national level under both the Fisheries Law 1380 and the Environmental Law 2872 (NBDSAP (2007)). And it was estimated that there were 300-400 individuals between 1987-1991. And less than 50 live along the coastline of Turkey according to NBDSAP (1998). This number was raised to 100 in NBDSAP (2007). In 1991 an International Conference for the protection of Mediterranean Monk Seal had been organized and sequentially several pilot projects have been initiated. Bodrum Volunteers with the support of Greenpeace had implemented the Conservation of species in coasts of Bodrum. Specifically, Underwater Research Society (SAD) and its Mediterranean Monk Seal Research Group (AFAG) paid particular attention to the conservation of the species.

Wetland management projects: The Society for Nature Conservation (DHKD) was an official partner of BirdLife International and WWF. And DHKD had executed several projects in several wetlands the early 1990s (NBDSAP, 1998). The bird counts were also carried out by the organization up to 2000s, then the Nature Society (DD) and Bird Research Foundation (KAD) had taken the responsibility.

Other examples mentioned in the NBDSAP are listed in Table 2.11.

Table 2.11. *Some project examples executed by NGOs and mentioned in NBDSAPs*

Project name	Responsible NGO	Reference
1992 “Coastal Management and Tourism in Turkey: Çıralı- Belek”	Society for Nature Conservation (DHKD) and WWF	NBDSAP, 2007
2001 Black Vulture (<i>Aegypius monachus</i>) Conservation	Former Bird Research Foundation (KAD), Nature Research foundation (DAD)	NBDSAP, 2007
The Sustainable Forest Utilization and Conservation in the Kaçkar Mountains Project	TEMA Foundation, Natural Conservation Centre (DKM) Artvin Culture and Solidarity Association	NBDSAP, 2007
Discovery of sea caves on the Black Sea coasts, Aegean and Western Mediterranean for Mediterranean Monk Seal	Underwater Research Society (SAD)	NBDSAP, 2007

Ex-situ conservation: In addition to the efforts performed by ministry and universities, there were two remarkable private examples in ex-situ conservation. Nezahat Gökyiğit Botanical Garden and Karaca Arboretum. Both owners and investors are the founder members of The Turkish Foundation for Combating Soil Erosion, for Restoration and the Protection of Natural Habitats (TEMA).

The comprehensive biodiversity conservation projects have been compiled by Zeydanlı et al. (2020), among these projects the ones executed by NGOs are selected in Table 2.12, together with other items not mentioned I there (such as red list studies).

Table 2.12. *The comprehensive biodiversity conservation projects (Zeydanlı et al., 2020)*

Name	NGO	Year
Important Bird Areas	Society for Nature Conservation (DHKD)	1990,1997
Important Bird Areas	Nature Society (Doğa Derneği)	2004
Important Plant Areas	WWF- Turkey, DHKD	2003
Southeast Anatolia GAP Analysis	DHKD	2001-2004
Lower Caucasus GAP Analysis	TEMA	2004-2006
Key Biodiversity Areas	Nature Society	2005-2007
Anatolian Diagonal Biodiversity Project	Nature Conservation Center (DKM)	2006-2008
Black Sea Region Systematic Conservation Planning	DKM	2010-2011
Red List of Butterflies	DKM	2011
Mediterranean Region Systematic Conservation Planning	DKM	2014-2019
Flora of Turkey	Flora Research Society, Nezahat Gökyiğit Botanical Garden, Ali Nihat Gökyiğit Foundation	2019-...

In recent years the observation carried out by nature photographers are highly inflated and increase public awareness. The leading media platforms exist for birds (TRAKUS⁸), butterflies (TRAKEL⁹), mammals (TRAMEM¹⁰) and herpetofauna (TURKHERPTIL¹¹). These web platforms are successful instants of civil movements and not directly linked to any NGO.

2.4. What Do We Know About Biodiversity Monitoring?

Observation of nature and biodiversity are the most plentiful and longest records in human history (Scholes et al., 2012). Monitoring biodiversity change, at various aspects are needed to track to the response of environmental change on genes, species, communities and ecosystems. From remote sensing to in situ techniques, any monitoring effort will develop our skills to better interpret the complex interactions (e.g. traits) and feedbacks (e.g. ecosystem functions) and matching various temporal, spatial and biodiversity scales.

Surveys at one point in one time estimate the diversity (for example the presence of species), on the other hand, monitoring is an estimation of diversity in the same point for more than one time to understand the change (Wilson et al., 1996).

Hellawell (1991) stressed the definition of the terms; survey, surveillance and monitoring. *Survey* is “an exercise in which a set of qualitative or quantitative observations are made, usually by means of a standardized procedure and within a restricted period of time”. *Surveillance* can be defined as “an extended program of surveys, undertaken in order to provide a time series, to ascertain the variability and/or range of states and values which might be encountered over time”. And *monitoring* is “*Intermittent (regular or irregular) surveillance carried out in order to ascertain the*

⁸ https://www.trakus.org/kods_bird/uye/?fsx=@

⁹ <http://www.trakel.org/kelebekler/?fsx=@>

¹⁰ <http://www.tramem.org/memeliler/?fsx=@>

¹¹ <http://www.turkherptil.org/>

extent of compliance with a predetermined standard or the degree of deviation from an expected form”.

Vaughan et al. (2001) has described four categories of monitoring;

1. *simple monitoring* is recording a single variable at one point over time
2. *survey monitoring* aims to establish a baseline where historical records are absent for a particular environmental problem in a specific area. The survey is done both in affected and not affected areas
3. *surrogate or proxy monitoring* compensates for the lack of previous monitoring by using surrogate information to infer changes
4. *integrated monitoring* uses detailed sets of ecological information.

Nichols and Williams (2006) proposed two comprehensive groups for monitoring: surveillance monitoring and targeted monitoring. Surveillance monitoring aims to generate a baseline and gather as much data as possible on a variable (such as population abundance across several taxa) over time. On the other hand, targeted monitoring answers a specific question such as whether the management actions of protected areas are successful to protect a particular species.

Furthermore, Lindenmayer and Likens (2010) grouped monitoring into three categories as follows. This categorization is more widely accepted.

1. **Passive / curiosity driven monitoring:** This group of monitoring is devoted to curiosity. A hypothesis and a pre-defined question are missing. It is very inefficient to allocate limited resource and budget to this type of curiosity-based questions however sometimes the findings might contribute the level of understanding in ecological processes.
2. **Mandated monitoring:** This group of monitoring is mandated by legislation and directives and has high relevance with policy and management questions. In general larger scales are under focus such as national or regional and not concentrated on causality rather the effort is condensed on identifying trends and state of the environment.

3. Question-driven monitoring: This group is engaged in scientific research. A clear monitoring question is defined with a conceptual model and experimental design. Test a hypothesis related to a management and its response increases the predictive capacity and triggers new questions and generates adaptive monitoring. Long- Term Ecological Research (LTER) can be assessed under this category.

Yoccoz et al. (2001) criticized the existing monitoring programs which were poorly designed in their principal components as they were not answering “why monitor?”, “what should be monitored?” and “how should be monitoring be carried out?” questions for better guiding the biodiversity management and development. However, today monitoring action is not just carried out for these purposes. Additionally political guidance, decision making and also reporting require monitoring information on wider extents.

The reasons for establishing monitoring programs can be grouped into three categories (Hellawell, 1991);

1. Assessing the efficiency of a policy or legislation: Policy instruments are developed to ensure the sustainability of a desirable state or to support progress towards such a condition.
2. Assessing the performance of management actions: The audits and performance assessments check whether the desired quality and condition of a site are secured by ongoing actions.
3. Detecting changes to create an early warning system: The stochastic, successional and cyclical changes in ecosystems can occur simultaneously or be superimposed. The adverse or favorable impacts of these changes may present an insight about future response and condition.

Lindenmayer and Likens (2010) contributed this list with the following items;

4. Establishing baselines against a change or extremes can be evaluated (e.g. climate change)

5. Providing empirical data for ecological theory and models

In summary, the importance of monitoring can be listed as follows (Spellerberg, 2005);

1. The processes of many ecosystems are not well understood, and monitoring programmes could deliver basic ecological knowledge about the underlying mechanisms.
2. Ecosystem management, if it is to be effective, requires a fundamental baseline, which can only be attained by monitoring ecosystems.
3. Anthropogenic perturbations in the world's ecosystems have long-term, partly synergistic, partly cumulative effects which can only be understood by long-term monitoring.
4. Data from long-term studies can provide a foundation for the early detection of potentially harmful effects over various levels of biological entities.
5. Given the ever-increasing loss of species, loss of habitats and damage to biological communities, ecological monitoring is essential to evaluate the consequences of these losses and damage.

It is obvious that the duration of monitoring is sensitive to the related question, species life history etc. For example, longevity for rapid generation time species such as bacterial assemblages might be one year, on the other hand, a decadal living woody plant should be monitored for several decades. In order to prevent confusion, Lindenmayer and Likens (2010) use the definition of long-term monitoring as an effort to continue beyond 10 years without interruption. Measuring something simply in nature is not monitoring. More precisely monitoring needs a particular question, an experimental design, a conceptual framework, and data integrity through the repeatable application of appropriate field protocols (Lindenmayer and Likens, 2010).

In this section, I present the global status of biodiversity monitoring in gene, species and ecosystem level. Under each sub-title, I tried to link the situation of Turkey in global efforts and data portals.

2.4.1. Gene Level Monitoring

Genes are the key material that life has formed and changed. The heredity material as DNA transfers the superior attributes to the next generation. Genetic diversification triggers speciation and it is important for species responses especially fast-changing and harsh environmental conditions. The genetic diversity among species delivers ecosystem resilience (Sgro et al., 2011). Narrow width genetic variation increases the extinction risk. For instance, climate change imposes a crisis for many species and adaptation requires to detect the resilient individuals, populations and communities especially for endangered species and forest management. Also, habitat fragmentation affects the genetic pool and causes homogenization.

On the other hand, the variability of genes is essential for humankind as it's the sources of agriculture. Food security and safety is highly dependent on crop genetic diversity (FAO, 2015). Monitoring genetic diversity also enables us to evaluate the “option value” of genetic variation such that the humans would benefit this potential power of resilience in future. However, it is hard to mention a coordinated approach of gene-level monitoring globally even for agricultural species (Dulloo et al, 2010). The reasons are unlike ecosystems or species, DNA cannot be accessed by visually or remotely. All genetic samples must be collected from the field and analyzed in a laboratory by specific laboratory equipment and consumables. Thus it is not the cost and time effective option and not applicable in most cases (Davies et al., 2012).

Brudorf et al. (2017) listed what to monitor as follow;

- *Domesticated animals are plants:* The diversity of domesticated species is being lost at farm scale due to the intended choice of the most productive seeds etc. Also in landscape-scale, the wide monoculture destroys the traditional varieties.
- *Socioeconomically and ecologically important species:* Socioeconomic species benefits human for food, shelter, medicinal, energy and nature-based tourism income, At the same time these species have fundamental ecological

functions such as nutrient retention, flood prevention etc. Forest trees are an example

- *Culturally valued species*: These species have particular attention for local communities, symbolic endangered species, financially valuable local breeds are examples.

Several molecular tools have generally accepted standards and are used to monitor genetic diversity. These are microsatellites, mitochondrial and chloroplast DNA, single nucleotide polymorphisms and direct sequencing (Brudorf et al., 2017). DNA barcodes are widely used for taxonomic identification. However, for monitoring purposes, DNA sequences and the studies of phylogenetic relations can be used for specific taxa over time in one or many places. The remarkable global efforts and the place of Turkey in them are listed below;

- The Genomic Observation Network (GOs)¹² is a collaboration between the Genomic Standards Consortium (GSC) and the Group on Earth Observations Biodiversity Observation Network (GEOBON). The network focuses on long term monitoring of genetic data. Its first activity was held in marine ecosystems (Ocean Sampling Day) with coordinated, standardized collection and sequencing of seawater. Dokuz Eylül University has joined the event (Kopf, 2015). Ocean Sampling Day Consortium commits to monitor marine microbial biodiversity same day annually.
- The European Molecular Biology Laboratory (EMBL)¹³ EMBL is an intergovernmental organisation established in 1974, generated the International Nucleotide Sequence Database Collaboration. It works to establish links and initiate collaborative projects between scientists in Europe and the wider world. Turkey is not a member state.
- International Barcode of Life (IBOL) was established in 2008 as a research alliance for the aim of the generation of DNA barcode reference libraries, the

¹² <http://www.genomicobservatories.org/>

¹³ <https://www.embl.org/>

sequencing facilities, the informatics platforms, the analytical protocols. By 2026 the goal of the international collaboration would extend its barcode coverage to 2.5 million species. This information would be used in tracking ecosystems and revealing symbioses and contribute to the global biodiversity observation system. Ankara University is representing Turkey.

2.4.2. Species-Level Monitoring

Species-level is the most practical and observable tool thus, inevitably efforts had condensed on composition diversity at the species level; identification and naming of new species, mapping their distributions (Noss, 1990, Scholes et al., 2017). Throughout centuries, samples were collected from museums, herbariums, field notebooks etc. Costello (2013) argued that currently 5 ± 3 millions of species exist on earth but only 1.5 million of them are named. Considering the accelerating extinction rates which range from 0.01 to 5% per decade, smart taxonomy tools together with collective collaboration are needed to prevent species from extinct which are not discovered yet.

However, the distribution of taxonomists do not match with geographically with the frequency of biological diversity (Gaston and May, 1992). Martin et al. (2012) highlighted that 75% of studies were executed in protected areas. Also, the studies are intensified in a temperate climate, developed countries, although the biodiversity is more concentrated in tropical, developing countries (Scholes et al., 2012).

Clark and May (2002) pointed out the taxonomic bias in conservation research. When Shine and Bonnet (2000) had reviewed 32000 records (1979-1998) in the "Zoological Records" database, they observed that mammal studies were ten times more than amphibian studies, whereas amphibians are numerically more diverse than mammal species. Bonnet et al. (2002) called this syndrome as "taxonomic chauvinism". In another study, Donaldson et al. (2016) confirmed the extreme bias towards threatened vertebrates (Figure 2.24). In the figure, letters represent species with a high number of

papers published on (A) tiger *Panthera tigris*; (B) European eel *Anguilla anguilla*; (C) common carp *Cyprinus carpio*; (D) Atlantic cod *Gadus morhua*.

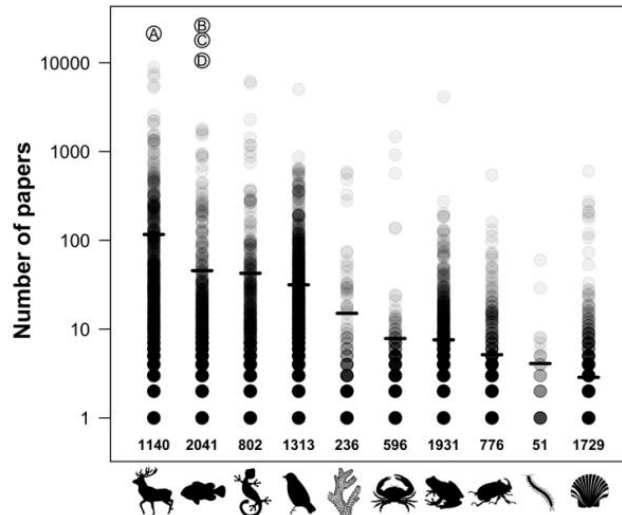


Figure 2.24. Distribution of papers across animal taxa (Donaldson et al., 2016)

Existing observations disproportionately focus on particularly popular and easily observed groups: birds, mammals and higher plants (Scholes et al., 2012). Balmford et al (2003), also reasoned this outcome since they are relatively species-poor groups compared to others (i.e. invertebrates). The challenges at the species level were described as (Cardoso et al., 2011);

- The Linnaean shortfall; all of the species cannot be identified in a location
- The Wallacean shortfall; distribution of the species cannot be limited geographically,
- The Prestonian shortfall; the abundance of species and their changes in space and time are unknown,
- The Hutchinsonian shortfall; It is hard to quantify the natural and anthropogenic responses of species.

Noss (1990), has grouped the species into five categories as they uphold particular attention; (1) ecological indicators: species that indicate the effects of disturbance on a variety of other species with similar habitat requirements; (2) keystones: central

species on which the diversity of a large part of a community relies; (3) umbrellas: species whose habitats cover larger areas, signify many other species; (4) flagships: popular, charismatic species that serve as symbols; and (5) vulnerable: species that are rare, genetically impoverished, of low fecundity, dependent on patchy or unpredictable resources, extremely variable in population density, persecuted, or otherwise prone to extinction in human-dominated landscapes. Beever (2006) extended this list as presented in Table 2.13.

Table 2.13. *Species as monitoring targets (Beever, 2006)*

Target	Definition
Umbrellas	Extensive home ranges; require contiguous habitat quality (grizzly bear, grey wolf, northern spotted owl)
Flagships	High charismatic appeal; used to attract conservation resources (panda)
Focal species	The most area-sensitive, dispersal- limited, resource-limited, and ecological process-limited taxa in a landscape
Indicator species	Usually, those species in a relatively species-rich single taxon thought to represent biological diversity as a whole
Common (vs. rare) species	Monitor species while still common because it is cheaper and more likely to produce long-term successes (Habitat generalists, species with high reproductive capacity)
Functional guilds	Well connected to .1 aspect of ecosystem functioning; may indicate both composition and function (Pelagic fish, neotropical migrant birds, granivorous small mammals, ground-nesting birds)

Table 2.14 shows some of the taxonomic lists which covers Turkey.

Table 2.14. *The taxonomic lists covering Turkey*

Name	Spatial Coverage	Covered years or release date	Note
Integrated Taxonomic Information System (ITIS) ¹⁴	Global	Monthly updated	Authoritative taxonomic information on plants, animals, fungi, and microbes of North America and the world
The Plant List ¹⁵	Global	2010: version 1.0 2013_version 1.1	The plant list is a comprehensive list of all known species. It covers 1,064,035 scientific plant names of species rank. Of these 350,699 are accepted species names.
The Encyclopedia of Life (EoL) ¹⁶	Global	v3 -2018	It aims to increase awareness and understanding of many life forms. It collaborates with many open-source platforms; Biodiversity Heritage Library (BHL) Barcode of Life (BOLD) Catalogue of Life (CoL) Global Biodiversity Information Facility (GBIF)
bizimbitkiler ¹⁷	National	2012 Updated on 2017	It is a national plant database governed by Nezahat Gökyağıt Botanical Garden. Scientific name and Turkish name, distribution maps, threat category and endemism status are shared in the database

2.4.2.1. Taxonomic sampling

The monitoring technique and the sampling scheme are depended on the species group and habitat type. Although it is hard to mention that a certain technique fits all circumstances in a species group, some techniques are efficient for most of the

¹⁴ <https://www.itis.gov/>

¹⁵ <http://www.theplantlist.org/>

¹⁶ <https://eol.org/docs/what-is-eol>

¹⁷ <https://bizimbitkiler.org.tr/v3/demo/index.php#>

individuals in that group. Table 2.15 prepared by this approach and shows the most appropriate sampling technique for the relevant species group and summarized the information presented in Pereira et al. (2017).

Table 2.15. Accepted methods of monitoring for species groups

Taxon	Monitoring technique	Variable
Medium to large mammals	Line transects	A robust estimate of species richness, relative abundances and habitat use
Small mammals	Live trapping transects	
Mammals	Capture-mark-recapture	Relative abundance
	Road traffic casualties	
Medium to large mammals	Camera trapping	Species richness, relative abundances and habitat use
	Radio-tracking collars	Habitat use
Amphibians	Clutch counts and nest counts	Population size
	Trapping	Species distribution and abundance
	Area-based surveys within defined plots and transects	Abundance and density of a species or survey the amphibian fauna of a site
	e-DNA	
	Auditory monitoring	Abundance of male frogs and toads
Butterflies	Opportunistic data	Species distribution
	Standardised day lists	Population parameters
	Standardised counts in fixed transects	Population trends
Plants	Quadrats	Density, frequency biomass
	Transects	
	Quadrats along transects	
	DAFOR (Dominant, Abundant, Frequent, Occasional or Rare), Braun-Blanquet (5 classes up to 100 % cover, not of equal size) Domin (10 classes up to 100 % cover, not of equal size) scales.	Cover
	Remote sensing	Cover
	e-DNA	Species richness and species abundances

2.4.2.2. Species metrics

Indicators serve as a currency to compare the occupancy and abundance through diversity, richness, evenness in different places or various times. On the other hand, diversity indices simplifies information and cause the loss of identical features of biodiversity. The other disadvantage is they are highly dependent on the sample size. Also, the abundant number of metrics and indices complicate the comparison (Noss, 1990). Santini et al. (2017) compared 9 scenarios of biodiversity changes and compared the performance of 12 biodiversity metrics. Metrics pose differently under different scenarios. It is hard to mention that one metric can detect the change for all scenarios. And also they concluded that the composite index approach may misguide the analyst. For example, Shannon's diversity index shows a misleading response or ineffective to capture change for some of the scenarios.

2.4.2.3. Citizen Science and Community Platforms

The most significant development in species monitoring is engaging communities to data acquisition and harmonizing this big data in giant networks. Engaging non-professional into ground-based surveys decrease the cost of monitoring. However to sustain the motivation of participants (Silvertown et al., 2013), the reliability of the attained data (Buesching et al., 2015) are some of the problems highlighted by several authors. Chandler et al. (2017) highlighted the contributions of citizen science as follows;

- Citizen science expands the coverage of biological data spatially and temporarily.
- Citizen science oriented programs record the location and abundance of species over time. Thus mapping species occurrence and abundance can be easily handled.
- The timing of nature's events on broad-scale processes such as phenology and migration can be monitored.

- Early detection and mapping of pests and invasive species can be done by citizen science projects.
- Citizen science can also contribute to process desktop jobs such as processing identification of species (for example photographs taken by a camera trap (Zooniverse projects <http://www.zooniverse.org>)) and land cover types (Geo-Wiki <http://www.geo-wiki.org/>) and preparing images for further analysis (<http://forestwatchers.net/>)

Some samples of community platforms and the status of Turkey in these portals/networks are presented below.

2.4.2.3.1. Global Biodiversity

Information Facility (GBIF)

Global Biodiversity Information Facility (GBIF) is a pioneer network organization that deals with the harmonization problem. It is an international network and research infrastructure funded by several governments and aimed to promote the open-access data. As of 2020, the database includes 1.600.946.848 occurrence records derived from 54.348 datasets, contributed by 1644 publishing institutions. Turkey government is not a partner of the network. However 1,594,411 records exist and cover the following major taxonomic groups as follows; Animalia (79.063%), plantae (18.989%), chromista (0.675%), bacteria (0.442%), fungi (0.433%), incertae sedis (0.359%), protozoa (0.03%), archaea (0.008%), viruses (0.002%). The density of the occurrence data for Turkey is shown in Figure 2.25. The main data provider is “e-Bird Observation Dataset” with a contribution of 66%, followed by “A global database for the distributions of crop wild relatives” with a contribution of 5%, and “Hesselbarth, Oorschot and Wagener Butterfly data of Turkey” and “Royal Botanic Garden Edinburgh Herbarium” with a contribution of 3% each and “EURISCO, The European Genetic Resources Search Catalogue” with a contribution of 2%. 319 mostly international data publishers contribute these data. There are two institutions in the

community publisher list (Gebze and Düzce University), however, only Düzce University contributed the data as Alien Flora of Turkey dataset which include 387 records (GBIF, 2020).

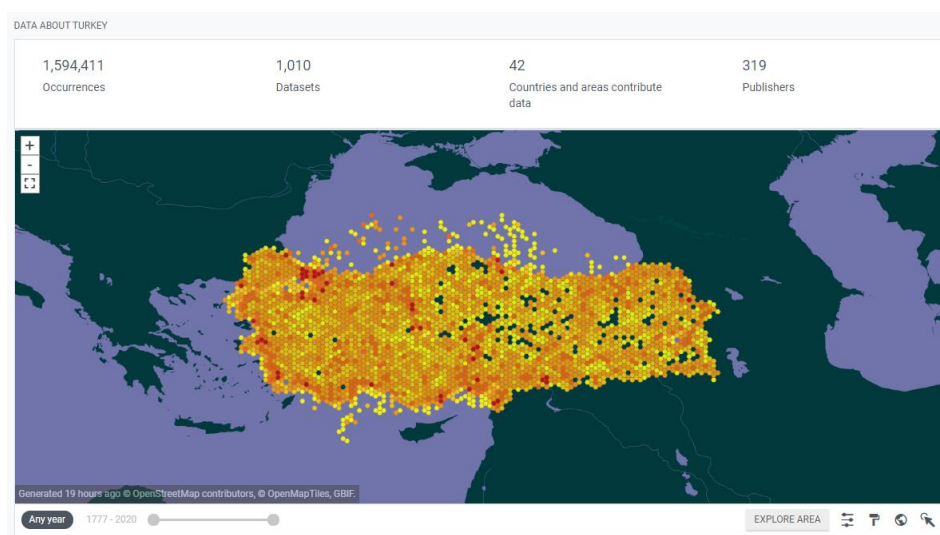


Figure 2.25. Distribution of biodiversity occurrence data, of Turkey in GBIF (GBIF, 2020)

2.4.2.3.2. e-Bird

e-Bird is the mostly used citizen science platform in Turkey. The online platform presents checklists of birds and enables archiving and sharing the observations with the public. It has hundreds of partner organizations, thousands of regional experts, and hundreds of thousands of users, eBird is managed by the Cornell Lab of Ornithology. One favorable attribute is the quality checks and assurance of observations. The observation density, which includes all years and all seasons are presented in Figure 2.26, which covers 452 species and 62 435 checklists. The color tone represents the species richness.

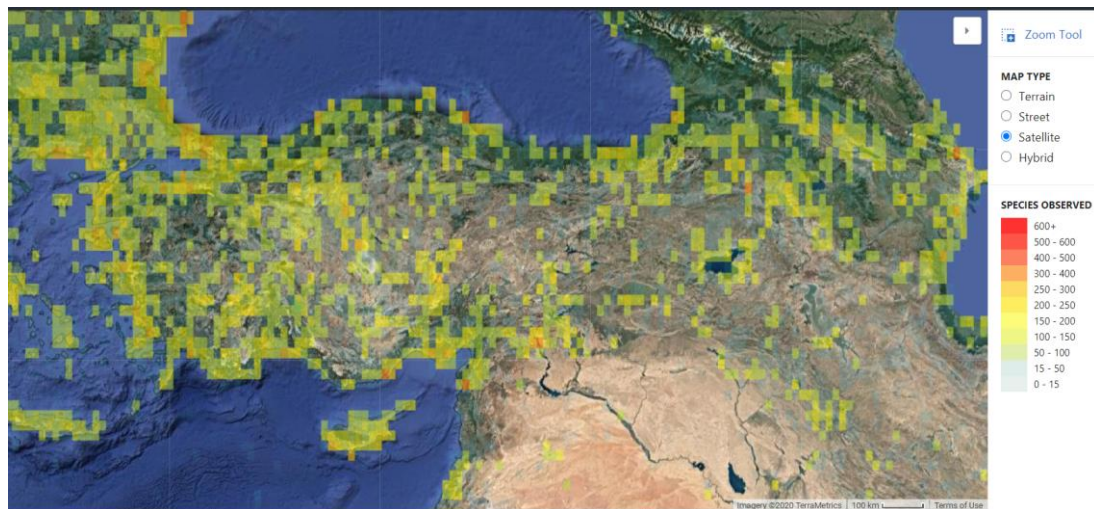


Figure 2.26. Bird richness of Turkey according to e-Bird observations
(<https://ebird.org/region/TR?yr=all>)

2.4.2.3.3. Map of Life (MoL)

MoL provides ‘best-possible’ species range information and species lists for any geographic area. MoL assembles and integrates different sources of data describing species distributions worldwide. These data include expert species range maps, species occurrence points, ecoregions, and protected areas from providers like IUCN, WWF, GBIF, eBird, and more. All data assets are stored, managed, backed up, and accessed using a hosted cloud instance. MoL presents several demonstrations regarding patterns species richness, rarity and facets and several indicators as species data coverage, habitats and protection gaps (www.mol.org).

2.4.2.3.4. iNaturalist

iNaturalist is an online social network whose contributors are citizen scientists and experts. Its mobile application interface provides comprehensive biodiversity data recordings and enables mapping and sharing observations of biodiversity across the globe. It is a joint initiative by the California Academy of Sciences and the National Geographic Society. As, 31 August 2020 the crowdsourcing platform has 1.271.270 contributors, with around 154.000 active identifiers and 293.627 species records

distributed over 48.201.420 observations. The country numbers are presented in Table 2.16 for to enable comparison also other countries (neighbouring or same ecoregion) are listed.

Table 2.16. *iNaturalist Countrywide statistics* (<https://www.inaturalist.org/>)

Country	Observations	Species	Identifier	Contributor
Turkey	78 506	8 190	3 431	4 766
Greece	131 804	10 112	4 383	6 620
Bulgaria	24 616	4 153	2 098	1 176
Iran	32 950	3 856	2 158	1 525
Georgia	20 092	2 737	1 161	836
Spain	748 284	18 723	10 139	33 242
France	1 696 925	24 389	16 350	89 280
Italy	980 380	19 912	12 104	37 250

2.4.3. Ecosystem Level Monitoring

Humans are modifying landscapes over millennia. The magnitude and the extent of change across the landscapes vary. The artificial urban environments or intensive agricultural transformations are extreme samples. On the other hand in the protected areas human disturbance is in evidence in the form of recreational or training activities. Additionally even in remote landscapes have been impacted by human-induced climate change (Ramankutty et al., 2006). As McKibben (1989) argued about cultural and natural dichotomy such that no untouched land (directly or indirectly) left anymore. Considering in a wider spectrum, instead of forcing categories in an envelope of natural/cultural, mapping landscapes is focusing on land cover and land-use change in a continuum (Theobald, 2004). It is obvious that a tradeoff exists between land-use practices and the exploited ecosystem. Land use practices are inevitable to meet the demands of civilization in the form of food, land, water etc. However, degrading an ecosystem leads a diminishing in its ecosystem services

capacity which are also essential for human's survival (DeFries et al., 2004; Foley et al., 2005). MAE-LULC (Millennium Ecosystem Assessment land-use and land-cover change) programme was focused to monitor the status and trends of ecosystems. Rapid assessments produce information about (i) deforestation and forest degradation; (ii) degraded lands in the drylands and hyper-arid zones of the world (referred to here as desertification, even though most definitions of desertification do not include hyper-arid zones); (iii) cropland expansion and abandonment; and (iv) urban settlements.

Establishing an ecosystem monitoring program has several advantages. Habitats are denominators of species, as it is evident that habitat structure impacts the presence of species. Also, the extent, composition and structure of the habitat defined the occupancy and abundance of species not only for plants but also for a range of species from various taxonomic groups (Olsvig-Whittaker et al., 2010). The configuration of habitats reflects the ecological disturbances such as fragmentation, degradation and loss. Because of these reasons, many monitoring programs use ecosystems as a conservation umbrella for biological diversity (i.e. EBONE project).

Ecosystem level monitoring (structure and function) is executed mostly by remote sensing opportunities (Turner et al., 2003; Pettorelli et al., 2005; Geller et al., 2017). Multi-temporal, multispectral, satellite sensor obtained data has its potential as a means of detection, identification, mapping and monitor ecosystem changes, regardless of their causal factors (Coppin, 2004).

Mostly acknowledged resources also available for Turkey extent are listed in Table 2.17.

Table 2.17. Major ecosystem monitoring products covering Turkey

Name	Time	Satellite	Min. mapping unit/width
USGS Global Land Cover 2.0 ¹⁸	1992-1993	AVHRR- MODIS	1 km
International Geosphere-Biosphere Programme (IGBP) Land Cover ¹⁹ (Loveland et al., 1999)	1992-1993	AVHRR- MODIS	1 km
Global Land Cover 2000 Project GLC2000 ²⁰ (Bartholomé, 2004)	2000	SPOT 4- VEGETATION-1	1 km
GlobCover Land Cover ²¹	2004-2006	MERIS-ENVISAT	10 arc-seconds (~300 m)
	2009	MERIS-ENVISAT	10 arc-seconds (~300 m)
CORINE Land Cover ²²	2000	Landsat-7 ETM	25 ha / 100m
	2006	SPOT-4/5 and IRS P6 LISS III	25 ha / 100m
	2012	IRS P6 LISS III and RapidEye	25 ha / 100m
	2018	Sentinel-2 and Landsat-8	25 ha / 100m
EUNIS (European Nature Information System) ²³	2015	Derived from CORINE, and other ancillary data	100 m
Global Forest Watch ²⁴	NRT ref to 2000-2012	LANDSAT	30 m
VIIRS I-Band 375 m Active Fire Data ²⁵	NRT	VIIRS	375 m
Fire Information for Resource Management System (FIRMS) ²⁶	Near Real Time (NRT)	MODIS	1 km
NOAA-20/JPSS-1 ACTIVE FIRES ²⁷	NRT	NOAA	750 m
ATSR World Fire Atlas ²⁸	1995-2012	ATSR-ENVISAT	1 km

¹⁸ https://www.usgs.gov/centers/eros/science/usgs-eros-archive-land-cover-products-global-land-cover-characterization-glcc?qt-science_center_objects=0#qt-science_center_objects

¹⁹ https://daac.ornl.gov/ISLSCP_II/guides/edc_landcover_xdeg.html

²⁰ <https://forobs.jrc.ec.europa.eu/products/glc2000/glc2000.php>

²¹ http://due.esrin.esa.int/page_globcover.php

²² <https://land.copernicus.eu/pan-european/corine-land-cover>

²³ <https://www.eea.europa.eu/data-and-maps/figures/ecosystem-type-map-all-classes-1>

²⁴ <https://www.globalforestwatch.org/>

²⁵ <https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms/v1-vnp14imgt>

²⁶ <https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms>

²⁷ https://www.star.nesdis.noaa.gov/JPSS/EDRs/products_activeFires_N20.php

²⁸ http://due.esrin.esa.int/page_wfa.php

As presented in Table 2.17 the sensors, together with land-cover classification systems and classification methods varies completely. Also, different definitions of classes (i.e. Forest) make the comparison of different classification outputs complicated (Pereira et al., 2006). Another difficulty is their usefulness in monitoring biodiversity. For example, in CORINE classes a broadleaved forest might be originated from the plantation with exotic species (i.e. *Eucalyptus globulus*) and in biodiversity monitoring perspective it is important to detect a native forest and an exotic plantation complicated (Pereira et al., 2006). Also in these global assessments, rare ecosystems (i.e. wetlands and coral reefs) which should be monitored with a particular focus might be dismissed due to the coarse resolution of the outputs.

2.4.3.1. Forest Monitoring

Since this study focuses on terrestrial realms, forest ecosystems require particular attention. The monitoring of forest cover and forest functions delivers the information needed to support the formulation of policies and decisions for the conservation, protection and sustainable management of forests. Forests play a significant role in the climate system. About 45% of the world's terrestrial carbon is stored in forests (Bonan, 2008). Moreover, forests are inevitable for humans since they regulate, provide and support several ecological functions (Miura et al., 2015). However forest is dynamic ecosystems, stimulus impacts such as the fire and logging, or long term processes such as drought and climate change can change the structure and composition of forests. Understanding the temporal and spatial extent of these dynamic interactions enables us to sustain vital ecosystem services in forests. Forest monitoring focuses the coverage and deforestation (i.e. Global Forest watch), the biomass (i.e. REDD projects) and the invasion of exotic species at the global scale. In a local scale, the management (such as thinning, clear-cut etc.), the disturbances such as pest and fire is monitored.

The Global Forest Watch aforementioned before in Table 2.17 is an open-source application to monitor forests in near real-time, globally. As of 2020 the loss graph presented in Figure 2.27.

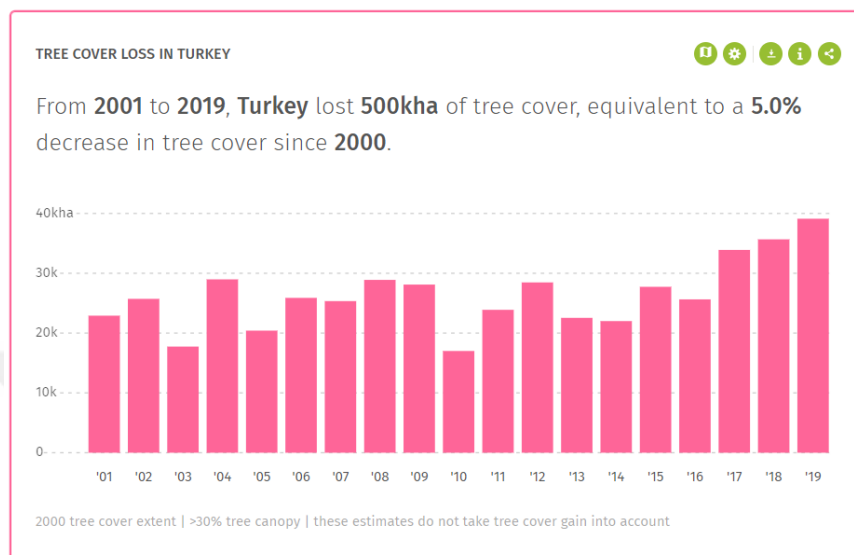


Figure 2.27. Turkey's tree cover loss between 2001 and 2019 (Source: GFW, 2020)

Another global forest monitoring program focus on fires. Fire Information for Resource Management System (FIRMS) is owned by NASA which uses Moderate Resolution Imaging Spectroradiometer (MODIS) and the Visible Infrared Imaging Radiometer Suite (VIIRS) and produces near real time active fire data. Figure 2.28 shows the fires in Turkey between 28-30 August 2020.

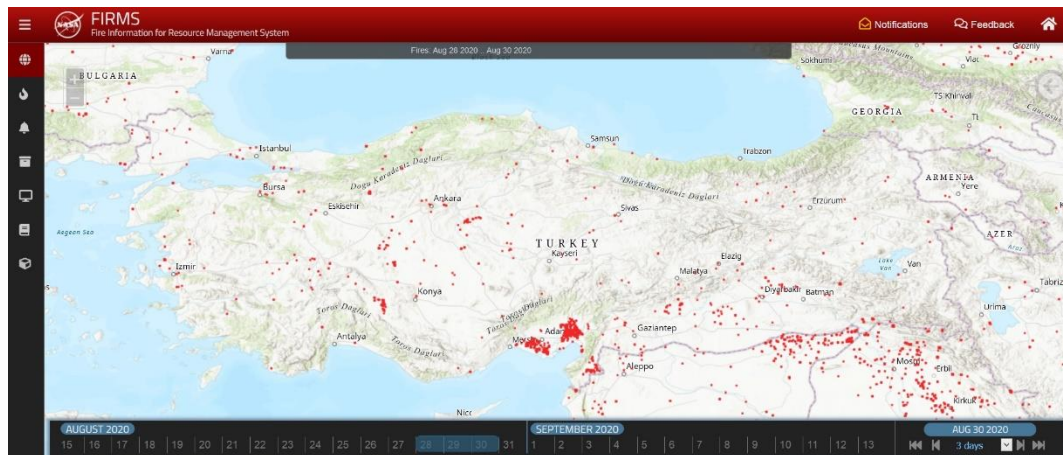


Figure 2.28. Turkey's forest fire timing statistics (FIRMS²⁹)

Sustainable forest management is a key component in sustainable development and this common international interest has initiated several global and regional efforts and rooted back to 1992 United Nations Conference on Environment and Sustainable Development (UNCED). There are eight international processes exist globally; The ITTO Process, The Helsinki Process (The Pan-European Forest Process), The Montreal Process, The Tarapoto Proposal, The Dry Zone Africa Process, The Near East Process, The Central American Process, The African Timber Organization Process. In Turkey, The General Directorate of Forestry, has generated national “Sustainable Forestry Management Criteria & Indicators” by adopting Forest Europe process and applied them in 2003. Turkey has reported the status of indicators in 2006, 2008 and 2010. After 2011, the monitoring has stopped temporarily and the criteria and indicator set together with the monitoring efficiency were discussed with wide spectrum of participants in 2017. The final set includes 40 indicators and 116 sub-indicators from six criteria (Akyol and Tolunay, 2014; GDF, 2018; Balkız et al., 2020). And Figure 2.29 indicate a sample map for one of the indicator (Naturalness) under forests biological diversity criteria. The criteria list presented below;

²⁹ <https://firms.modaps.eosdis.nasa.gov/map/#t:adv;d:2020-08-28..2020-08-30;@35.7,38.3,6z>

1. Forest resources and global carbon cycles
2. Forest health and vitality
3. Productive functions of forests
4. Forests biological diversity
5. Protective functions (soil and water)
6. Socioeconomic functions

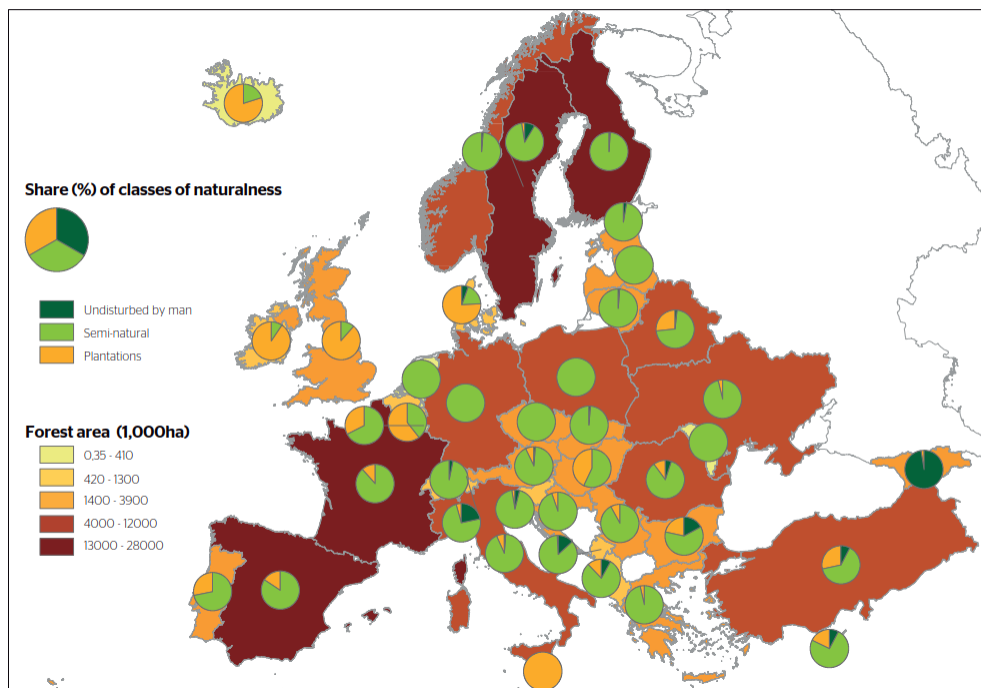


Figure 2.29. Share of naturalness in the forest area (FOREST EUROPE, 2015)

Turkey is a partner of the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) Network. It was launched in 1985 under the Convention on Long-range Transboundary Air Pollution (Air Convention, formerly CLRTAP) of the United Nations Economic Commission for Europe (UNECE). ICP Forests monitors forest condition in Europe at two monitoring intensity levels:

The Level I monitoring is based on 5852 observation plots (as at 2019) on a systematic transnational grid of 16 x 16 km throughout Europe and beyond to gain insight into the geographic and temporal variations in forest condition.

The Level II intensive monitoring comprises 623 plots (as at 2018) in selected forest ecosystems with the aim to clarify cause-effect relationships.

General Directorate of Forestry has been monitoring the forests at constant sites across the country until 2006. The monitoring variables are presented in Table 2.18. Turkey has 608 Level I and 52 Level II plots (Figure 2.30) (GDF, 2013). However, ICP forests 2018 technical report reveals that Turkey has reported only crown condition variable for 52 Level II plots in 2016.

Table 2.18. *Data surveys and frequency of ICP plots*

Type of Travel	Level I	Level II	Frequency
Crown condition and damage	X	X	Annual
Soil condition assessments	X	X	10-20 years
Foliar chemistry	X	X	2 years
Tree growth	X	X	5 years
Vegetation and biodiversity	X	X	5 years
Atmospheric deposition		X	2-4 weeks
Meteorological assessments	X	X	Continuous
Soil solution assessment		X	1-2 weeks
Phenological assessments		X	Every week
Ambient air quality		X	1-2 weeks
Ozone induced injury		X	Annual
Litterfall		X	1-2 weeks

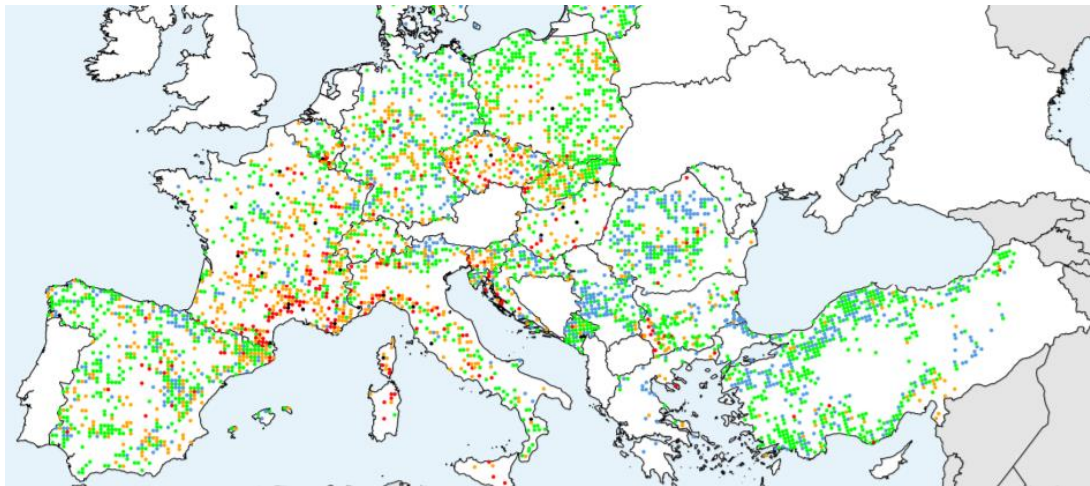


Figure 2.30. Distribution of ICP plots (Michel et al., 2018)

2.4.3.2. Long-term Ecosystem Research (LTER) Network

LTER sites are respectively smaller sites (about 1-10 square kilometers), they simply comprise one habitat type and form of land use. Activities are concentrating on small scale ecosystem processes and structures (biogeochemistry, selected taxonomic groups, primary production, disturbances etc.). The site-level has been the most common in-situ component of LTER over the past two decades. Many sites, set up for pure research purposes, have been maintained for subsequent projects and were thus equipped with certain long term monitoring components. There is also a platform level which is composed of several sites within a defined boundary. The LTER sites constitute an excellent basis for the development of a research infrastructure with an internal uniform design and standardized measurements with the aim of (1) representing various socio-ecological gradients, (2) monitoring not only ecosystem structures and functions but also critical driving forces, (3) enabling comparison between Europe to other continental ecological research infrastructures (Mollenhauer et al., 2018). Turkey has joined the network with two sites 1) Beyşehir Lake, 2) Mogan and Eymir Lakes.

2.4.3.3. UNEP/WCMC- Protected Planet

Protected Planet is an open-online platform where updated marine and terrestrial protected areas are shared globally. It is managed by the United Nations Environment World Conservation Monitoring Centre (UNEP-WCMC). “It works with scientists and policymakers worldwide to place biodiversity at the heart of environment and development decision-making to enable enlightened choices for people and the planet” (<https://www.protectedplanet.net/c/about>). Information about protected areas is submitted by governments, non-governmental organizations, and other authoritative sources and only IUCN protected areas equivalent protected areas are included in the database. Protected Planet offers a foundation for monitoring and reporting on progress towards international environmental targets such as the Aichi Biodiversity Targets and the 2030 Sustainable Development Goals. UNEP-WCMC publishes the Protected Planet Report every two years that reflect the status of the world's protected areas and recommendations on how to meet international goals and targets. However, Turkey's protected area network is not shared with this platform, yet. Thus, the biannual reports do not include Turkey protected area statistics.

2.4.3.4. Monitoring Ecosystem Services

Millennium Ecosystem Assessment (MEA, 2005), had stated that similar to biodiversity, ecosystem services were also declining and a few services (mainly provisioning services e.g. food supply) had monitored periodically yet, the rest had been monitored intermittently.

CBD, Aichi Target 14 is related with ecosystem services: “By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable”.

EU Biodiversity strategy 2020 is also highlighting the ecosystem services concept, and put as a target of mapping and assessing the ecosystem's state and services (Maes et al., 2016).

Monitoring the ecosystem services requires to understand the underlying mechanism in supply and demand sides in socio-ecological systems. Tallis et al. (2012) described monitoring components as supply, delivery, contribution to well-being and value. The status of the ecosystem together with the human management (positively or negatively) identifies the amount of supply. However, delivery is the identical utilization or benefit from that service. The social attributes, demographic properties and distribution of society and how they connect with nature define the amount/level of delivery. Contribution to well-being is the benefit to society for consuming or accessing that service. However, matching key conceptual issues in neoclassic welfare economics and ecological economics is hardly achieved. Issues are highlighted in Gowdy and Erickson (2005). Value is assessed often in monetary values. Apart from direct market values, hedonic values, willingness to pay, avoided costs, preference surveys are also used in valuation (Balvanera et al., 2017)

National statistics, local field surveys and estimations and enhanced remote sensing techniques are sources for ecosystem services monitoring. However, these sources are directly used only for a couple of services (water amount, crop yield, harvested timber, total carbon, etc.). For to understand the distribution of the service across space and time numerical models are used in general. Some examples are given below;

- INVEST: The Integrated Valuation of Environmental Services and Tradeoffs (Tallis et al., 2013).
- LPJmL: The Lund-Potsdam-Jena managed Land Dynamic Global Vegetation and Water Balance Model (www.pik-potsdam.de/research/climate-impacts-and-vulnerabilities/models/lpjml) (Bondeau et al., 2007).
- ARIES: The ARTificial Intelligence for Ecosystem Services (www.ariesonline.org) (Bagstad et al., 2013).

- ESTA: The Ecosystem Service Trade-off Analysis (White et al., 2012).
- MIMES: The Multi-scale Integrated Models of Ecosystem Services (www.ebmtools.org/mimes.html) (Altman et al., 2014).
- Co\$ting Nature (www.policysupport.org/costingnature) (Mulligan 2015).

2.5. What Makes Biodiversity Monitoring Difficult?

Globally, biodiversity monitoring has not had a successful story. Appleby (1991) reported several problems for a county-level monitoring program as lack of coordination, lack of statutory support, inadequate funding, insufficient attention to users' needs and failure to exploit new technology.

Roberts (1991) stated that most of the monitoring programs are descriptive or hypothetical which means that first collect data secondly look for patterns and third think of possible causes. Another process is post-hoc correlative which means that collecting data followed by establishing a question and then checking the data fits an answer. These two approaches are highly inefficient. Monitoring everything is impossible because there will never be enough resources which can be listed as time, money, equipment and expertise.

Bawa and Menon (1997) advise not only biological monitoring but also an integrated socioeconomic monitoring was needed to understand the underlying major factors of change. Then, with this sufficient information of the state of biodiversity could be used in policymaking conservation decisions. For example, land-use patterns change are linked to population density and growth rate. Other causes might be consumption patterns, competition for resources by different segments of society or individuals at national and global scales. Also, the inequity in share and access to natural resources, and inadequate economic valuation of nature contribute to the mounting loss of ecosystems. They also criticize the scale problem in monitoring. Mostly the biological data and socioeconomic data do not match.

Lindenmayer and Likens (2018) provided examples of failures. For example in New Zealand grasslands more than 55% of monitoring programs were unreported. "Data-

rich but information poor” syndrome is also reported by water quality monitoring. Dixon et al. (2019) conducted a survey of 243 protected area staff from 55 countries about the effectiveness of monitoring and evaluation. They indicated that 64% of the respondents informed the ineffectiveness of monitoring efforts. So, what makes monitoring successful? What are the key components of successful programs? The failure reasons are listed by Lindenmayer and Likens (2018) as in Table 2.19.

Table 2.19. The list of problems causing failures in monitoring (Lindenmayer and Likens, 2010)

<i>Problem</i>
Mindless, lacking question
Poor experimental design
Monitoring too many things poorly rather than fewer things well
Failure to agree on what entities to monitor
Flawed assumption that all monitoring programs can be the same
Scientific disengagement from monitoring programs
Poor data management
Loss of integrity of the long-term data record
Lack of funding
Loss of key personnel
Unexpected major event

In addition to Lindenmayer and Likens (2010) findings which were listed in Table 2.19, new items have been highlighted by Dixon et al. (2019) such as organizational culture and commitment, staff capacity, lack of thresholds and protocols (Figure 2.31). They listed broader implications for improvement as (1) increasing cooperation between science and management, (2) developing and implementing standard protocols for data entry, share and storage, (3) increasing reporting frequency, (4) generating biodiversity thresholds or triggers for action; and (5) documenting management intervention options.

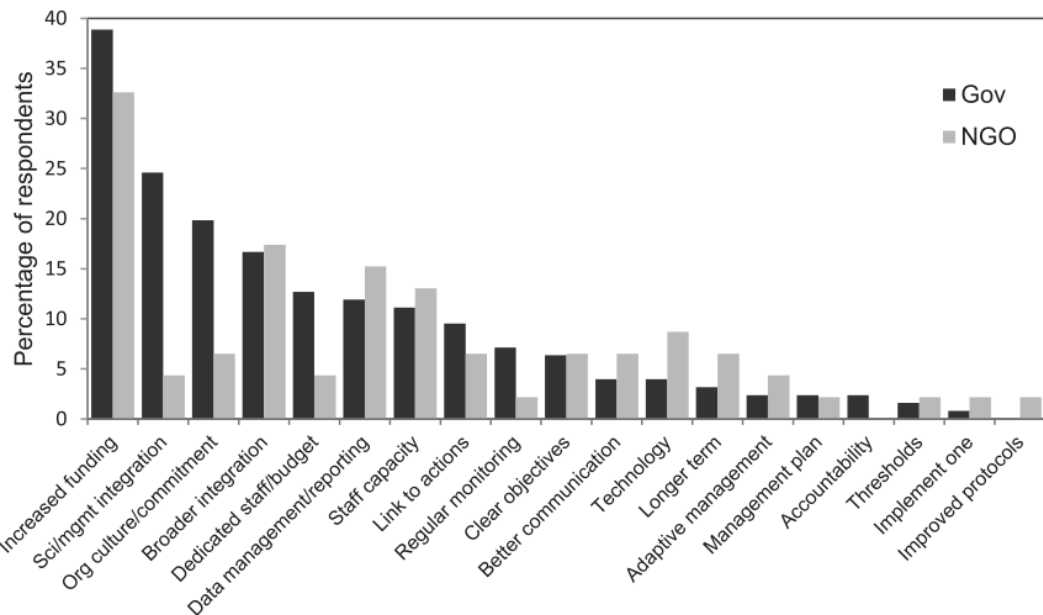


Figure 2.31. Suggestions for better monitoring (Dixon et al., 2019)

Another challenge arises on “what to monitor?” question. Lindenmayer and Likens (2010) summarize two approaches. The first one is the “laundry list” approach which is simply monitoring a large amount of the entity. This approach is out of establishing monitoring on a well-designed question and makes monitoring highly resource (time, money etc.) consuming. The second approach is focusing on “indicator species or groups”. It is necessary to state indicators by answering two issues; (1) which ecosystem components are characterized by this indicator? (2) Which circumstances cannot be characterized by this indicator? However establishing a monitoring program mostly rely on indicators is still problematic because of the following reasons; 1) Indicators are specific to organisms, landscapes and ecosystems. Once the situation changes, then the responsiveness of indicators may decrease. 2) Environmental change can impact different organisms in different ways. Furthermore, the same species might respond to different ways in different ecosystems. 3) Considering the wide spectrum of environmental change, it is hard to detect the causal relationship between the indicator and its representative group.

Another issue is the reliability of monitoring. This problem has several aspects;

- Involving citizen science and non professionals create reliability problems (Buesching et al., 2014). Data reliability in species identification are highly dependent upon taxonomic groups. In general higher taxonomic groups can be correctly identified by volunteers. In case a misidentification is made, quality assurance and quality control are keys to overcome this problem. For example iNaturalist use community not only for species recordings but also for confirming observations.
- Data validation which requires extra effort, is the missing ingredient in most monitoring activities. Establishing checklists with constraints of time and space, and generating automated evaluation of data submission are tools used in validation.
- Existing monitoring data have some common biases (uneven observations in temporal, spatial, taxonomic aspects). Accurate information can be attained by statistical approaches, such as sampling bias, detection, measurement error, identification, spatial clustering, and uncertainty analyses (Chandler et al., 2017).
- Lack of standard sampling protocols cause variance in measurements by different people.

2.6. What Makes Biodiversity Monitoring Efficient?

Biodiversity monitoring should be goal-oriented and provide a framework for predicting the behavior of key ecological attributes to improve management, expand management options and provide early warning of system changes. Successful monitoring criteria can be listed as (Stork et al., 1996):

- Precise description of the spatial and temporal scales of investigation and management
- Clear-mind on the feasibility of the monitoring activity considering the time scale of the project

- Use of an appropriate taxon or taxa to provide the information necessary to illustrate relevant changes
- Use of constant methodologies, including statistics while providing results that are comparable with other sites at a local, regional and global level
- Standardisation of data collection and statistical analysis
- Assuring data on not only biotic variables but also abiotic and anthropogenic variables are recorded

The monitoring is a case sensitive subject; specific methods and particular entities can only be relevant with a given place and time under certain circumstances. So the gained knowledge (and answers to the above-listed questions) commonly cannot be transferable to other circumstances and regions (Lindenmayer and Likens, 2010). A vast amount of studies focus on the experimental design, indicator development, and interpreting plausible results. Although this knowledge cannot be adopted simply, this information is still valuable to guide and develop monitoring efforts. In this section, some examples are presented to set up some basic background.

2.6.1. Building Consensus in Indicators

Up to now several indicators and index (indices) were commonly used in monitoring due to the community interest both in science and policy, the ability to compare them for different times and different places. However, some complex issues arise with the usage of them. Here, I will give the definition first and present examples on them.

An indicator is a parameter or value derived from parameters which describe the state of a phenomenon /environment. In biological studies, an indicator is a selected variable that indicates something about the condition of the environment by way of its condition, behaviour or presence (Spellerberg, 2005). Broadly accepted indicator term evokes “indicator species”. Noss (1990) put forward the definition of indicators far beyond its common usage as “measurable surrogates for environmental endpoints”. According to Noss (1990) indicators should have fundamental attributes;

- be sufficiently sensitive to provide an early warning of change
- be distributed over a broad geographical area
- be capable of providing continuous assessment over a wide range of stress
- be relatively independent of sample size
- be easy and cost-effective to measure
- be able to differentiate between natural and human-induced stress

The index is defined as a set of aggregated or weighted parameters or indicators (Spellerberg, 2005). For many decades, indices have been used in monitoring environment, tracking standards and quality of the environment. Also, there are many composite indices covering environmental and sustainability parameters. Some examples are presented in Table 2.20.

Table 2.20. *Examples of Biodiversity Index*

Index Name	Content	Coverage
The Living Planet Index ³⁰	3 subindex covering ; 4,658 monitored populations of 1,678 terrestrial species. 3,324 monitored populations of 881 freshwater species. 6,170 monitored populations of 1,353 marine species.	Global
The Environmental Performance Index ³¹	32 indicators across 11 issues	180 countries
Ecological Footprints ³²	6 indicators	Global
Biodiversity Intactness Index (Scholes and Biggs, 2005)	The average richness- and area-weighted impact of a set of activities on the populations of a given group of organisms in a specific area	8 countries in Africa

These index-based monitoring provide valuable trend information however their accuracy depends on the available information. For example, the population data is

³⁰ https://www.panda.org/knowledge_hub/all_publications/living_planet_index2/

³¹ <https://epi.yale.edu/>

³² <https://www.footprintnetwork.org/our-work/ecological-footprint/>

restricted to the temperate region and even the distribution of the target population is incomplete due to global data gaps. Thus, it is hard to estimate the magnitude of change with this summarized extract information (Pereira and Cooper, 2006).

Biodiversity measurements guide to track the change for the same place over time and enable to compare the status of biodiversity for different places. However broadly accepted biodiversity measures are highly ambiguous since its complexity in the forms, types, spatial arrangements, processes and interactions (Scholes et al., 2012). Considering the complexity one broadly used metric can be given as an example; the number of species. It is influenced by the scale of observation and the change in the metric is visible only after the species have been lost (Scholes et al., 2008). The biodiversity data can be transformed into indices. Those indices present sensitivity to track change but it is hard to understand the triggering mechanism and trends behind (Scholes et al., 2008).

Several authors have developed methodological studies for selecting indicators. Primarily, Niemeijer and Groot (2008) presented a framework for selecting environmental indicator sets. They put casual chain frameworks (Figure 2.32) in the center of their study and highlighted the importance of selecting criteria for each node in the selected chain. For example, land conversion creates pressure on biodiversity, and the state of biodiversity may shift to a new stage. And in this scenario, the response might be regarded as developing protected areas (PSR chain). Another example is the decrease of fertilizer's market price and an increase in market demand (driving force) then simultaneously the use of fertilizer increases (pressure). This pressure changes the nitrogen concentrations in air, water and soil and its process in the N cycle such as run-off, deposition, leaching (state). This new stage impacts organisms starting from algae population to fish and birds (impact). The enhancement of regulations on fertilizer use is the response. Monitoring should regard each stage in this chain. However, it is very complicated to distinguish the incidents and labelling them because of complex ecosystem interactions together with the uncertainties in policy and socio-economic systems.

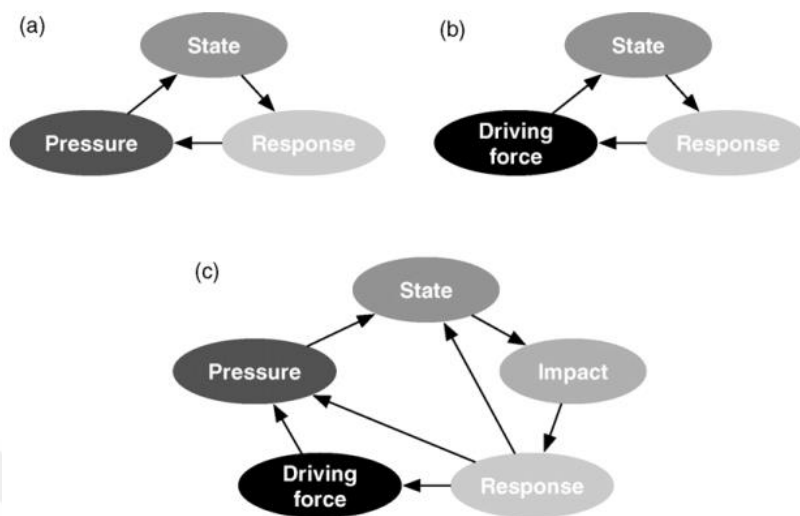


Figure 2.32. Conceptualization of three casual chain frameworks: a) PSR, b) DSR and c) DPSIR (Niemeijer and Groot, 2008)

Niemeijer and Groot (2008) also presented a basin for traditional selection criteria by searching for nine discussed resources (Table 2.21). They suggested first constructing a casual chain for each monitoring question and mapping a network and identifying the most essential nodes in the network and consequently applying these useful traditional criteria presented in Table 2.21. The most acknowledge criteria are measurability, low resource demand, analytical soundness, policy relevance and sensitivity to changes within policy time frames.

Table 2.21. Commonly used environmental indicator selection criteria (Niemeijer and Groot, 2008)

Criterion	Description/explanation
Scientific dimension	
Analytically soundness	Strong scientific and conceptual basis
Credible	Scientifically credible
Integrative	The full suite of indicators should cover key aspects/components/gradients
General importance	Bear on a fundamental process or widespread change
Historic dimension	
Historical record	Existing historical record of comparative data
Reliability	Proven track record

Table 2.21. Commonly used environmental indicator selection criteria (Niemeijer and Groot, 2008)
(continued)

Systemic dimension	
Anticipatory	Signify an impending change in key characteristics of the system
Predictable	Respond in a predictable manner to changes and stresses
Robustness	Be relatively insensitive to the expected source of interference
Sensitive to stresses	Sensitive to stresses on the system (likelihood of response, the magnitude of the response)
Space-bound	Sensitive to changes in space
Time-bound	Sensitive to changes within policy time frames
Uncertainty about level	High uncertainty about the level of the indicator means we can really gain something from studying it
Intrinsic dimension	
Measurability	Measurable in qualitative or quantitative terms
Portability	Be repeatable and reproducible in different contexts
Specificity	Clearly and unambiguously defined specificity to the threat. Is x responsive to other threats?
Statistical properties	Have excellent statistical properties that allow interpretation
Universality	Applicable to many areas, situations, and scales
Financial and practical dimensions	
Costs, benefits and cost-effectiveness	Benefits of the information provided by the indicator should outweigh the costs of usage
Data requirements and availability	Manageable data requirements (collection) or good availability of existing data
Necessary skills	Not require excessive data collection skills
Operationally simplicity	Simple to measure, manage and analyse
Resource demand	Achievable in terms of the available resources
Time demand	Achievable in the available time
Policy and management dimensions	
Comprehensible	Simply and easily understood by the target audience
International compatibility	Be compatible with indicators developed and used in other regions
Linkable to societal dimension	Linkable to socio-economic developments and societal indicators
Links with management	Well established links with specific management practice or interventions
Progress towards targets	Links to quantitative or qualitative targets set in policy documents
Quantified	Information should be quantified in such a way that its significance is apparent
Relevance	Relevance for the issue and target audience at hand
Spatial and temporal scales of applicability	Provide information at the right spatial and temporal scales
Thresholds	Thresholds that can be used to determine when to take action
Use-driven	User-driven to be relevant to target-audience

Another framework was developed by Rice and Rochet (2005) for monitoring fisheries management success. In their approach first, the user groups and their needs were identified. Secondly, a list of candidate variables was selected. In the third step, the candidate indicators were weighted into nine screening criteria which can be listed as concreteness, theoretical basis, public awareness, cost, measurement, historic data, sensitivity, responsiveness, and specificity (Table 2.22). Then, the indicators were scored against the criteria and the outputs of the scoring were summarized. This synthesis was used for prioritizing indicators in the final stage.

Table 2.22. List of criteria and an example of relative importance among user groups (Rice and Rochet, 2005)

Criterion	<i>Technical experts & advisors</i>	<i>Decision-makers &managers</i>	<i>General audience</i>
Concreteness	Minor	Moderate/high	High
Theoretical basis	High	Minor	Minor
Public awareness	Minor	Moderate	High
Cost	Minor	High	Minor to High
Measurement	High	Minor	Minor
Historical data	High	Minor	Minor to High
Sensitivity	High	Moderate	Moderate
Responsiveness	Moderate	High	Minor
Specificity	Moderate	High	Minor

Scheele et al., (2019) evaluated the quality and extent of monitoring efforts for threatened species in Australia based on nine metrics (Table 2.23).

Table 2.23. Description of metrics used for evaluating the monitoring efforts by Scheele et al., 2019

Metric	Description
Fit-for-purpose	The use of methodologies designed to optimize detection of the target species.
Coverage	The spatial extent of monitoring efforts across the target species' distribution.
Periodicity	Frequency of monitoring.
Longevity	The longevity of monitoring.
Design quality	The statistical power of monitoring to detect trends in the occupancy/abundance of the target species.
Coordination	The coordination of monitoring efforts among relevant jurisdictions and stakeholders.
Data availability and reporting	The availability and reporting of monitoring information.
Management linkage	Integration of monitoring and management actions.
Demographic parameters	The inclusion of demographic parameters in monitoring efforts.

2.6.2. Optimizing Sampling Effort

Hoffmann et al. (2019) hypothesized that the information content of diversity and richness indices level off with the number of subplots (Figure 2.33). They sampled various sizes of plots and subplots and compare the results for diversity and richness indices. For all plot sizes and diversity indices, it is valid to say that as plot quantity increases the information also increases. However, when plot quantity stays constant, the information does not saturate as increasing plot size. The results showed that richness values increased with subplot size, regardless of the subplot number. Thus, the largest plots appear to be the optimal size for the delivery of richness information. And for both (diversity and richness) indices the optimum number of plots are recorded as 54 and 36 for plot sizes 2 m x 2 m and 4 m x 4 m, respectively. But they also mentioned that the plot shape and spatial arrangement of plots can affect the

information entropy and this output may not be applicable to other regions due to the dispersal mechanisms of organisms, species density effects and small scale heterogeneity of environmental conditions.

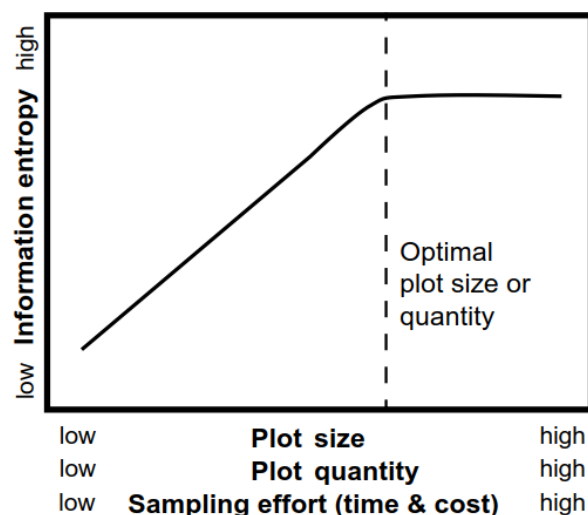


Figure 2.33. Theoretical relation between optimal size and number of sampling plots (Hoffmann et al., 2019)

Similarly, Archaux and Bergès (2008) performed another optimization problem in temperate forests such that detecting 10% change in initial species richness with $\alpha = \beta = 0.5$ over 5 years for ongoing long-term floristic monitoring program by comparing sampling sizes. They illustrated decreasing quadrat size from 300-400 square meters to 100-200 square meters lowers the inventory cost approximately 15% (Figure 2.34). The confidence intervals are overlapping for 300 and 400 square meters quadrat sizes. In case the detection target would be manipulated from 10% to 20% then quadrat sizes could be easily shifted to 100-200 square meters so that the corresponding sampling cost does not exceed some fixed amount.

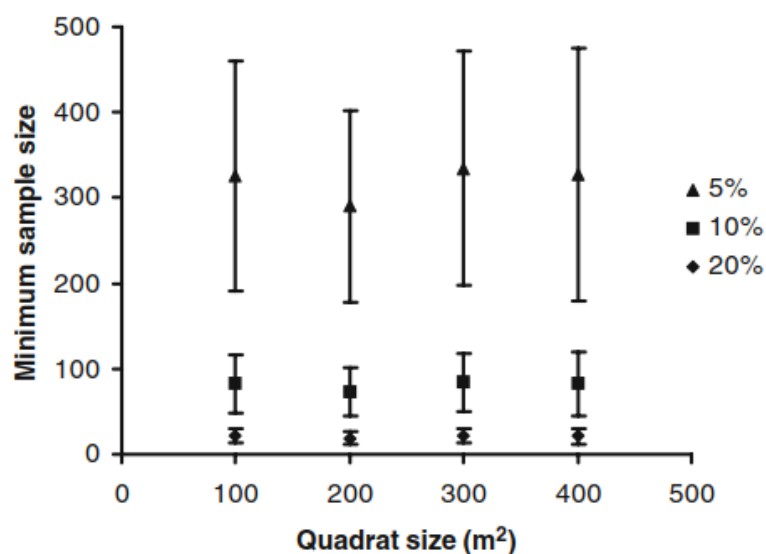


Figure 2.34. Effect of minimum detectable effect size (5, 10 or 20% of initial mean species richness) on the relationship between quadrat size and MSS (Archaux and Bergès, 2008)

Gardner et al. (2008) executed a cost-benefit analysis for biodiversity survey in tropical forests. They compared 14 different taxa across three forest types in the Brazilian Amazon. This was the first study for the region which explicitly accounted survey costs (e.g. c.\$200 for dung beetles to c. \$13 000 for fruit flies). And they concluded that the cost of processing specimen (or deriving species records) and body size has no systematic relation. It is obvious that easily detectable large mammals are the cheapest taxonomic group and the most expensive taxonomic groups have the smallest body size (such as fruit flies). However many plants and a number of vertebrate taxa (e.g. rodents and marsupials, leaf-litter amphibians and lizards) often required intensive processing for species identification. They demonstrated the economies of scale in combining sampling techniques for several groups can reduce survey costs, and consequently improve the cost-effectiveness of monitoring.

2.6.3. Identifying the Survey Details

Identification of species to be monitored constitutes another debate in monitoring. Each author highlighted the importance of defining a clear monitoring goal. For example, Tulloch et al. (2013) developed a framework by conducting a cost-benefit analysis in monitoring invasive mammals for the recovery of 14 native Australian mammals. Similarly, Joseph et al. (2008) studied the management of the threatened species of New Zealand with the aim of securing the greatest possible number of unique species. They used project prioritization protocol (PPP) for optimizing resources and assessed the costs, benefits and the likelihood of management success. Geijzendorffer et al. (2016) conducted a comprehensive analysis of the cost-effectiveness monitoring in farmlands by collecting 12 case studies across Europe. Their research question was whether “a 10% change in species richness in 5 years could be identified with a 10% probability error for farmland biodiversity”. They compared species richness overtime for four taxa (vascular plants, earthworms, spiders and bees) and develop scenarios for Common Agricultural Policy (CAP) budget (2014–2020).

Also, expert judgements were used in ranking the species importance. For instance, Boykin et al. (2013) used mapping and included stakeholder evaluation for developing an approach in a national-scale product by comparing 20 mappable biodiversity metrics related to ecosystem services in the USA.

Additionally, Nielsen et al. (2009) benefit the simulation models (i.e. Generalized Estimating Equation) to determine the number of monitoring sites and duration of monitoring necessary to detect a 3% annual change in species prevalence and they choose certain taxonomic groups by comparing the statistical power of species (prevalence, detectability, etc.) in Canada.

Another contribution was done by Henry et al. (2008) by assessing the monitoring schemes in Europe (EuMon consortium, 2006). Their findings presented that there are

clear linkages between the taxonomic groups and their cause of change (Table 2.24). So definition of “why to monitor” also guides the “what to monitor question” question.

Table 2.24. *Proportions of monitoring schemes which documents a given cause of change (Henry et al., 2008)*

Taxonomic group	Land use	Fragmen- tation	Climate change	Pollution	Invasive species	Nb. schemes
Birds	0.79	0.28	0.48	0.31	0.19	95
Mammals	0.83	0.58	0.15	0.13	0.10	48
Reptiles, amphibians, & fishes	0.88	0.67	0.33	0.55	0.55	33
Butterflies	0.82	0.57	0.57	0.14	0.14	28
Other invertebrates	0.78	0.41	0.41	0.52	0.33	27
Plants	0.82	0.48	0.27	0.34	0.39	44
Fungi & lichens	0.57	0.29	0.57	0.86	0.14	7
Several taxonomic groups	0.89	0.70	0.33	0.26	0.33	27
Nb. schemes	228	146	107	92	72	309

Another discussion is choosing the most effective survey technique. Franco et al. (2007) compare the radio-telemetry and transects surveys, in the study of habitat selection by the lesser kestrels (*Falco naumanni*). They developed a cost-efficiency analysis by comparing the achieved results for different subsamplings. Although telemetry is more resource-demanding (312 EUR) technique, it allows data sampling in areas with poor access. In contrast, transect counts require specific expertise, but cheaper (82.5 EUR) than telemetry but highly depended on the existing road network.

2.6.4. Collaboration between Environmental Agents

Collaboration between the biodiversity actors and the global environment agenda (such as sustainable development, carbon and land degradation) is needed.

Venter et al. (2013) highlighted monitoring effort would be maximized by engaging the REDD+ projects (Reducing emissions from deforestation and forest degradation, plus the conservation, sustainable management and enhancement of forest carbon stocks). In lower-carbon areas, using the novel REDD opportunities for protecting forests and allocate the remaining fund in biodiversity monitoring creates free-ride. They solved the optimization problem with MARXAN and develop options for several scenarios regarding REDD+ strategies together with conservation values in Berau, Indonesia where the Bornean orangutan (*Pongo pygmaes morio*) and High Conservation Value (HCV) areas exist.

Another recommendation was done by Henle et al. (2013) about analyzing reporting priorities in supranational biodiversity legislation and policies in Europe. They compared the Annexes of the Bird and Habitat Directives, international conventions and the IUCN European red lists. They highlighted that monitoring priorities attached to policy needs can obtain governmental funds. Also, there is a high overlap of taxonomic lists (Figure 2.35) defined by several policy reportings. This synergy among policies can increase efficiency.

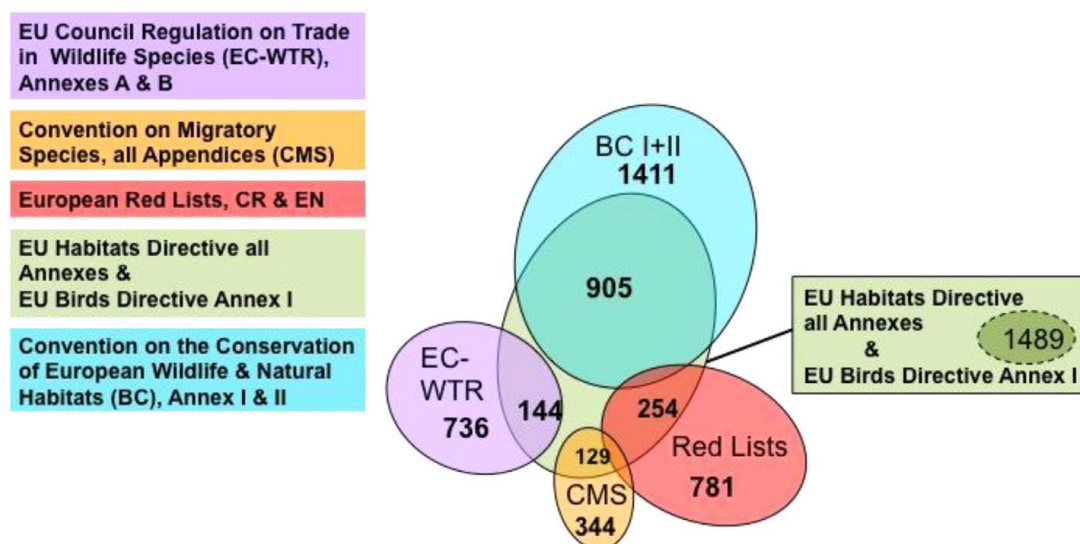


Figure 2.35. Number of species listed in European policy documents (Henle et al., 2013)

Another study evaluated the monitoring networks of Brazilia at national extent (de Oliveira Roque et al. 2018). They suggested developing a Network of Networks connected by indicators using fuzzy logic from existing monitoring programs (for example linking water quality monitoring (currently 1000 station) more into protected areas (only 94 of them are inside PAs). The first step should be connecting all of the frameworks and ongoing initiatives in the same platform. They highlighted the problematic issues as; (1) development and implementation of an integrated information chain from monitoring to policy reporting; (2) capacity building to establish a comprehensive spatial monitoring program; and (3) developing and optimizing semantics and ontologies for data interoperability.

2.6.5. Engaging Citizen Science

Due to the inherent nature of human behaviour in space and time, some redundancies and gaps exist in data. Some popular sites are visited more frequently and some sites are unsampled. The data are noisy and uncertainty exists in most of the unstructured or semistructured projects. For example, Callaghan et al. (2019) highlighted the potential of citizen science data in biodiversity monitoring in the greater Sydney region Australia. In Figure 2.36, they showed the noisy character of population trend models developed from approximately 26000 sampling events between 2010 and 2018. In this study, they examined the options for decreasing uncertainty in population trends by searching the marginal value of each sampling event for 5, 10, 25 and 50 km² grids. They found that while grid size increases, the importance of visiting an unsampled site also increases. They also highlighted the importance of understanding the minimum number of sampling events in a region. They used the definition of a checklist as “a list of all species identified for given spatiotemporal coordinates” and clarified the minimum number should be approximately 11.700 checklists for fifty species. A similar study conducted by Horns et al. (2018) used list length analysis (LLA) to detect the variation and used it as a proxy for observer skill and effort in the USA. They highlighted that approximately 10.000 e-bird checklists are enough to

provide reliable trend analyses. However, the marginal distribution of species in geographical and elevation ranges can impact the trend estimate. Thus, they recommended that opportunistic data can be used to estimate population trends of species, especially of widespread species.

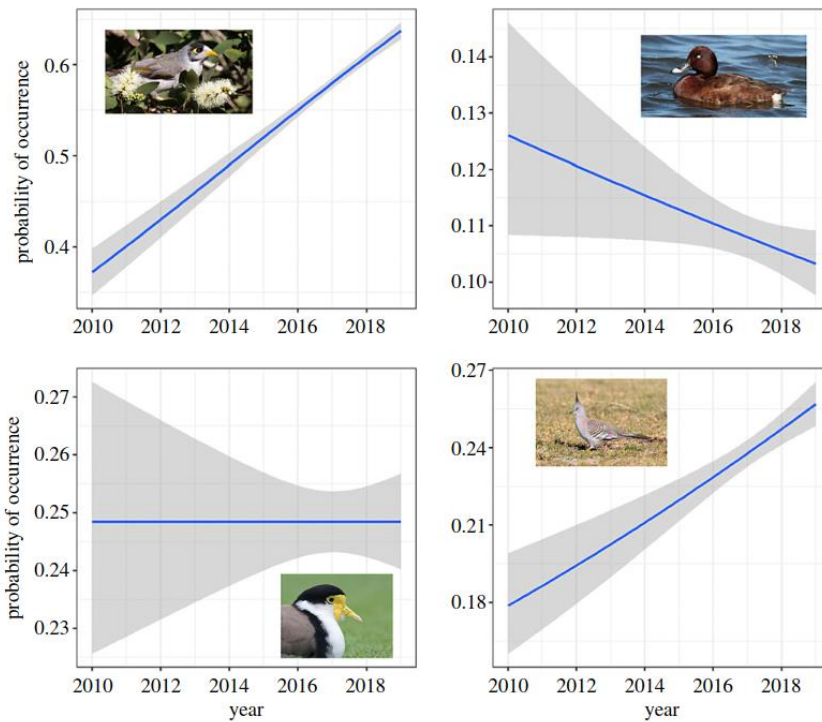


Figure 2.36. Noisy character of e-bird data for Greater Sydney (Callaghan et al., 2019)

2.6.6. Adopting Technological Improvements into Monitoring

2.6.6.1. Camera traps

Novel shooting techniques in photography with better technology of cameras make the usage of camera traps popular. The motion-sensitive sensors capture the species photo without disturbance. These traps are extremely efficient in large mammals. Photos are used in analyzing the distribution of species, estimating species abundance, tracking behaviours and also detecting poachers.

2.6.6.2. Web Sites and Portals

Several examples of citizen science engagement presented in Citizen Science and Community Platforms section. Apart from these community sites, the national databases provide customization of needs. These platforms present a great opportunity to acquire data and to disseminate the knowledge.

2.6.6.3. Mobile Devices and Sensors

Cellular phones are the most important device for several reasons 1) their network access is well-distributed around globe. 2) their battery power is improving by about 20% every year. 3) the application development is a growing industry and there are many successful free applications (Kelling, 2018). Mobile devices enable instant recording of observations with an acceptable degree of spatial certainty since most of the smartphones and tablets have GPS (Global Positioning System).

High-quality photos taken by these devices, provide evidence of observation, and also used in quality controls of non-professional data contributors. Also special sensors such as microphones etc. are used in measuring environmental variables (NoiseTube project; <http://noisetube.net/>). Also, other sensors wore or transported by volunteers are used in measuring air quality, air pollution, water quality and flooding (<http://www.citizen-obs.eu/>).

2.6.6.4. Artificial Intelligence and Augmented Reality

Either audio or image data streams records petabytes of data every year. Storing big data and analyzing and processing it is a huge challenge. However recent technological advances augment the process, transfer and store by the Internet of Things and cloud computing and storage. Any sensor connected in a communication network can transfer data from remote inaccessible areas to smaller base stations then to data loggers and servers. Deep learning techniques are highly used in audio and image data exploration (Klein et al. 2015).

Machine learning is a subdivision of artificial intelligence and frequently used in remote sensing applications (for instance ecosystem condition and function maps, land cover classifications) and generation of species distribution models. They are efficient in both regression and/or classification of nonlinear systems. They are universal approximators and they learn the behaviour of a system component from a set of training data (or species occurrence data), they don't require apriori knowledge or estimation about the system. The types of the algorithms commonly used are artificial neural networks (ANN), support vector machines (SVM), self-organizing map (SOM), decision trees (DT), ensemble methods such as random forests, case-based reasoning, neuro-fuzzy (NF), genetic algorithm (GA), multivariate adaptive regression splines (MARS), etc. (Lary et al., 2016)

Artificial intelligence is used in global camera trap data management and analytics. For example, wildlife insights (<https://www.wildlifeinsights.org/home>) monitors millions of camera-trap images around the world. Its artificial intelligence service distinguishes automatically images with people, non-human animals and no animals. Then the non-human images are further analyzed to detect specific species and labels are sent back to the submitter for review (Thau et al., 2019).

Fedor et al. (2009) used artificial neural networks in monitoring pests. They evaluated 101 European economically important thrips (Thysanoptera) species and their results showed 95% reliability in detection.

Augmented reality is used in identifying species in the field and make a huge contribution in the identification of plants. Mobile augmented reality systems inspects a large database of virtual species and displays specimens and inspects computer vision-based visual search results in the form of virtual vouchers (White et al., 2006). Law et al. (2012) developed a smart application by using augmented reality and increased the reliability of citizen science data for monitoring trees, shrubs, non-native plants, canopy cover etc.

2.6.6.1. Soundscape Ecology

Automated acoustic recognition of species aims to provide a cost-effective method for biodiversity monitoring especially for not only detect species but also quantify the anthropogenic disturbance (Farina et al. 2014). Amphibians, birds and mammals have unique acoustic signatures (singing of birds, croaking of amphibians, chirping of grasshoppers, etc.). Progress has been made in the automatic analysis of soundscapes with the creation of 3D sound profiles (<https://www.recordtheearth.org/index.php>) through sound patch analysis and acoustic gap analysis (Schmeller et al., 2017). Kasten et al. (2012), developed a system which automates to classify acoustic sensor observations into the Remote Environmental Assessment Laboratory (REAL) digital library. They tested unsupervised machine learning techniques for synoptic patterns clusters and manual census patterns in a wetland. The method is useful also for estimating abundance.

The acoustic diversity of a soundscape can be indicative of the richness of an acoustic community and the structural/vegetation characteristics of a habitat. Turner et al. (2018) tested the efficiency of acoustic diversity tools in a forest in the UK. They distinguished between acoustic communities of birds and found a strong correlation between sound patterns and landscape (canopy characteristics and forest stand age). They suggested this low-cost monitoring, can guide the adaptive management of forests while securing the taxonomic diversity of the biological community.

2.6.6.2. Environmental DNA (e-DNA)

e-DNA is a promising technique which can be used in rapid measurements and monitoring of biodiversity. The environmental samples taken from several environments (soil, water, ice) are analyzed with DNA sequencing methods. The most powerful attribute of the method is its ability to present information about species distribution, abundance and population dynamics without collecting the organism (Beng and Corlett, 2020). e-DNA studies based on barcoding (PCR) and

metabarcoding. The difference is barcoding uses species-specific primers while metabarcoding uses universal primers from millions of DNA fragments of the most possible species ranges. Thus detection of single species can be done by barcoding and community measurements done by metabarcoding. Beng and Corlett (2020) listed the beneficial areas of e-DNA as;

1. Detection of invasive, rare, cryptic species and biodiversity monitoring in difficult access habitats.
2. Metabarcoding is useful to understand the current but also the ancient biodiversity patterns
3. To understand diet and trophic interactions and ecosystem dynamics
4. To monitor ecosystem health and dynamics

The environmental conditions defines the applicability of e-DNA methods. The major sampling areas are soil, permafrost, freshwater and seawater. However degradation of genetic material in warm and humid conditions is faster (Beng and Corlett, 2020). Also, the water samples present information about contemporary status of biodiversity. On the other hand soil samples can give information back to decades or centuries. Also deep sediments in water column includes ancient DNA and possible release of them creates suspicion in measuring current status. The other problematic issue is the spatial transfer of DNA traces by predators, humans especially in flowing waters (Thomsen and Willerslev, 2015).

2.6.6.3. Remote Sensing

Remote sensing can be defined as a technique for acquiring data on an object without coming into direct contact with it. Fundamental of remote sensing is the fact that objects reflect or emit different amounts of radiation at different wavelengths. Almost all the radiation wavebands can be exploited for remote sensing, ranging from radar to microwave (Budd, 1991).

Remote sensing allows large-scale characterization of biodiversity in a systematic, replicable and spatially comprehensive way. Duro et al. (2007) synthesized the capabilities of remote sensing for a national monitoring system in Canada. They used four key indicators of diversity that can be inferred from earth observation data: productivity, disturbances, topography and land cover. Monitoring these indicators overtime at the ecosystem level has the potential to create a national early warning system, pointing out areas where the biodiversity may be altering.

Turner et al. (2015), defines remote sensing as a key to overcome monitoring globally. They determined three factors which significantly contributes to this outcome; 1) Data continuity which refers to long-term data products (this attribute allows historical, time-series analysis) 2) Affordability which refers the cost of images. Many free and open access satellite galleries provide invaluable resources. 3) Data access describes the ability of end-users to discover, query, modify and extract values from satellite images and link them to necessary information and monitoring goals.

In terrestrial ecosystems remote sensing can be used to map the following items (Geller et al., 2017);

1. Ecosystem structure and composition by means of supervised and unsupervised classification.
2. Ecosystem function such as net primary production, albedo, land surface temperature, and also ecosystem functional types which characterize energy dynamics and exchange of matters.
3. Ecosystem change by assessing the land cover and land-use change.
4. Species identification by using very high-resolution images (<5cm). Low-cost drones (<\$2000) are used in census counts.
5. Plant Functional Types which are groups of species having similar functions. The idea is species with similar functions share similar spectral signatures. Creating a functional combination allows scaling of vegetation communities.

6. Landscape genetics. For example identifying landscape spatial features (how fragmented, how wild etc.) can guide the genetic research. The major questions are; How habitat fragmentation affects the genetic pool? Which areas should be protected in order to maximize genetic diversity?

Several remote sensing instruments and methods can serve to track biodiversity. Vihervaara et al. (2017) summarized different resources and their utilization in Finland (Table 2.25). They also investigated the usefulness of earth observations for meeting the essential biodiversity variables and concluded that ecosystem function, ecosystem structure, community composition and species traits could considerably benefit from remote sensing at a national scale.

Table 2.25. *Contribution of remote sensing instruments in Finnish Biodiversity Monitoring*
(Vihervaara et al., 2017)

Instrument	Spatial resolution	Biodiversity indicator
Coarse spatial resolution (MODIS, AVHRR, MERIS, Sentinel 3)	250-1200m	Algae, Organic matter, pollen season*
Medium to high spatial resolution (Landsat, SPOT5&6, RapidEye, Sentinel 2)	5-30 m	Forest fragmentation, tree line, tree species compositions*, bird and butterfly habitats*
High temporal resolution (MODIS, AVHRR, Sentinel 2)	22-1000m	Tree species composition, pollen season*
Very high spatial resolution (IKONOS, QuickBird, GeoEye, WorldView)	0.5-4 m	Forest vegetation, tree species composition, deadwood*, bird and butterfly habitats*, butterfly range shifts*, seals
Hyperspectral (Hyperion, AISA, AVIRIS)	1-2 m and 30m	Forest vegetation, tree species composition
Active remote sensing data (SARs, ERS, ASAR, Radarsat, Cosmo-Ksymbed, Sentinel 1, LIDAR)	1-100m	Forest age structure, forest birds*, wildlife richness, tree species composition
* requires other datasets (e.g. in-situ data, statistics)		

Remote sensing is also used to detect natural disturbances. An experiment was conducted in Kruger National Park to test the fire detection performance of Sentinel-2. On October 16, 2018, the fire team managed to ignite two controlled fires on the experimental plots, just in time for both Sentinel-2 and Sentinel-3 to detect these fires during their daily quotidian overpasses.

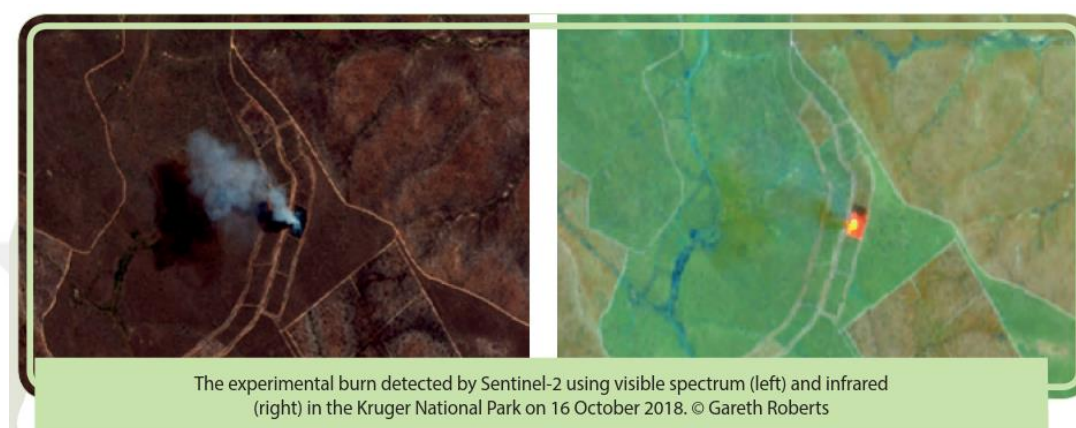


Figure 2.37. The experimental fire ignition caught by Sentinel 2 (Source: SAN Parks Research Report 2018-2019³³)

In Table 2.26 especially large scale national monitoring programs which use remote sensing are listed.

Table 2.26. Large scale monitoring programs using remote sensing

Definition	Scope-Ecosystem	Gallery	Reference
National Inventory of Wetlands	Canada-Wetlands	Sentinel 1 & 2	Mahdianpari et al., 2020
Change detection for ecological monitoring	USA, Protected areas	Landsat & MODIS	Willis, 2015
Natura 2000 habitat monitoring	Europe, Natura 2000-	Review	Borre et al., 2011
Large area biodiversity monitoring system	Canada-national scale	Landsat, MODIS, SRTM	Duro et al., 2007

³³ <https://www.sanparks.org/scientificservices/wpcontent/uploads/2020/04/2019-research-report.pdf>

Table 2.26. Large scale monitoring programs using remote sensing (continued)

Definition	Scope-Ecosystem	Gallery	Reference
Biodiversity monitoring framework for the Australian rangelands	Australia-rangelands	Review	Eyre et al., 2011
Growing stock and above-ground biomass in forests	Europe, Forests	MODIS	Gallaun et al., 2010

Unmanned aerial vehicles (drones) are increasingly popular in the conservation community since they are effective and cost-saving solutions for field-based tasks such as the detection and monitoring of wildlife and their habitats (e.g. Koh and Wich, 2012; Hodgson et al., 2018). Although it is widely considered as a promising instrument for wildlife surveys, drone technology in combination with a variety of associated sensors, such as thermal or RGB cameras, has been used in a very limited range of conditions. Such cases include the measurement of large animals (Corcoran et al., 2019) or the location of bird nests (Andrew and Shephard, 2017).

2.7. Some Examples of Large Scale Monitoring Programs

2.7.1. Switzerland

The national biodiversity monitoring programme of Switzerland (<https://www.biodiversitymonitoring.ch/en/home.html>) comprises 34 indicators based on three pillars of indicator sets; pressure indicators, state indicators and response indicators until the end of 2015 (Table 2.27). From 2016 the program focuses measuring species diversity of selected plant and animal species (also covers common species) in systematic sampling grids at three scales; species diversity in landscapes, species diversity in habitats and diversity of species communities. Species diversity in landscapes consists of app. 450 sampling areas covering 1 square kilometer. Vascular plants, butterflies and breeding birds (by the Swiss Ornithological Institute) are under focus and 20% of the total surface being sampled each year. Species diversity in

habitats covers roughly 1,450 sampling areas covering 10 square meters each. Habitats include forests, grassland, settlements, arable land, alpine pastures and mountains. Surveys target vascular plants, mosses and mollusks. Diversity of species communities describes the development of species compositions in various habitats and within Switzerland's regions. It is based on presence and absence data of individual species gathered in the other samplings.

Table 2.27. Indicator set of National Biodiversity Monitoring of Switzerland until 2015

Pressure Indicators	State Indicators	Response Indicators
- Size of Areas of Defined Use - Size of wilderness areas - Length of linear landscape features - Diversity of Land Use and Land Cover - Nutrient supply in the soil - Intensity of Agricultural Land Use - Forest area dominated by non-indigenous trees - Area of artificially regenerated young woodland - Deadwood - Volumes of water withdrawn from watercourses - Proportion of adversely affected watercourses - Water quality - Landscape Fragmentation	- Number of Livestock Breeds and Plant Varieties - Proportion of Livestock Breeds and Plant Varieties - Species Diversity at National and Regional Level - Number of species in Switzerland facing global extinction - Change in the Endangerment Status of Species - Population Size of Endangered Species - Species Diversity in Landscapes - Population Size of Common Species - Species Diversity in Habitats - Size of Valuable Habitats - Quality of Valuable Habitats - Diversity of Species Communities	- Size of Protected Areas - Size of Secure Protected Areas - Endangered Species Living in Protected Areas - Biodiversity priority areas - Areas farmed organically

2.7.2. New Zealand

New Zealand Department of Conservation develops a comprehensive and integrated biodiversity inventory and monitoring programme focusing to understand better the biodiversity, ecological integrity and ecological processes. The systematic approach includes three layers of information namely as tiers (<https://www.doc.govt.nz/our-work/monitoring-and-reporting-system/>).

Tier 1: Broad-scale monitoring for national context: It is started in late 2011, involves the regular assessment of a selection of native species and pests at locations 8 km apart and spaced evenly across the landscape – except where the site falls in a river or lake. To provide consistency this monitoring is carried out with the stakeholders and community support. The terrestrial monitoring programme has been established at approximately 1400 plot locations that are evenly spaced. Approximately 280 plots are measured each year, with every plot being measured on a 5-year rotation cycle. This spatially extensive monitoring programme has been designed to provide unbiased, repeatable, national-scale estimates of priority biodiversity indicators and measures.

Tier 2: Nationally-consistent monitoring of managed places and species on land, freshwater and in the ocean to report on management effectiveness: It involves consistent, rigorous monitoring of the outputs (management results) and outcomes (management achievements) of specific activities on land, in freshwater, or in the marine environment. A nationally consistent approach is needed so the data can be combined and compared across projects and used to build an understanding of New Zealand's ecological integrity.

Tier 3: Intensive, targeted monitoring for research and evaluation: It combines intensive research and monitoring at a few key sites distributed throughout New Zealand and maintenance of some important historic datasets. This context is needed to help predict and interpret national and local-scale trends.

2.7.3. Norway

Certain et al. (2011) has developed the Nature Index and applied in Norway. The framework uses the existing information by incorporating expert judgement and monitoring- based and model-based estimates for any ecosystem type. The gap areas for further research become apparent for any ecosystem or any target with this comprehensive approach. In the framework, a biodiversity indicator is defined as: A natural variable which refers to any aspect of biodiversity is intended to react to environmental changes and is representative of a defined area. It is a quantity for which a value can be estimated in a reference state. The set of indicators should cover all aspects of biodiversity as homogeneously as possible and any inclusion of a new indicator should result in the addition of information.

And they also defined the reference state as; the environmentally sustainable status for certain indicator “i.e. the numerical value of the indicator in the reference state, is a value that minimises the probability of extinction of that indicator (or the species or community with which it is associated), maximises at least one measurable aspect of the biodiversity of the natural system with which it is associated, and does not threaten any measurable aspect of biodiversity in that or any other natural system”. In practice, the reference state can be defined by scaling observed or estimated values for each indicator. In addition to actual measurement model predictions and expert judgements are valuable information sources. Totally 308 indicators were selected and 238 of them were specific to a major ecosystem (Table 2.28). The indicators were selected by experts primarily by specialist and generalist species and further extending the classes into primary producers, decomposer of organic matter, primary consumer and filter feeder, intermediate predator, top predators. Understanding how reference states were set across major ecosystems enhances our understanding of how inferences can be drawn from the indicator set they also develop ecosystem indicators (grey rows in Table 2.28). The reference data were collected for four years (1950, 1990, 2000, and 2010) using 430 Norwegian municipalities as spatial units.

Table 2.28. Number of indicators per major ecosystem (white cells show the indicators used in thematic groups, grey cells show the indicator for an operational definition for the reference state) (Certain et al., 2011)

Indicators	Ocean bottom	Ocean pelagic	Coast bottom	Coast pelagic	Open lowland	Mires & wetland	Freshwater	Forest	Mountain
Spe: specific to only one major ecosystem	10	16	27	9	30	29	36	59	22
Key: related to a keystone species	5	7	6	5	7	6	14	11	7
Red: related to VU, EN, CR Red list species	6	7	5	4	12	10	14	12	6
Comm: related to an ecological community	3	2	8	2	2	1	9	5	2
Serv: related to the provision of ecosystem services	26	32	35	27	30	22	21	23	16
Ext: considered as extra-representative by the experts	4	5	8	3	4	4	4	5	3
Tot: total number of indicators	31	40	48	35	57	40	42	72	30
CC: carrying capacity	4	2	4	1	1	0	1	8	5
Sust: maximum sustainable value	0	0	0	0	1	1	2	2	0
Past: knowledge of past conditions	12	17	12	4	8	4	4	18	5
Prec: precautionary level	6	15	5	23	17	0	0	1	0
Prist: pristine or near-pristine nature	3	3	22	6	24	32	27	40	20
Best: best theoretical values of indexes	0	0	0	0	0	0	8	0	0
Trad: traditional management	6	3	5	1	6	3	0	3	0

Apart from the trend in biodiversity change, one important finding of the study is highlighting the gap in certain ecosystems and regions. In Figure 2.38 the distribution

of data sources to accomplish this framework is presented. Expert-based judgements increase the uncertainty of the study thereby one future direction has been identified as to reduce the proportion of expert-based judgments.

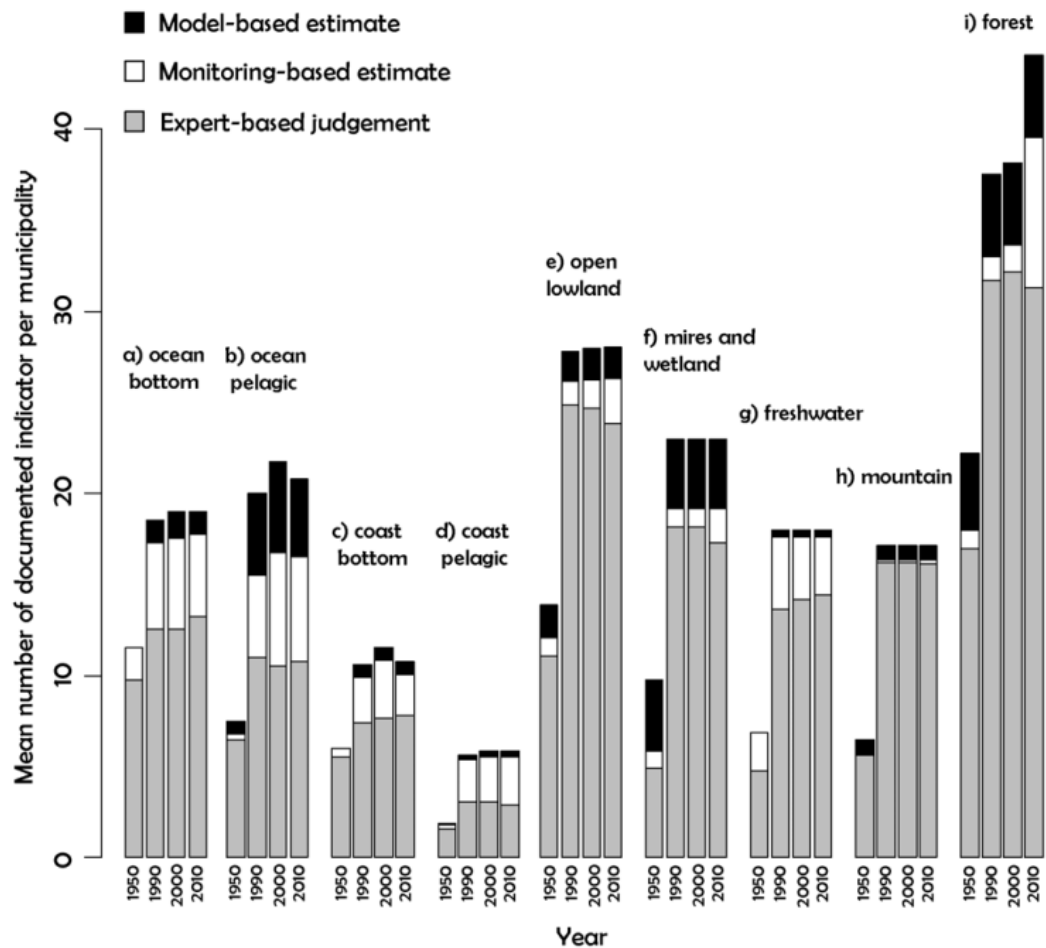


Figure 2.38. The share of data source for the mean number of documented indicators per municipality for date, and major ecosystem (Certain et al., 2011)



CHAPTER 3

AN EVALUATION OF CURRENT KNOWLEDGE IN EBVS PERSPECTIVE FOR TURKEY

This chapter identifies the concurrent situation of biodiversity monitoring in Turkey and highlights the gaps in taxonomic, spatial, temporal and, technical perspectives in accordance with EBVs. In the previous section, two findings become prominent and affecting biodiversity monitoring; (1) Expertise appeared to be the major limitation after budget constraints, (2) Up to now current efforts concentrated on species level and specific species groups. This chapter focuses on answering the following questions in the light of the methodological findings collated by questionnaires and literature surveys;

1. Budget cannot be changed but expertise can be enhanced. What is the distribution of the technical expertise distributed taxonomically among EBVs?
2. Is “species-level condensation” a choice or a limitation related to the expertise?
3. Which species, ecosystems are well-known and vice versa little-known?
4. Which EBVs can be sustained with the current knowledge?
5. Which internal attributes of existing monitoring efforts make them weak or strong?
6. What are the opportunities and challenges for future monitoring programs?

Previous efforts examine this knowledge level by comparing the biological data itself. For example, Fernández et al. (2015) conducted a similar study in Bolivia and analyzed the taxonomic, temporal and, spatial coverage of biodiversity data with 648.534 observations from 27.534 species, had recorded between 1789-2015. Another study revealed the existing observation’s gaps in taxonomy, spatial and temporal ranges in Europe extent (Wetzel et al., 2018) by evaluating thirteen integrators (i.e. GBIF, Atlas Florae Europaeae, Fauna Europaeae, LTER etc.) of biodiversity occurrence data in Europe. Lengyel et al. (2018) evaluated European monitoring

performance based on a survey aimed at collecting metadata information. They have sent more than 1600 survey forms and conducted the analysis with 646 species and 35 habitat monitoring schemes.

However, data is so scattered and data access is highly problematic in Turkey. Some of the obstacles behind not obtaining biodiversity data are listed below. The reasons are not limited to these items.

1. Scarcity of biodiversity data;
 - a. Biodiversity data is scarce and limited across space and taxonomic groups
 - b. Existing data is scattered through several organizations. The lack of centralized, coordinated biodiversity monitoring.
2. Restrictions in data access
 - a. National governmental organizations' unwillingness to share data
 - b. Personal unwillingness to share data in academia
 - c. Absence of standardized data storage and data share tools
3. Lack of metadata;
 - a. Metadata is a piece of useful tag information that is mostly used to explore and harmonize data. Up to now metadata generation is not required or forced due to the lack of shared culture between institutions and people
 - b. The unorganized data storage scheme
 - c. Data is mostly stored by personal use

Because of these reasons, throughout this study, I cannot reach the exact biodiversity data. Thus, I compiled the metadata information via literature surveys and questionnaires and generate a portfolio for further investigation. I focused on the terrestrial realm. Even though the Noah's Ark Biological Diversity Database includes thousands of species occurrence records, the government data share policy prevents to use the data for scientific purposes (Personal Communication). The information I

got from the grey literature (Noah's Ark and progress reports, and province reports) are contradicting and the generic information presented by governmental reports and websites are not enough to fill even basic metadata information.

3.1. Generation of Biodiversity Monitoring Portfolio

Active and potential monitoring programs were searched by questionnaires and the grey literature search. The questionnaire form includes questions related to the technical details of the monitoring program and also information about data gathering, storage and management phases of the monitoring. The questionnaire form is presented in Appendix A.

3.1.1. Active Monitoring Programs (AMP)

These programs are executed in the field by governmental agencies or nature conservation NGOs for long time. The programs have been screening according to the following two criteria;

1. Monitoring has been continued at least 5 years
2. Monitoring has been repeated at least 3 times within the last 20 years
3. Sampling technique is constant in monitoring actions

The exceptional cases in this review that did not fulfil the criteria are; (1) wildlife abundance counts that are collected by the aim of defining poaching quota of game species, since the sampling is irregular and unreliable and subjective (2) inventory efforts that have been demanded by the government under the context of Environmental Impact Assessment Studies and Reports, since the monitoring activities are executed only during the preparation of the project. In total 16 monitoring programs have been assessed. The selected active monitoring programs are presented in Table 3.1.

Table 3.1. The list of Active Monitoring Programs

Name of the program	Target Species / Species Group
Monitoring of Forest Ecosystems (ICP Level I & Level II)	Forest
Mid-winter Waterfowl Survey	Birds
Common Birds Census	Birds
Turkey Bird Atlas	Birds
Monitoring breeding of <i>Bald ibis</i>	<i>Geronticus eremita</i> Birds
Monitoring of the ferruginous duck	<i>Aythya nyroca</i> Birds
Monitoring of the flamingos	<i>Phoenicopterus roseus</i> Birds
Monitoring Manyas Bird Paradise	Birds
Monitoring Biodiversity in Kars and Iğdır	Birds and Large Mammals
Monitoring Ankara's threatened plants	Plants
Monitoring of the sociable lapwing	<i>Vanellus gregarius</i> Birds
Monitoring of the white storks	<i>Ciconia ciconia</i> Birds
Monitoring of the otter	<i>Lutra lutra</i> Small mammal
Monitoring sea turtles in Çukurova Delta	<i>Caretta caretta</i> & <i>Chelonia mydas</i> Herpetofauna
Monitoring of the loggerhead sea turtle	<i>Caretta caretta</i> Herpetofauna
Monitoring the habitats and population of the Mediterranean Monk Seal	<i>Monachus monachus</i> Large mammal

Seven of the monitoring programs are a part of greater international monitoring efforts: Mid-winter Waterfowl Survey, Common Birds Census, Turkey Bird Atlas, Monitoring of the flamingos, Monitoring of the sociable lapwing, Monitoring the habitats and population of the Mediterranean Monk Seal, Monitoring of Forest Ecosystems (ICP Level I & Level II). Almost all programs are executed by the coordination of governmental organizations together with NGOs and funded by governmental organizations and international organizations. Thirteen of them are

reported to governmental organizations and nine of them are reported to international organizations. The distribution of species groups are presented in Figure 3.1. The birds are dominating the current monitoring effort which are executed mostly on wetlands.

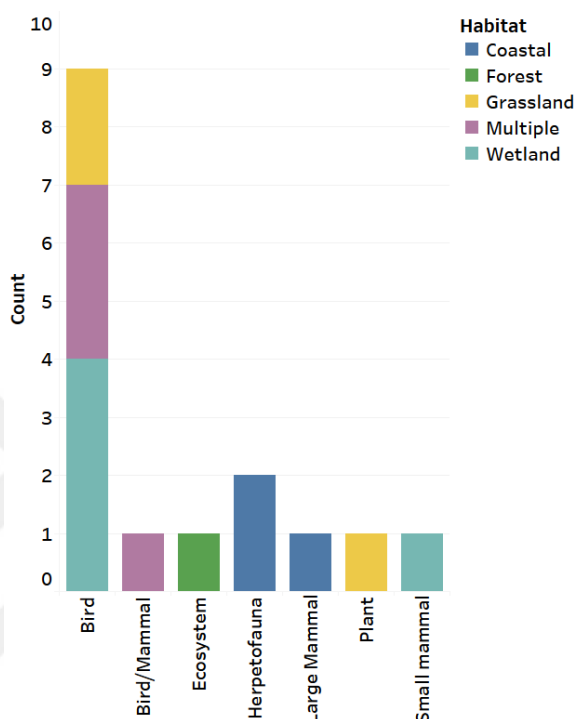


Figure 3.1. Distribution of monitoring efforts among species groups and ecosystems

All of the items focus on the species distribution and population abundance except “Monitoring of Forest Ecosystems” all of them focusing population abundance. Considering the spatial coverage, six of them are executed countrywide and seven of them particularly performed in one study area. However the countrywide studies less represent the Eastern and Southeastern Anatolian region. Figure 3.2 shows the spatial coverage monitoring programs. The map organized in accordance with species groups. And color tones represent the frequency of efforts. Studies performed in multiple areas cannot digitized accordingly because of the irregular information. Thus the geographical regions were shown. For example Mid-winter Waterfowl Survey is executed on wetlands but the surveyed lakes and wetlands may change according to

the level of participation, weather conditions etc. each year. Five of them are not paying attention to covering protected areas but the following items are particularly performed within the protected areas, the other items can include some protected areas unconsciously;

- Monitoring breeding of Bald ibis (Birecik Bald ibis wildlife breeding station, Şanlıurfa Birecik Fırat Wildlife Conservation Area)
- Monitoring of the flamingos (Tuz Lake Special Environmental Protection Area and Gediz Delta Ramsar Site)
- Monitoring Manyas Bird Paradise (Manyas Bird Paradise National Park). *This monitoring effort is the only sample which is directly linked with the protected area itself.*
- Monitoring Biodiversity in Kars and Iğdır (Kuyucuk Lake Ramsar Site and Wildlife Conservation Area, Kars Sarıkamış National Park)
- Monitoring Ankara's threatened plants (Gölbaşı Special Environmental Protection Area)
- Monitoring of the Otter (Gökova Special Environmental Protection Area)
- Monitoring sea turtles in Çukurova Delta (Akyatan Lagoon Wildlife Reserve & Ramsar Site, Yumurtalık Lagoons National Park & Ramsar Site)
- Monitoring of the ferruginous duck (Kızılırmak Delta Ramsar Site and Wildlife Conservation Area)

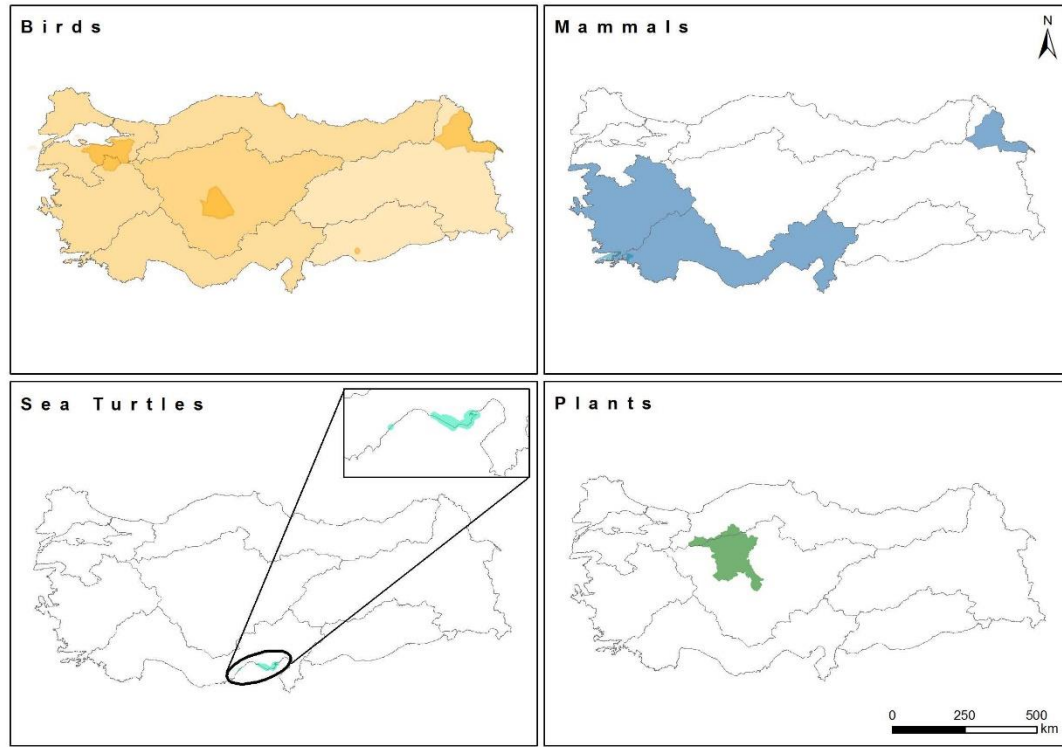


Figure 3.2. Spatial coverage of monitoring efforts in species groups

Especially the efforts executed by citizen science cover larger areas (i.e. Mid-winter Waterfowl Survey, Common Birds Census, and Turkey Bird Atlas). Apart from these also “Monitoring of the white storks, Kars-Iğdır Biodiversity Monitoring” projects executed by integrating citizen science. Although the spatial coverage varies largely only five of them use citizen science in data collection and half of them executed by the same small number of experts (up to 10 people). Despite this lower participation and contribution the spatial coverage of study areas are relatively higher; one third of them is larger than 1000 km² and 62% is larger than 100 km².

Except four efforts (Common Birds Census, Monitoring breeding of Bald ibis, Monitoring of the otter, Monitoring of the ferruginous duck), the rest of the programs are ongoing. Despite these efforts are planned to be executed annually, half of them has interruptions in their history.

Considering the database management and reporting; five of them are stored in Noah's Ark National Biodiversity Database, nine of the monitoring data is stored in other databases (e-bird). Seven of the activities have strict data limitations. None of them shares data or metadata online. But reports or summary maps/ information are available for the following monitoring efforts; Turkey Bird Atlas (<http://kustr.org/kusatlası/>), Mid-winter Waterfowl Survey (<https://www.tarimorman.gov.tr/DKMP/Sayfalar/Detay.aspx?OgeId=71&Liste=Duyuru>).

3.1.2. Potential Monitoring Programs (PMP)

As described in “2.3.3. National Policies and Organizations” section General Directorate of Nature Conservation and National Parks has set two goals in 2013 to be completed until 2023;

- (1) to prepare 10 Species Action Plans (SAP) each year (in total 100 plan)
- (2) to complete the biodiversity inventory throughout country (UBENIS project-National Biodiversity Inventory and Monitoring project)

This accelerated movement of species inventory and conservation have shifted the monitoring issue. Even though any assessment has been reported regarding monitoring, these governmental strategies are substantial for guiding monitoring and are probable for near future. In the grey literature accessed from web sites of responsible organizations were collated and I reached the species action plans. Since the SAPs have projected monitoring actions, I consider them as potential monitoring programs.

39 SAP reports which were available online. However the official website of GDNCNP does not include them anymore. Maybe due to the change in 2018; The Ministry of Forestry and Water Affairs transformed to The Ministry of Agriculture

and Forestry. The metadata of suggested monitoring activities in these grey literature were compiled in accordance with the desired metadata.

3 of them focusing endangered fish species. Those SAPs are eliminated from the portfolio. The list of evaluated SAPs (36 in total) are presented in Table 3.2. They were completed between 2013- 2016. After these year the SAP reports were not shared public.

Table 3.2. The list of Species Action Plans (SAPs)

Name	Species Group	Name	Species Group
<i>Grus grus archibaldii</i>	Bird	<i>Crocus speciosus subsp. xantholaimos</i>	Plant
<i>Otis tarda</i>	Bird	<i>Erodium hendrikii</i>	Plant
<i>Tetrao mlokosiewiczi</i>	Bird	<i>Ferula mervynii</i>	Plant
<i>Acanthodactylus schreiberi</i>	Herpetofauna	<i>Fritillaria baskilensis</i>	Plant
<i>Darevskia sapphirina</i>	Herpetofauna	<i>Iberis halophila</i>	Plant
<i>Rafetus euphraticus</i>	Herpetofauna	<i>Lilium candidum</i>	Plant
<i>Vipera anatolica</i>	Herpetofauna	<i>Polygonum samsunicum</i>	Plant
<i>Vipera kaznakovi</i>	Herpetofauna	<i>Pseudodelphinium turcicum</i>	Plant
<i>Formica pratensis</i>	Invertebrate	<i>Rhodothamnus sessilifolius</i>	Plant
<i>Dama dama</i>	Large Mammal	<i>Salvia siirtica</i>	Plant
<i>Felis chaus</i>	Large Mammal	<i>Scilla mesopotomica</i>	Plant
<i>Hyaena hyaena</i>	Large Mammal	<i>Thermopsis turcica</i>	Plant
<i>Monachus monachus</i>	Large Mammal	<i>Tulipa orphanidea</i>	Plant
<i>Monachus monachus</i>	Large Mammal	<i>Verbascum eskisehirensis</i>	Plant
<i>Ajuga xylorrhiza</i>	Plant	<i>Verbascum yurtkuranianum</i>	Plant
<i>Alyssum nezaketiae</i>	Plant	<i>Meriones dahli</i>	Small mammal

Table 3.2. The list of Species Action Plans (SAPs) (continued)

<i>Astragalus beypazaricus</i>	Plant	<i>Myomimus roachi</i>	Small mammal
<i>Iris peshmenian</i> , <i>Hypericum malatyanum</i> , <i>Ornithogalum malatyanum</i>	Plant	<i>Myotis brandtii</i>	Small mammal

Mostly these SAPs have been developed for threatened species. Critically endangered plants among species and grassland among ecosystems are dominated the SAPs (Figure 3.3). High endemism rates in plants unsurprisingly lead to a strong emphasis on them.

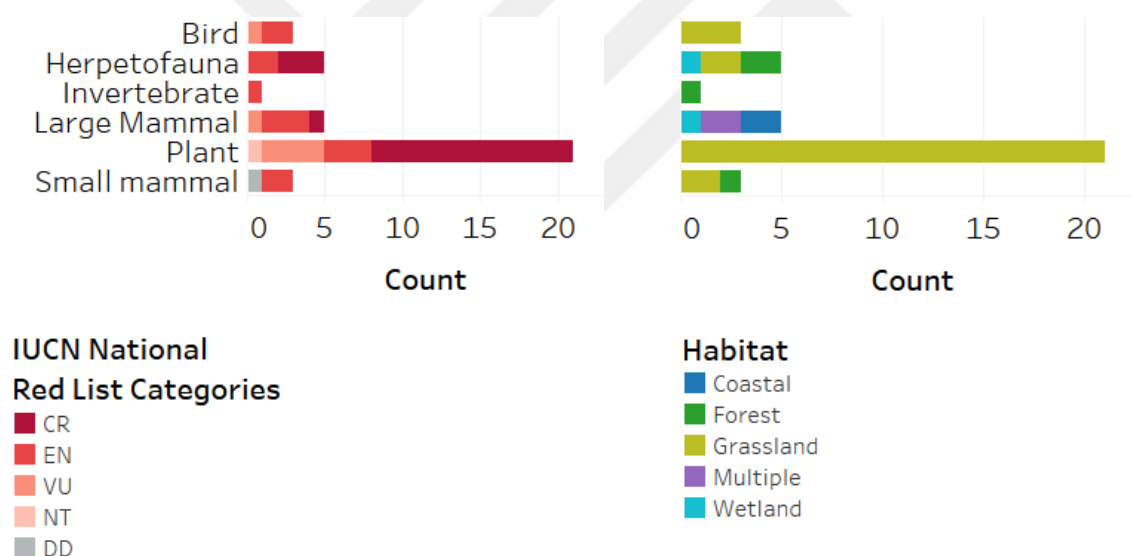


Figure 3.3. Distribution of SAPs among IUCN Red list Categories and Habitats

All of them propose monitoring activities commonly in species distribution (100%) and abundance (82%). And %10 of them suggest genetic studies as a monitoring tool. Some of them mention also community level interactions and ecosystem change as a

monitoring activity however they do not specify the details of these activities. Due to these reason only the genetic and population level monitoring activities are considered.

The population size is presented as the number of individuals observed during site studies, only e few studies estimated population size. Only one SAP included a population viability analysis (*Polygonum samsunicum*).

The SAPs were prepared by tenders. So even though a target species distributes over wider regions, the SAPs were prepared within a province (Figure 3.4). About half of the target species range are wider then their SAP's coverage. For example Mediterranean Monk Seal SAPs were prepared two times for Muğla and Mersin provinces instead of covering the whole Mediterranean region. Only two of them (*Grus grus archibaldii* and *Otis tarda*) were prepared at national level (These 2 SAPs are not shown in the map). While the reviewed SAPs have patchy geographical coverages and distributed throughout the country. Most SAPs propose new sites for protection of the target species. Existing protected area or connection with them were not mentioned.

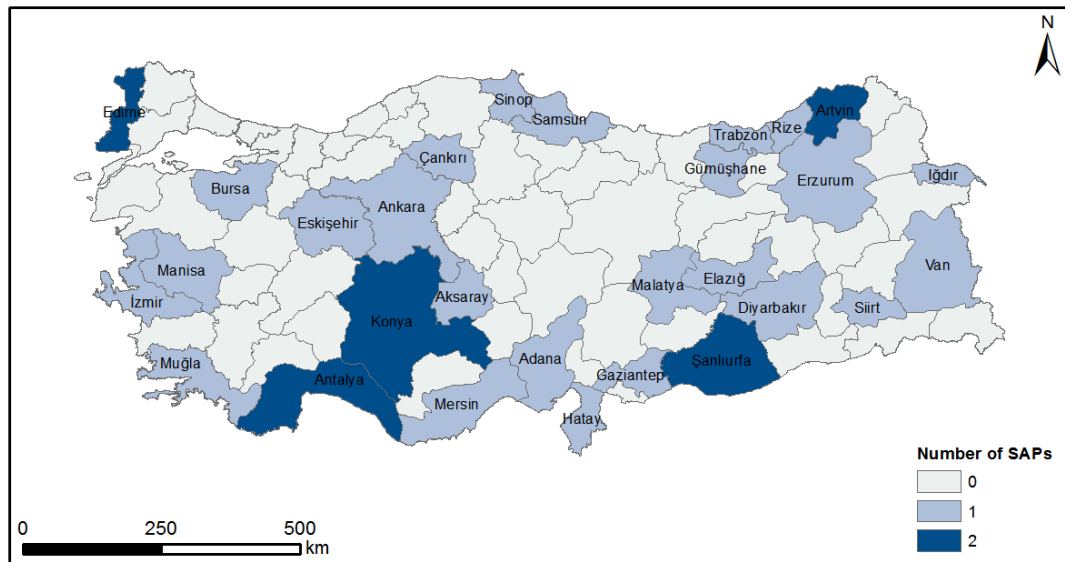


Figure 3.4. Map of SAPs locations

3.1.3. Academic Studies (AS)

The academic studies (thesis and peer review articles) were quarried from SCOPUS and YÖK National Thesis Databases between 1985 and 2018. A descriptive query were applied with the following words in title, abstract or keyword; (“ecolog*” OR “biolog*” AND “monitor*”). This study particularly focuses the EBV requirements thus, exact EBVs exact names were added to query sentence (Step 1- Identification). “Breed and variety diversity” variable in the EBV table (presented in introduction section Table 1.1) are excluded from the search strings because there are a lot of agricultural studies related with this item and might be irrelevant for the scope of this dissertation. In Step 2 eligibility of the studies were searched and studies in aquatic (freshwater and marine) ecosystems; studies focusing pest, pathogens, virus, bacteria and microbes; environmental quality indicators; pollution, water or air quality, and also studies not performed in Turkey were executed. For the rest of the studies a further screening criteria was applied. The research must have a descriptive reputable methodology (Figure 3.5) and the study should represent a gene/species/ecosystem diversity related with EBVs in a particular area within Turkey, for a particular time (for example many species distribution studies are related with new specimen records, type localities, first records, or the methodology applied does not have scientific reputation, or the study is experimental and/or performed in laboratory, or review studies). Later a screening was applied to eliminate the repetitive studies from the dataset (Step 3-Screening). For example same studies had produced one thesis and one article or same study had produced two articles. There may be particularly valuable efforts and practices which are not included in this research since we used the EBVs exactly as key components. These studies most likely do not use EBVs as keywords thus I cannot reach them however these results enough to capture the snapshot of current situation.

Since academic efforts are not actual monitoring studies, the attributes of this source type will be discussed in the following section by comparing active and potential

monitoring programs. Totally, 315 studies were distinguished matching with EBVs. These items' data are not accessible, I interpret the necessary information through publications to fill the metadata.

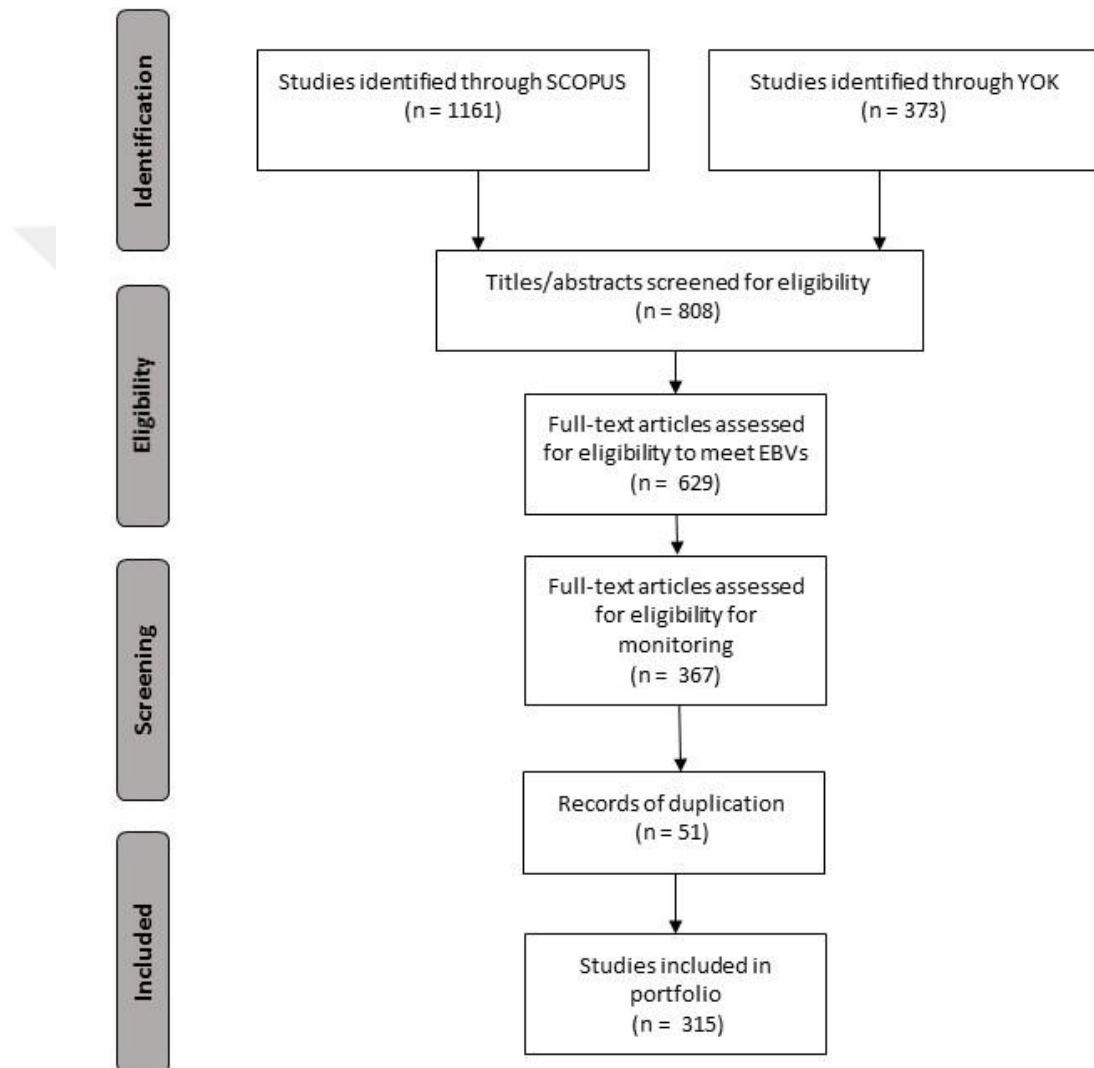


Figure 3.5. PRISMA flow diagram steps for the selection process of literature

3.2. Compiling the metadata

Each study or effort in the final portfolio has evaluated as an item and its metadata is filled according to the columns and descriptive variables presented in Table 3.3.

Table 3.3. Metadata structure

Column name	Description
Year/ Time period	Date of the publication or time period of the monitoring effort
Species Group	Bird Herpetofauna Invertebrate Small mammal Large mammal Plant
Species	Scientific name of target species
IUCN threat category (IUCN, 2018)	Data deficient (DD) Least Concern (LC) Near Threatened (NT) Vulnerable (VU) Endangered (EN) Critically Endangered (CR)
Target habitat	Agriculture Coastal Forest Grassland Multiple Urban Wetland
EBV class	Genetic composition Species populations Species traits Community composition Ecosystem function Ecosystem structure
EBV	All Essential Biodiversity Variables except “Breed and variety diversity”
Protected Area	Name of the protected area if the study/effort conducted within it.

3.3. Results

3.3.1. General Attributes

The portfolio consist of academic studies (315 unique academic studies (ACA)), ongoing efforts (16 active programs (AMP)) and potential monitoring practices (36 Species Action Plans (SAP)). This monitoring portfolio composed of 367 rows that are equivalent to a unique study/effort (“item”).

Among these 367 items, 29 items (4 SAPs and 25 ACAs) have been focusing more than one EBV class. The partitioned portfolio includes 396 rows. The distribution among EBV classes are presented in Table 3.4.

Table 3.4. Distribution of monitoring portfolio among different EBV classes ACA: Academic study, AMP: Active Monitoring Program, SAP: Species Action Plan)

EBV class	ACA	AMP	SAP	Total	%
Genetic composition	91	0	4	95	24
Species populations	69	15	36	120	30
Species traits	72	0	0	72	18
Community composition	43	0	0	43	11
Ecosystem function	16	0	0	16	4
Ecosystem structure	49	1	0	50	13
Total	340	16	40	396	

The most studied EBV class is species populations (30%) followed by genetic composition (24%). The least studied EBV class is ecosystem function.

All of the active monitoring programs focus one EBV class: species populations (one exception exist on forest ecosystem monitoring; it is focusing the ecosystem structure EBV class). Similar to monitoring programs, all of the Species Action Plans suggest monitoring actions on species population class. Only four items in the SAPs list are proposing genetic level researches in addition to species level.

On the other hand among academic studies; 25 items conducting their researches in two level EBV classes. This can be listed in descending order; species populations-species traits (10 items), species populations-genetic composition (4 items), community composition-species population (3 items), ecosystem structure-community composition (2 items), ecosystem structure- species populations and species traits- genetic composition (1 item). The accompanying EBV classes are changing in academia and in SAPs. The SAPs tendency is to conduct species population-genetic composition level, on the other hand academic researches focusing species populations-species traits.

The distribution of the biodiversity portfolio among EBVs are presented in Table 3.5. For three categories of sources the species level especially in “species distribution” and “population abundance” variables are more abundant than other EBVs. Population genetic differentiation follows them. The least studied EBVs are; co-ancestry, nutrient retention, net primary productivity and ecosystem composition by functional type.

Table 3.5. Distribution of monitoring portfolio among EBVs (* excluded from the search strings)

EBV class	EBV	ACA	AMP	SAP	Count
Genetic composition	Co-ancestry	1			1
	Allelic diversity	44			44
	Population genetic differentiation	59	4		63
Species populations	Species distribution	37	16	36	89
	Population abundance	31	15	30	76
	Population structure by age/size class	11	14		25
Species traits	Phenology	18			18
	Body mass	6			6
	Natal dispersal distance				0
	Migratory behavior	9			9
	Demographic traits	33			33
	Physiological traits	6			6
Community composition	Taxonomic diversity	42			42
	Species interactions	6			6
Ecosystem function	Net primary productivity	5			5
	Secondary productivity				0
	Nutrient retention	2			2
	Disturbance regime	10			10
Ecosystem structure	Habitat structure	27	1		28
	Ecosystem extent and fragmentation	19			19
	Ecosystem composition by functional type	3			3
TOTAL					485
<i>Color defines the count ranges (yellow to brownish)</i>					
0 or NA	≤ 5	≤10	≤25	≤50	>50

3.3.2. Taxonomic Attributes

The distribution of the combined portfolio according to the species groups are presented in Table 3.6. One academic research is focusing five species groups (plants, birds, butterflies, mammals and herptiles), one academic research focusing both large and small mammals and one monitoring program is focusing both bird and mammals, The rest of the items are focusing either one species group or ecosystem. So the total number of items per target group matching rows increases to 375 from 367 items. The most studied species groups are plants and birds. Ecosystem target studies are following them.

The results indicate that both in academic research and monitoring practices birds are the dominant species group. This is due to readiness of qualified experts professionally and voluntarily. Totally 38 bird species have been focus in these research. And these 36 birds are distributed to 3% of critically endangered, 11% of endangered, 6% vulnerable, 8% near threatened and 72% least concern birds.

Table 3.6. Distribution of monitoring portfolio among different resources (ACA: Academic study, AMP: Active Monitoring Program, SAP: Species Action Plan)

Species Group & Ecosystem	ACA	AMP	SAP	Total	%
Bird	59	10	3	72	19
Herpetofauna	41	2	5	48	13
Invertebrate	40	0	1	41	11
Large Mammal	20	2	5	27	7
Small Mammal	36	1	3	40	11
Plant	68	1	19	88	23
Ecosystem	58	1	0	59	16
Total	322	17	36	375	

Figure 3.6 shows the distribution of species groups or ecosystem among EBVs. The predominant matches of EBV/species groups are;

- Genetic composition; Plants (31) and small mammals (31)
- Species populations; Birds (53) and herpetofauna (39)
- Species traits; Birds (26) and herpetofauna (14)
- Community composition; Invertebrates (22) and plants (15)

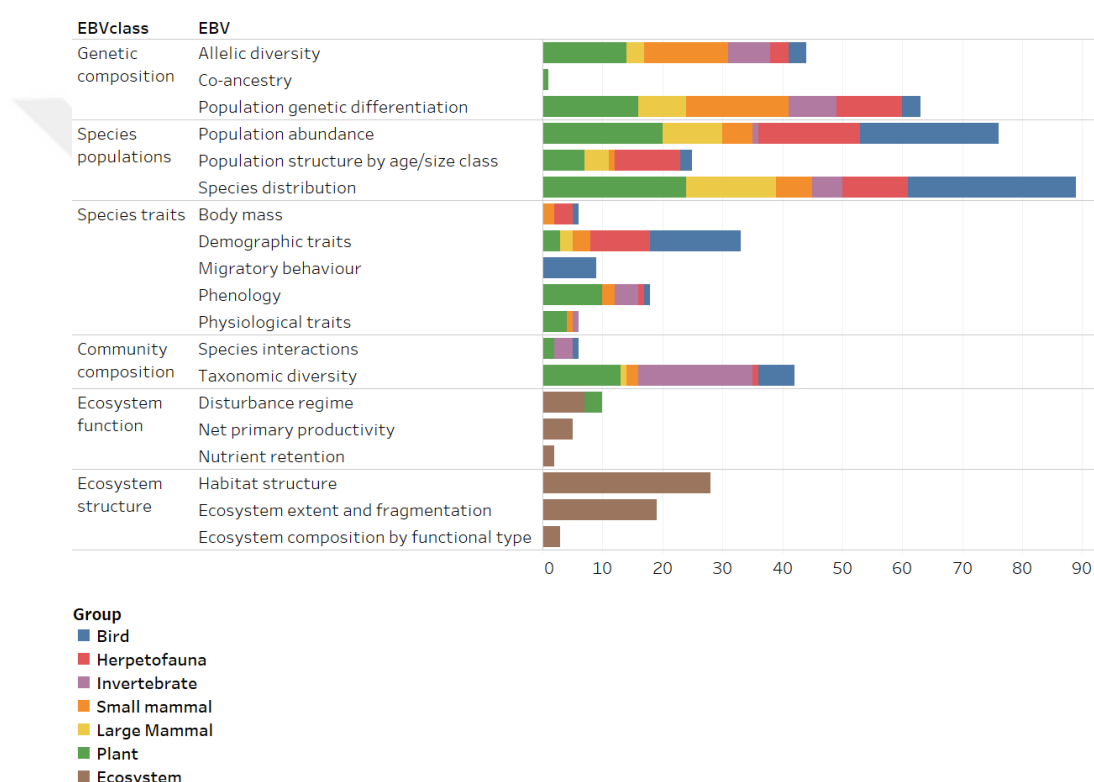


Figure 3.6. EBVs versus target groups

Lambeck (1997) and Noss (1990) suggest to use keystone, umbrella, flagship, limited dispersal capacity, resource limited or process limited species as indicator species in monitoring. It is hard to categorize the species list in accordance with this definitions however IUCN red list categories were used (Figure 3.7). The NA labelled species are

mostly grouped under taxonomic studies or genetic studies focusing particular taxa, and/or common species which do not have red list assessments. 18% of the plants are critically endangered. The least concern species are the predominantly selected species among herpetofauna (48 %), birds (50%) and small mammals (50%).

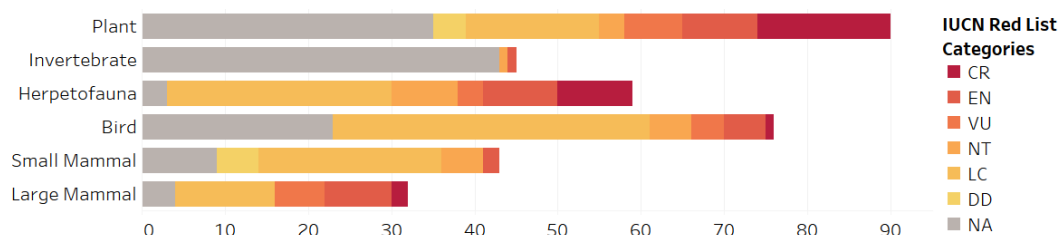


Figure 3.7. Distribution of Species among IUCN Red List Categories

According to the results, the featured species are *Monachus monachus*, *Caretta caretta* and *Phoenicopterus roseus*. Those flagship/ charismatic species were tracked in academy too. The other highlighted species are *Sitta kruperi*, *Grus grus archibaldii*, *Aegypius monachus* and *Tetrao mlokosiewiczzi*, that have regional distribution importance. Except for these charismatic species there is not any significant tendency in species selection. Some of the frequently selected species are;

- Birds; *Ciconia ciconia* (5), *Sitta krueperi* (5), *Phoenicopterus roseus* (4), *Aegypius monachus* (3), *Grus grus archibaldii* (3), *Tetrao mlokosiewiczzi* (3)
- Herpetofauna: *Caretta caretta* (8), *Rafetus euphraticus* (4), *Rana holtzi* (4), *Acanthodactylus schreiberi* (3), *Chelonia mydas* (3), *Emys orbicularis* (3), *Vipera anatolica* (3), *Vipera kaznakovi* (3)
- Large mammals: *Monachus monachus* (10), *Dama dama* (4), *Felis chaus* (4), *Hyaena hyaena* (4)
- Small mammals: *Spermophilus xanthoprymnus* (4), *Glis glis* (3), *Lepus europaeus* (3)
- Plants: *Pinus brutia* (7), *Astragalus beypazaricus* (3), *Polygonum samsunicum* (3), *Scilla mesopotamica* (3), *Thermopsis turcica* (3), *Tulipa orphanidea* (3), *Verbascum yurtkuranianum* (3)

3.3.3. Temporal Attributes

One important finding is both academic research and monitoring practices started to increase after 2000 in all aspects of EBVs. Genetic researches and ecosystem level researches have been intensified after 2005. The plants and the large mammals were the first studied groups in genetic researches. Species populations and species traits showed similar tendency, both of them had accelerated after 2000. Community composition researches have been intensified in plants and invertebrates after 2005. It is evident from Figure 3.8 that SPAs enrich to the portfolio except invertebrates.

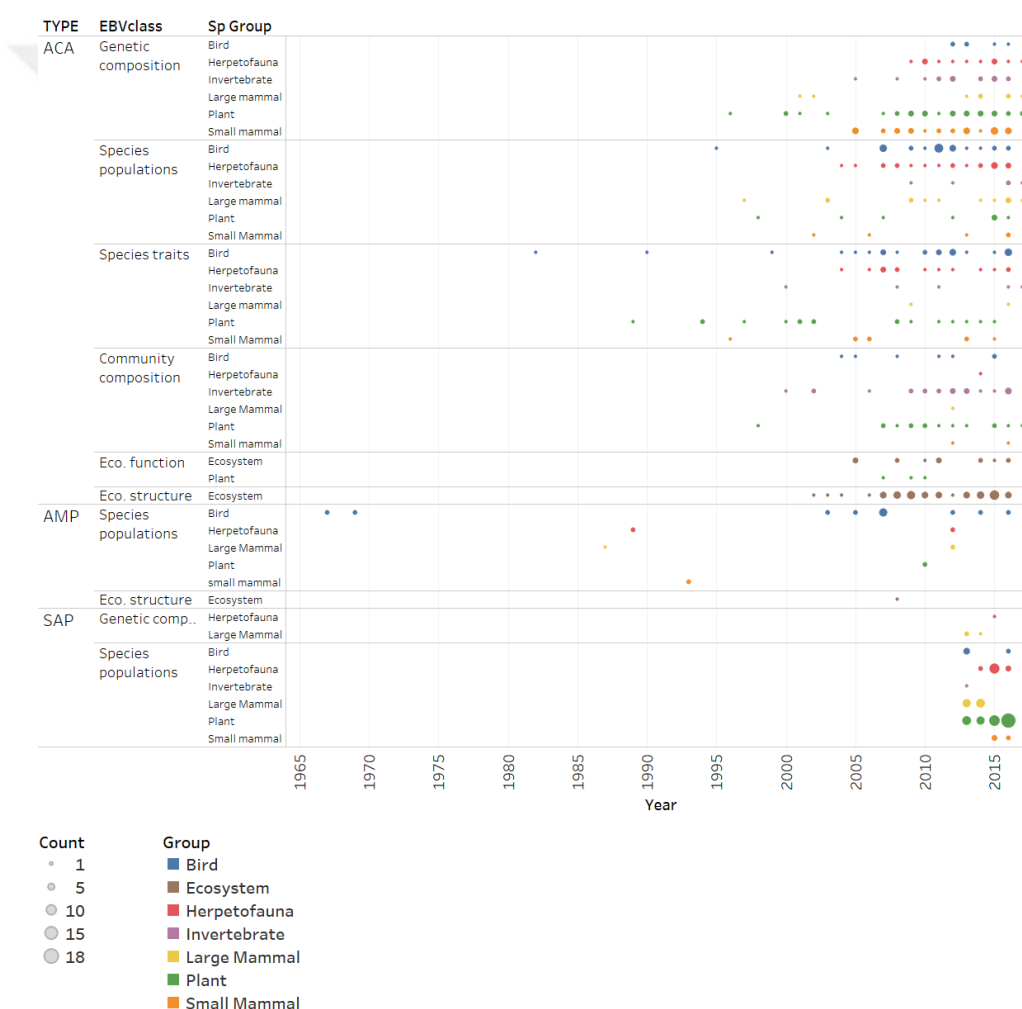


Figure 3.8. Time series analysis of the monitoring portfolio according to the source, EBV class and target group.

3.3.4. Spatial Attributes

The distribution of spatial coverages among different resources are presented in Figure 3.9. 56.91% of studies/researches were performed in local scale, and consecutively 27.63% in regional scale and 15.46% in countrywide.

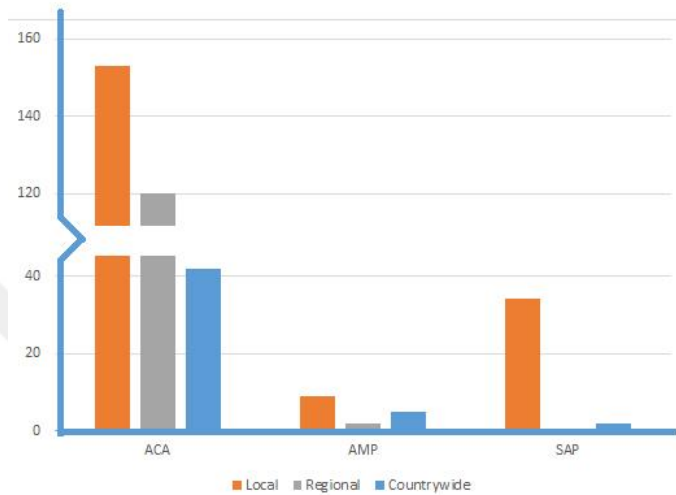


Figure 3.9. Distribution of monitoring portfolio among different resources

Allelic diversity, population genetic differentiation, co-ancestry and net primary productivity researches have been conducted on regional or countrywide scales. The distribution of EBV classes among spatial domains are presented in Figure 3.10.

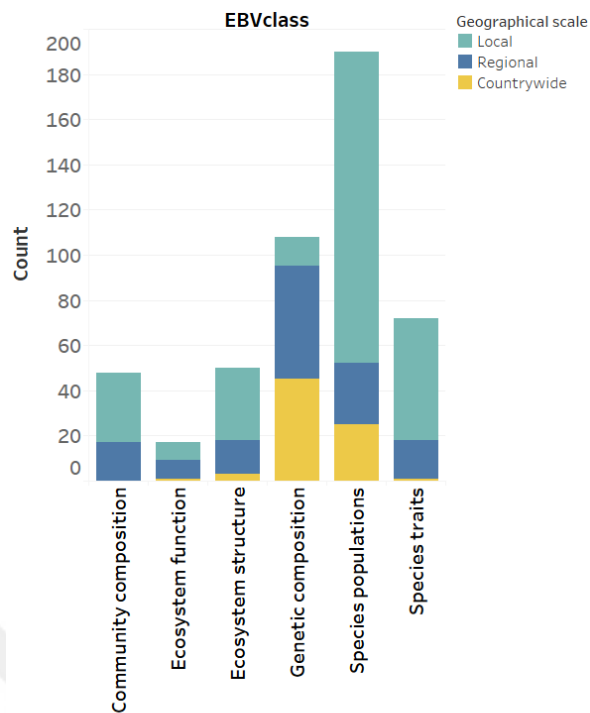


Figure 3.10. Distribution of geographical scales among EBV classes

According to the target groups or ecosystems, the geographical scale of small mammals' research and efforts are dispersing evenly among local, regional and countrywide scales. And except invertebrates all of the groups are mostly performed at local scale. Invertebrates are more abundant in regional scale (Figure 3.11).

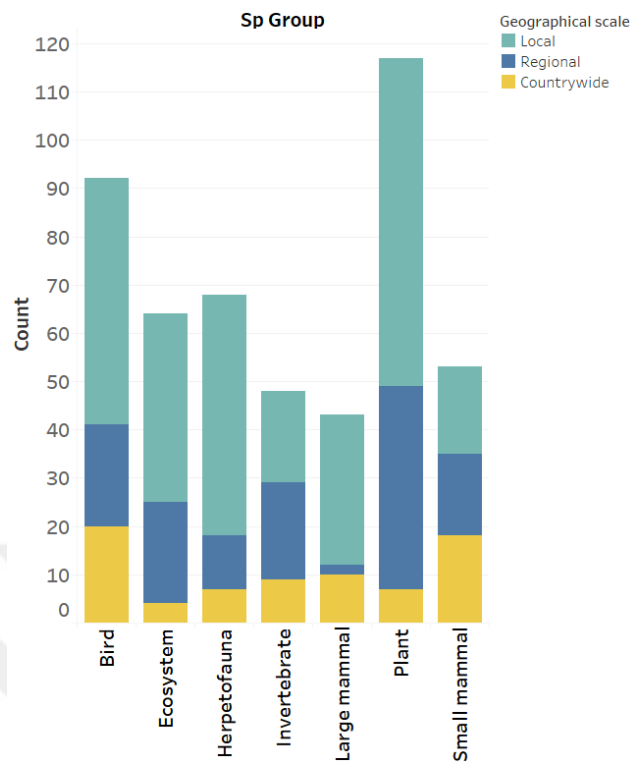


Figure 3.11. Distribution of geographical scale among species groups and ecosystems

The items were also matched with the corresponding ecosystem. Figure 3.12 shows the distribution of ecosystems where the items were conducted. The agricultural and urban ecosystems are the least studied ecosystems whereas forests and grasslands are the most studied ones. For all of the studies local scale is the most studied scale.

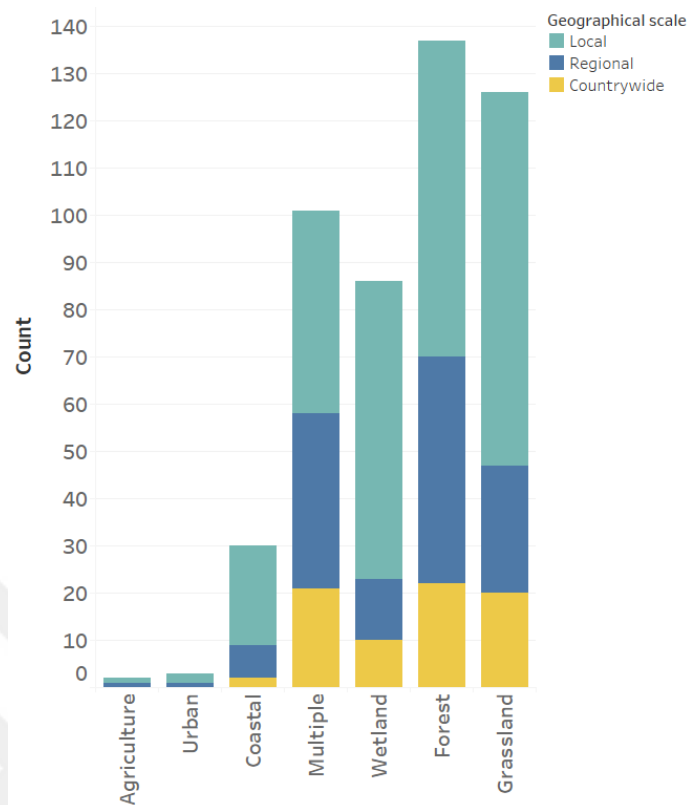


Figure 3.12. Distribution of geographical scale among ecosystems

Understanding the spatial characteristic of the portfolio, I generated two cumulative graphs for species and ecosystems (Figure 3.13 and Figure 3.14). Grassland ecosystem at species population class (covering mostly plants), followed by wetlands (covering birds and herpetofauna), forest ecosystems are represented fairly in all EBV classes.

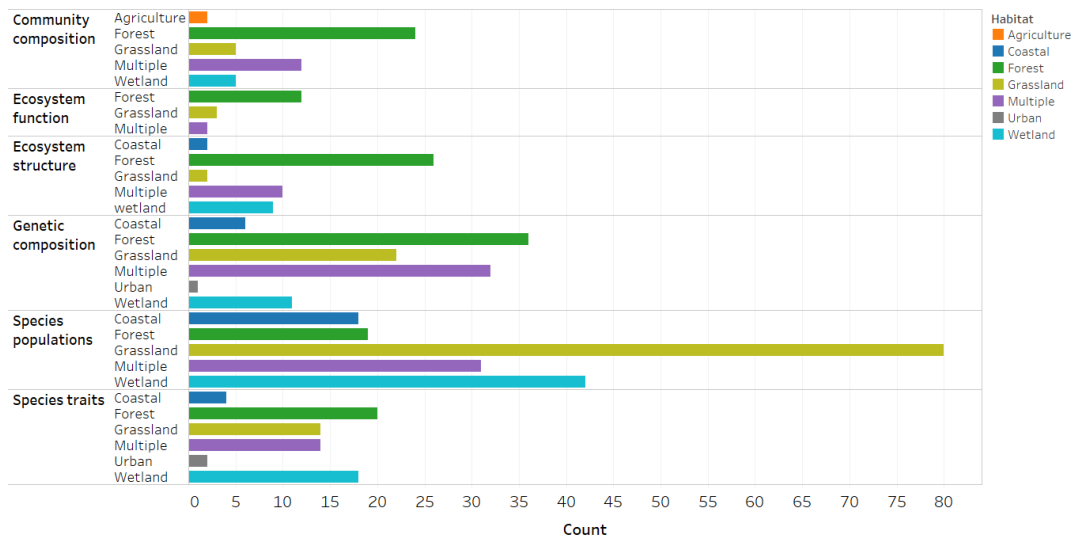


Figure 3.13. Distribution of EBVs among ecosystem types

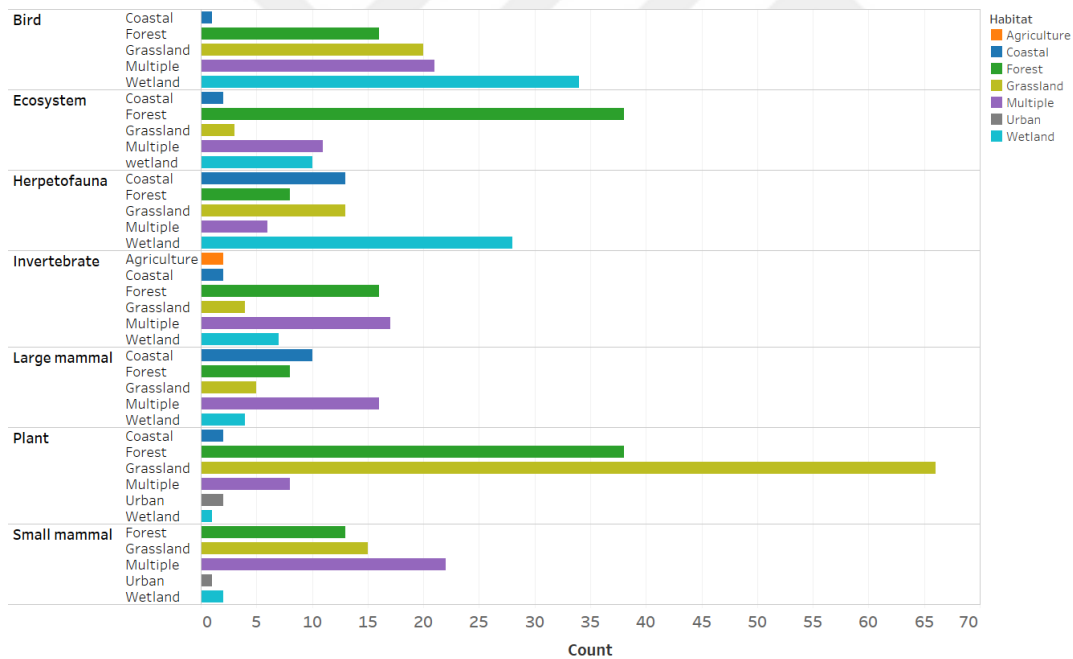


Figure 3.14. Distribution of target species and ecosystem among ecosystem types

Only, our results indicates that 16% of academic research and 17% of concurrent practices have been executed within protected areas. Within these items 38 % is within National Parks, 21% is within specially Environment Protected Areas, and 20 % is in

Wildlife Reserves and 19% is within Ramsar Sites. Only one study was performed within Nature Conservation Areas (Isparta Kasnak Meşesi TKA).

3.4. Evaluation of Knowledge

This is the first metaanalysis for Turkey which provides an evaluation of biodiversity data monitoring considering all aspects of data users and contributors. Although the data universe have certainly more efforts and studies that I cannot include into portfolio, it is the most comprehensive and up to date metadata generated under data restrictions. In 2.4.2.3. Citizen Science and Community Platforms section I have presented the concurrent situation of GBIF, e-Bird, Map of Life and iNaturalist and Turkey's contribution. Using these web platforms in the analysis would cause a high bias towards birds. And also randomly collected samples would not reflect the situation of monitoring exactly.

The existence of Noah's Ark National Biological Diversity Database is very promising however up to now any university or NGO could benefit from the database (section 2.3.3.1. page 90). Thus, the database existence is highly speculative and has no benefit for data users at the moment.

During data collection of this dissertation I observed that the biodiversity data of Turkey cannot be described mostly as monitoring data according to its global definition. So far I evaluated the research which have potential to be a base for monitoring, especially in academic research. On the other side active monitoring efforts which I believed are the closest practices of being well structured and systematic, do not fulfill the criterions of long term ecological monitoring temporal sensitivity (Lindenmayer et al, 2012).

With the contribution of species action plans and provincial biodiversity inventories which had started in 2013, the responsible authority MAF has completed the "surveillance monitoring" phase and having baseline data accomplished. Now Turkey

should move to smarter, “targeted monitoring” phase. Here, I present the weak and strong attributes of the monitoring portfolio and discuss the challenges and opportunities embedded herein. I also suggest ways to improve the conditions to guide the next-generation monitoring.

3.4.1. Strengths and Caveats

3.4.1.1. EBVs Perspective

It is globally criticized by several authors that the monitoring concentrated on the species population’s level (species distribution and abundance) (Noss, 1990). Even though it’s simplicity in monitoring, the higher tendency towards species, cause gaps and misunderstandings in other aspects of biodiversity globally (genetic and ecosystems). EBVs’ one of the main motivation is to present a condensed list which covers all aspects of biodiversity (Pereira et al., 2013). Using EBVs as data tags in metaanalysis highlights the density which can be transformed into particular aspects of biodiversity.

First of all the most important finding is there is a huge distinction between in practice and academia considering EBVs. All of the AMPs rely on species distribution level. Only ICP Forest Monitoring reflects ecosystem level. However the plot base survey can also be assessed as a species level study. On the other hand academic studies diversify the portfolio which is a promising picture and proves that in case other EBVs would be used in a monitoring scheme in the future, expertise is readily available.

Similar to global findings (Pereira et al., 2017) species level studies (Species populations and species traits) occupy the monitoring portfolio (comprises 48% of the portfolio). Species level followed by genetic composition which occupies 24% of the portfolio. Tydecks et al. (2018) detected exact ordering in global studies in descending order species (68%), genetic (47%), ecosystems (15%).

A possible explanation for this surprising tendency into genetic composition in the academia might be, the persistent interest into “speciation”, and eager to find, name

new species. Isaac et al. (2004) called this phenomenon as “taxonomic inflation”. They identified between two species concepts; 1) biological sense geographically isolated reproductive species, 2) phylogenetic sense, species differ each other by at least one taxonomic character maybe resulted from hybridization. This recent paradigm shift in species concept, doubled the number of “newly” named species. Phylogenetically identified species are 48% more than traditional one. Isaac et al. (2004) concluded that charismatic data biased toward certain groups (i.e. vertebrates) has been redescribed more than once. 408 new mammalian species have been named since 1993 (Ceballos and Ehrlich, 2009).

Species are fundamental units in conservation and natural resource management. And these action needs full-standard list of species to assess the situation (such as species richness). Isaac et al. (2004) argued that from conservation perspective subspecies level taxonomic effort has minor contributions and misguide the action. Garnett and Christidis (2017), advocated “to restrict the freedom of taxonomic action” since “the scientific community’s failure to govern taxonomy threatens the effectiveness of global efforts to halt biodiversity loss, damages the credibility of science, and is expensive to society”. On contrary, Ceballos and Ehrlich (2009) disagreed about the opposition and suggested paying attention to conserving each subunit in an ideal world. Thomson et al. (2018) pointed out that conservation should focus on ecosystem integrity rather than fixed entities of species. They suggested to define vulnerable biological units by using taxon names.

Only, 1.5 million of species (out of 5 ± 3 estimated million) have discovered yet (Costello et al. 2013). Identifying all of the species (covering bacteria, invertebrates etc.) before they go extinct in Turkey is highly unlikely. Also the active monitoring programs reveals that species assessments such as IUCN Red List have the most influential power in practice and policy. Science community should consider other aspects of biodiversity.

Another interesting finding is the fewer numbers of items carried out in ecosystem structure class, compared to global monitoring schemes. In general terms open archives of satellite imagery maintain input into ecosystem structure and function variables globally (Skidmore and Pettorelli, 2015; Pettorelli et al., 2018). In particular we lack data about ecosystem functions, thus, we have little knowledge about the disproportionate effects on how biodiversity loss impacts ecosystem functions (Geijzendorffer and Roche, 2013). However this is vital information because humans receive ecosystem services as a mechanistic form of ecosystem functions (Duncan et al., 2015). Thus this topic is very popular both in policy and society (Vihervaara et al., 2020). The monitoring programs should include more actions related with ecosystem structure and ecosystem function especially at national level. These activities can be planned by utilizing remote sensing. Skidmore et al. (2015) introduced “Remote Sensing - Essential Biodiversity Variables (RS-EBVs)”, which can be derived by satellite products. O’Connor et al. (2015) highlighted the contribution of earth observation-based measurements as 11 out of 20 Aichi Biodiversity Targets can be tracked by them and also these measurements can fully or partly contribute to 14 of the 22 EBVs. There is a distinction between the fully and partly measurable EBVs. Fully measurable EBVs (i.e. ecosystem extent and fragmentation) can be maintained by earth observations while partly measured (i.e. habitat structure) EBVs require additional ancillary data from earth observations to interpret. The ancillary data can be derived from in-situ measurements, or simulated and modelled variables.

The other least studied EBV title is community composition. However this can help us how species reacts especially in the face of climate (Sutherland et al., 2015). Also for example in BIP indicators suggest some proxies for Community Composition, Ecosystem Structure and Function, by usage of remote sensing (Geijzendorffer et al. 2016b).

Even so, EBVs presents a structured ground for the future of biodiversity monitoring, its applicability is highly debatable. Peterson and Soberón (2018) highlight the global gaps in their “Essential biodiversity variables are not global” article. They did not

evaluate ecosystem structure and functions EBV classes since they can be measured by remote sensing feasibly in case the necessary infrastructure set, the required information is available at global extent. However, the other EBV classes (genetic composition, species populations, species traits, community composition) demonstrate clear and consistent gaps at continental scale.

3.4.1.2. Taxonomic Perspective

The monitoring portfolio polarized towards particular species groups. In overall the plants and birds have the highest efforts (23% and 19 % respectively). However the choice of species group varies between practice and academia.

In global perspective, existing monitoring schemes focus on popular and apparent species groups; birds and butterflies (Proença et al. 2017). Pawar (2003) named this situation as ‘taxonomic chauvinism’. This argument is also valid for birds and plants in Turkey. Although 11% of the academic studies were focused on invertebrates, in practice invertebrates have not been monitored until now. Invertebrates is harder than other species, phylogenetic variation is wider and most of the species require laboratory studies in addition to standardized field surveys (Gardner et al. 2008).

Stronger bias towards bird might result from the following situations, each item will be discusses under “opportunities and challenges” title, later;

- Readily abundant expertise of birdwatchers (either professional or volunteer) and citizen science
- Existence of global or regional monitoring schemes (i.e. Common Bird Census, Mid-winter Waterfowl Survey, Breeding Bird Atlas) impose well established standards
- Birds have impacted the nature conservation history, many NGOs have roots in birding and international cooperation and funds exist (such as BirdLife, RSBP, Tour de Valat), NGOs enthusiasm to follow the monitoring actions is stronger than government and academia
- E-bird data storage provides easy data storage and access

The other successful active monitoring effort, may be name as the most charismatic species of conservation action: sea turtles (*Caretta caretta* and *Chelonia mydas*). Pioneer efforts (1989) owned by the Society for Nature Conservation (DHKD) and then followed by WWF-Turkey. Also these species are defined in the ANNEX list of Bern and Barcelona Conventions. Specially Environment Protected Areas where the sea turtles breed, governed by a different department, have stronger dedication to these conservation values, unlike other protected areas managed by GDNCNP.

Mediterranean Monk Seal (*Monachus monachus*) is in the same situation with sea turtles. Both are threatened species and use coastal areas for breeding and have particular national and international focus. Monitoring is carried out by primarily by Underwater Research Society until 1987. However, the monitoring continuity is not like sea turtles, due to the financial limitations and difficulties in monitoring monk seals due to their rarity and habitat specialization.

Despite the SAPs contribute to diversify the taxonomic research, the government's choice to prepare action plans dominantly for plants. Certainly, the SAPs aiming to improve the conditions of threatened species, and higher plant endemism and vulnerability have biased the SAPs towards plants.

In academic perspective the allocation of taxonomic groups is fairer. Plants and birds are again the most studied species groups whereas the studies reflect other species groups as well. Yet, the large mammals are the least studied groups. Global assessments revealed that taxonomic bias towards birds, large mammals and higher plants because of the detection probability and their popularity (Scholes et al., 2012). This rather contradictory result in mammals may be due to research interest of academia. In general genetic composition studies were concentrated on plants, species populations and traits concentrated on birds and herpetofauna, and community composition in invertebrates and plants. This finding is relevant with the link between three issues, the species group, EBV, and its data design and effort requirements. Such

that for example it is easier to collect plant specimen in a constant location compared to search for wider extent large mammals.

The taxonomic groups and EBVs represents some level of disconnection. A notable example is waterfowls. Although the monitoring efforts were concentrated on the wetland birds, there is not a strong reflection into academia. This group is the most monitored group in species population level but the other contributing variables such as genetic composition of waterfowls or ecosystem structure of wetlands variables are missing links. This disconnection exists for other taxa, too. A prevailing EBV is not supported with other aspects of biodiversity to clarify the states, pressures, responses and benefits (Butchart et al., 2010).

According to the distribution of IUCN Red List categories non-threatened species are more abundant than threatened species except plants. In one fourth of plant studies focus on critically endangered. Usage of common species will provide an early warning of ecosystem change, since they provide inference of a greater proportion of a study area (Beever, 2006)

3.4.1.3. Temporal Perspective

Historically, the pioneer efforts had started with surveillance of charismatic species *Monachus monachus*, *Caretta caretta*, *Chelonia mydas* and *Phoenicopterus roseus*. Also the surveillance of bird populations by birdwatchers provide historical baseline. Apart from these data obtained by active monitoring programs, it is hard to say we have a baseline information for others.

After 1990s, it is visible the strong acceleration of biodiversity studies in all aspects. Detrimental impact of humans on nature was recognized by multilateral agreements (CBD, Ramsar, Bern etc.) from 1980s. The common interest in biodiversity has triggered the studies in species level.

Time-series analysis of metaanalysis shows the strong influence of technological improvements in scientific research. Such that both ecosystem structure and genetic composition studies have triggered after 2000s, when the remote sensing galleries become open and free (the milestone was Landsat archive in 2008 (Zhu et al. 2019)) and when the DNA sequencing techniques become more cost-effective and applicable.

Institutional perspective, in 2003 a separate department has been established regarding particularly Biodiversity Monitoring under GDNCNP. However the influence of this branch become visible after a decade (2013) with the beginning of SAPs.

3.4.1.4. Spatial Perspective

The wider surface area of Turkey is challenging the monitoring practice. Due to the environmental heterogeneity monitoring should be comprehensive and representative considering the ecoregions and ecosystems. However only bird monitoring in practice is covering national extent. The Eastern Anatolian Region and Southeastern Anatolian Region are suffering from the lower citizen science contribution. These regions have been managed under temporary state of emergency conditions until 1987 because of terrorist attacks. To execute scientific research requires special permissions. On the other hand it is promising to see the SAPs distribution into that regions.

Regardless of source type (AC, AMP, SAP) local scale is the most studied scale because of its feasibility. The tendency is increasing spatial coverage of monitoring. However temporal and spatial frequency namely precision is a descriptive property which increase accuracy. Especially in ongoing efforts the precision is highly depend on the human resources at the time of monitoring activity. In general, none of the items in the portfolio describe a threshold for biodiversity change. Thus, the sampling effort seems arbitrary. Another difficulty is to harmonize and aggregate, these non-standard localized items in the portfolio.

In spatial perspective, there are five caveats impacting the success of the monitoring;

1. Setting up monitoring activities in countrywide scale cause temporal interruptions and collapse (Common Bird Monitoring)
2. Compression of academic studies into local and regional scales due to the lower support
3. The defined study area of SAP is covering the administrative border instead of species distribution range.
4. 69% of monitoring is performed within protected areas globally of ecological field studies have been performed within protected areas, Martin et al. (2012) criticized this proportion as being overrepresented in protected areas. However this metaanalysis shows conversely the misrepresentation of protected areas in Turkey. Protected areas are monitored only for management efficiency, variables such as number of visitors, stuff, recreational facilities etc. are monitored regularly. However the refuges of the biodiversity, or outcomes of conservation actions are not monitored purposely ('targeted monitoring').
5. Monitoring is ignored in urban and agricultural ecosystems where the humans most suffer from absence of ecosystems services.

In '2.7. Some Examples of Large Scale Monitoring Programs' section, I presented successful examples with different approaches. For example a small country like Switzerland use constant plots for monitoring. On the other hand New Zealand develops a tier approach considering spatial coverage, the contributor profiles and temporal sensitivity. And Norway adopted a prioritization considering the importance of indicators and representing ecosystems.

However in Turkey monitoring seems to be random. "Where to monitor" is a fundamental question before starting resource demanding monitoring actions. Up to now all of the agents conducts monitoring in the areas either because they *can* or they *must* (somehow to complement bigger efforts). In this next generation monitoring we must ask the question 'where *should* we monitor?'

We need to prioritize the monitoring action with smart decision tools. Morán-Ordóñez et al. (2017) suggested a spatial prioritization design by using Marxan to best monitor birds (Ball et al., 2009). They developed four scenarios 1) ignoring all previous efforts and developing something new in blank space, 2) considering only protected areas, 3) extending protected areas, 4) considering protected areas and distribution of citizen science potential.

Machine learning increase our ability to model species distributions (Ferrier et al. 2017). And with multi criteria decision tools and artificial intelligence we can develop the optimal choice of monitoring considering spatial constraints such as;

1. Representing eco-regions evenly (Mediterranean basin, Caucasus and Irano-Anatolian) and also transition zones
2. Representing ecosystems fairly (forests, grasslands, wetlands, coastal, mountains) and also ecotones
3. Covering various status of protected areas and assessing management actions
4. Identifying targets of monitoring and setting spatial and temporal scales identifying constant measures
5. Covering different aspects of biodiversity and relating them with various levels (ecosystem, species, genes)
6. Representing different species groups fairly

3.4.2. Opportunities and Challenges

3.4.2.1. Policy

Politically international commitments i.e. conventions require reporting and evaluations periodically (in general voluntarily). Geijzendorffer et al. (2016b) investigated the reporting requirements by reviewing match between reported indicators and the EBVs. Here I used this approach for the following international commitments that Turkey has been ratified. In addition to conventions and protocols

listed in Table 3.7, Turkey has also ratified European Landscape Convention and The Cartagena Protocol on Biosafety to the Convention on Biological Diversity. But the monitoring of these two include political and institutional measures instead of biological indicators. Thus they are not assessed. In the table the International commitments are shown in common descriptors; Ramsar - Convention on Wetlands, CITES - Convention on International Trade in Endangered Species of Wild Fauna and Flora, Bern - Convention on the Conservation of European Wildlife and Natural Habitats, UNFCCC - United Nations Framework Convention on Climate Change, CBD - Convention on Biological Diversity, UNCCD - United Nations Convention to Combat Desertification, Barcelona - Mediterranean Action Plan- Barcelona Convention. And EBVs are shown in abbreviations indicating that GC- Genetic Composition, SP - Species Populations, ST- Species Traits, CC- Community Composition, ES - Ecosystem Structure and EF - Ecosystem Function. The grey cells in Table 3.7 denote that the monitoring report include relevant indicators correspond to that EBV class.

Table 3.7. The EBV requirements of monitoring and evaluation reports in international conventions and protocols

International commitment	GC	SP	ST	CC	ES	EF	Reference
Ramsar							Geijzenborffer et al., 2016
CITES							https://www.cites.org/sites/default/files/reports/17-18Turkey.pdf
Bern							https://rm.coe.int/explanatory-notes-and-guidelines-for-the-period2013-2018-part-1-the-r/16808d336f
CBD							Geijzenborffer et al., 2016
Barcelona							https://www.rac-spa.org/publications#en13
UNCCD							https://www.unccd.int/sites/default/files/relevant-links/2019-04/LDN-TSP-EvalReport%20final.pdf

Table 3.7 The EBV requirements of monitoring and evaluation reports in international conventions and protocols (continued)

International commitment	GC	SP	ST	CC	ES	EF	Reference
UNFCCC							https://www4.unfccc.int/sites/SubmissionsStaging/NationalReports/Documents/9645137_Turkey-BR4-1-FOURTH%20BIENNIAL%20REPORT%20OF%20TURKEY.pdf

Two EBV class become prominent: species populations and ecosystem structure in the reporting phase of international conventions and protocols.

The XI. Development Plan and NBDSAP (2018) are the two strategy documents which will guide the current and future monitoring. However as aforementioned before (section 2.3.3.2. Strategical Documents) NBDSAP feeds the development plan. For preventing replications I analyze only NBDSAP (2018) in detail and match the EBVs with actions and evaluation criteria.

In NBDSAP (2018) seven national objectives are set. The second objective is defined as “*Biological diversity component (ecosystems, species and genetic variability) will be determined, monitored and species specific and ecosystem based conservation approaches (traditional and modern) will be developed by determining current condition of biodiversity.*” Under this objective five actions have been defined. The actions and indicators defined in this scope are presented in Table 3.8.

Table 3.8. Actions related with monitoring defined in NBDSAP (2018)

Action	Activities
Action 2.1: National biological diversity inventory will be determined and by doing so, the current condition of biodiversity will be defined and species will be registered; DNA Barcoding method will be started to be used within this process.	• Number of registered species through National Biodiversity Inventory and Monitoring Project • State of populations of species under IUCN threat category (CR, EN, VU) • State of populations of local and local endemic species • Number of species registered through DNA barcoding method
Action 2.2: Monitoring studies will be performed for the registered national biodiversity data and e-DNA (environmental DNA) monitoring technique will start to be used within the process	• Number of species to be monitored and state thereof under IUCN threat category • Monitoring of population status of endemic and local endemic species
Action 2.3: Studies to determine and monitor endemic and endangered species; develop and implement species specific conservation methods will increasingly be continued	• Number of species protected ex situ and in situ • Species Action Plans • Population status of endemic and endangered species
Action 2.4: In order to conserve biological diversity, studies to develop and implement species specific or ecosystem-based conservation approaches by using traditional or advanced biotechnological methods will be conducted	• Species specific pilot studies • Ecosystem based field studies
Action 2.5: Studies to detect terrestrial and aquatic microorganisms and to identify them at molecular level to determine their functions in ecosystems will be conducted	• Number of detected microbial species • Detected functions of species in the ecosystem

The National Goal 4 defined as “Awareness of the public and administrators on ecosystem services will be raised, benefits from ecosystem services will be increased and sustainable biodiversity management will be ensured.” However in this section

Synthetic Biology is defined as a case in actions and highlighted as *“with synthetic biology technique, benefits are ensured effectively from ecosystem services within the framework of conservation and sustainable use of biodiversity via preventing over use of natural resources.”*

The National Objective 5 defined as *“Rehabilitation and restoration of ecosystems damaged due to different reasons will be ensured, measures to prevent damage to healthy ecosystems will be developed and legislative gaps thereon will be fulfilled.”* In this section the action 5.3 is defined as *“Alarm systems (biosensors and pollution indicators etc.) will start to be used to warn against the degradation of ecosystem balance in order to provide monitoring in healthy ecosystems”*.

And also the following items are quite debatable. In goal 6 *“the promotion of cooperation between public and private sector to be ensured in the process of commercializing of the products developed with modern biotechnological methods and biological resources”* and in goal 7 *“access to genetic resources and fair and equitable sharing of the benefits arising from their utilization and the necessary technical infrastructure will be established.”*

For further investigation I matched the specified actions and indicators with EBVs in Table 3.9. The items that relate to legislation, capacity building and education are not matched.

Table 3.9. The EBV requirements of monitoring and evaluation of criteria in NBDSAP (2018)

Action scope	GC	SP	ST	CC	ES	EF
1.2. Invasive alien species						
1.3. Synthetic biology						
1.4. GMOs						
2.1. Monitoring						
2.2. eDNA						
2.3. Endemic and threaten species						
2.4. Traditional conservation techniques and innovative biotechnology						
2.5. Microbiology						
3.1. Agricultural, forestry and fishery						
4.3. Ecosystem services						
5.1. Restoration						

The results indicate that there is a mismatch between international and national agenda. International commitments biased towards ecosystem level monitoring however national strategy focuses on genetic level. Both of them underlines the importance of species level monitoring.

The current status of action plan is reflecting that future strategy would rely on biotechnological improvements and genetic studies. Despite it was mentioned the all levels of biodiversity particularly genetic level studies were emphasized often by mentioning DNA barcoding, environmental DNA, Gene Bank, synthetic biology and biosensors.

It is arguable to protect and monitor nature with these set of criteria. To complete species inventory by the National Biodiversity Inventory and Monitoring Project took almost 10 years. This ambiguous goal of setting DNA barcoding might took another decade. Then more likely eDNA monitoring would begin. Considering the magnitude of adverse impacts caused by several human activities and also climate change, we need urgent tools to assess the status and detect trends, if exists.

The ultimate goal of national monitoring motivation seems to feed policy reporting's especially in accordance with multilateral agreements (CBD, Bern, Barcelona etc.). However, biodiversity monitoring cannot save the world alone without integrating information into decision- making and adopting crucial conservation actions (Bawa and Menon, 1997). "What gets measured, gets managed". Without reflecting monitoring outcomes into conservation actions and natural resource management, accounting something in nature is useless. Information gain is not necessarily conservation gain (McDonald-Madden et al., 2010). The development obsession highlighted previously by several authors (Şekercioğlu et al., 2011; Atmış, 2018) prevent the policy-management integration. The most dramatic outcome of this study is the current, conscious policy of not monitoring protected areas. The government cannot protect the nature from "itself". The most recent example was the comprehensive zoning amnesty (2018) applied to unauthorized buildings and illegal land transformations. By 31 December 2019, 7.393.413 buildings or building parts applications were acquired and total application cost was 24.744.721 Turkish Liras. Only 30.458 applications were rejected (AA, 2020). These kind of regulations promote land cover transformations. Another example is the forest permissions. According to 6831 Forest Law, infrastructure projects or investments which provide public welfare can get permission to occupy the forest land. The public welfare is a broad topic which covers construction of roads, railways, stations, dams, religious and sports centers etc., but also mining permissions.

Considering the future prospects climate change protected areas are important laboratories for humanity where we can learn and develop adaptation solutions. An effective monitoring program should cover the protected areas.

Stephenson et al. (2017) identified four barriers for the flow of biodiversity data into decision making. These are; (i) availability of data, (ii) willingness to use data, (iii) accessibility, usability and quality of data, and (iv) capacity for data collection, management and use. In the policy dimension the strongest obstacle in Turkey circumstances is "the willingness to use data".

The vision and roadmap set in NBDSAP- 2007, is relatively successful to develop and implement milestones projects particularly at species level. In accordance with UBENIS observations, the important biodiversity areas are identified for monitoring purposes. Despite this output is very promising, it does not seem applicable and reasonable for the following reasons;

- The areas are defined considering the provincial borders and intervening new monitoring sites and avoiding protected areas.
- Some of the target species more likely have wider distribution ranges. We need to monitor these species vulnerable and marginal populations. A national scale prioritization should be done considering the threat, ecosystem, ecoregion, species vulnerability, rarity etc.
- The monitoring target is missing. Surveillance monitoring is costly. Considering the low personnel number in local departments of ministry, we need smart monitoring targets.
- There is a tradeoff between sampling efforts (precision) of monitoring with accuracy. The current policy is to conduct monitoring by the institutional own capacity or make monitor by tender process. Even if a long term quantitative, protocols are defined, both options would decrease the accuracy of the output. The limited number of personnel in ministry might only conduct up to a level of monitoring with decreased precision due to limited effort. The temporal limitation in tender process is maximum three years in special circumstances. However in general, governmental organization choose to apply yearly tenders because of annual budget allocations. Thus, tendering these monitoring every year (most probably by different private companies) would cause professional team changes every year, which is quite against the nature of long-term monitoring.

The updated NBDSAP-2018 significantly mentions genetic level studies frequently (2.3.3.2.1. The National Biological Diversity Strategy and Action Plans section). To complement monitoring with work at various biodiversity levels is important.

However, even though genetic studies are relatively cheaper in recent years, they are still expensive, and to allocate another decade into unsustainable research is not feasible. On the other hand, ecosystem level monitoring can be done for broader extents, with open and free remote sensing galleries. Hence several national extent monitoring schemes focus more onto this option.

SDGs also impose multi sectoral monitoring which covers also biodiversity (McKenzie et al., 2014), engaging SDG targets into monitoring goals would increase the efficiency.

Other institutions and governmental organizations should be included in the monitoring schemes. If the environmental pressure data (explanatory data) is missing (such as air/soil/water pollution, climate or land-use), we cannot link the biodiversity loss or change rigorously. Under The Ministry of Agriculture and Forestry umbrella this coordination can be sustained. Because the ministry includes all of the agricultural and forestry departments in addition to General Directorate of Nature Conservation and National Parks (GDNCNP), General Directorate of Combating Desertification and Erosion, General Directorate of Water Management, State Metrological Service, State Hydraulic Works. Ecological, socioeconomically and environmental data would need to be integrated at appropriate scales (Bawa and Menon, 1997). The 99% of forests and all of the protected areas are managed by government, which is another advantage to set up long-term monitoring programs.

Combining different schemes returns economies of scale. Combination might include different sampling techniques or combining different taxonomic groups. Thus, it is possible to reduce survey costs and to improve cost- efficiency. For example Targetti et al. (2014) shows that integrating habitat mapping into monitoring scheme reduces the cost at 50%. In that regard, using constant plots in existing programs (such as ICP forests) and adding missing variables into these schemes would decrease the monitoring cost for Turkey.

Monitoring needs strong collaboration between the agents. At the moment data restrictions applied by governmental agencies build a strong barrier to establish cooperation. Data governance is a mandatory attribute for success in biodiversity monitoring and covers (i) engagement of stakeholders, (ii) building a strategy for data acquisition, data share and management, (iii) system design and infrastructure, and (iv) implementation. Certainly there may be several reasons for not sharing data in Noah's Biological Diversity Database, in political, sociological or psychological contexts. However it is hard to achieve successful monitoring programs without solving these obstacles and generate mechanisms to support cooperation between biodiversity monitoring agents. The likely reasons of this strict policy listed below – although not complete - are mentioned by questionnaire respondents through informal conversations:

- Data is an asset and a power tool in governance, and they may not want to share this asset with other organisations and people. This ambition of power might stem from personal attitudes or be due to organizational strategy.
- System design and database structure do not allow sharing, making it necessary to first overcome this technical obstacle. One reason might be the underestimating the required time effort and technical expertise in database management during design.
- Low data reliability might be an issue and they want to resolve this issue before sharing data with others.
- Higher priority towards economic development in the national policy might make decision makers hesitant to make biodiversity values public, since this may potentially hinder such “development”
- The tender process privatizes and values biodiversity data in monetary terms and this tendency prevents public share

Data storage and share tools are fundamental components of any successful monitoring. The lack of a central node which facilitates data sharing is tragic,

considering the existence of the Noah's Ark National Biological Diversity Database. Removing barriers in accessing information would enhance trust and improve the transparency of a governmental organization. Currently, only four of the active monitoring programs share their data with Noah's Ark. In addition, changing data policy will lower expenses (time & money) in data collection and data storage, not only for the government but also for all other agents.

3.4.2.2. Science

A long-term monitoring study in academia was nonexistent. Short-term funding, shorter study positions for researchers, and a keen interest into new and innovative projects are possibly the main reasons for the lack of long-term studies. Another reason identified by Nisbet (2007, "Monitoring is science's Cinderella: unloved and poorly paid") was that monitoring work did not provide glittering prizes and that their publication requires much more time. Modern research has a plan about milestones and delivers to certain destinations.

The higher number of genetic studies especially in academic studies in the monitoring portfolio can be an outcome of this situation since 1) easy to publish, 2) relatively shorter periods of research time requirements, 3) it requires generally more time to understand the dynamics in other aspect of biodiversity such as communities and ecosystems, 4) studies require longer time spans are not easily funded. The pressure of publishing can be modified to active participation into practice. Supporting scientist to develop long-term monitoring actions in biological researches would increase the quality of the publications.

Another prospect is making scientific data more discoverable and digestible. The general tendency in academia is to keep the data and publish only results. However considering the urgency of biodiversity loss, our understanding in changes at various levels of biodiversity should develop as fast as possible. Data publications should be counted on for academic promotions. Developing the conditions of intellectual copy rights, data citations and open science would likely enhance the conditions for data

sharing. Another tool may be developing a reward system which encourages people to contribute ongoing monitoring efforts rather than setting up new ones (Lindenmayer and Likens, 2010).

Data management and storage phases require more attention. Especially in monitoring efforts only a few utilized statistical analysis to improve overall data reliability. The greater scientific community should lead the monitoring community in data validation, bias correction and other statistical tools.

3.4.2.3. Culture

On one hand biodiversity data is not accessible, while on the other it is not discoverable. But this is not a unique problem, many authors highlighted this situation earlier (Wetzel et al., 2018, Reichman et al., 2011). This is a result of dispersed knowledge and a problem of harmonization among several governmental organizations, NGOs, and academia. Unfortunately each agent occupies their niche, with little sharing of data. We can only fill the gaps by improving collaboration between biodiversity agents (Turner et al., 2015). Both academia and NGOs present great opportunities to support governmental organizations.

Fieldwork is the most expensive activity in monitoring (Targetti et al., 2014). Available scientists, government personnel and NGO workers cannot easily tackle biodiversity issues, considering the size of Turkey and its rich biodiversity. Engaging non-professionals into data acquisition would dramatically increase its extent and efficiency (Sutherland et al., 2015). Many community data portals would increase the potential of citizen science. Schmeller et al. (2009) calculated that without volunteer contribution the cost of annual monitoring in Europe would increase three fold. And this would impact mostly Western Europe (Germany and France) where the salary of professionals are higher than in Eastern Europe.

More than 150 birdwatchers has participated in the Breeding Bird Atlas Project between 2014-2017 and proves the capability of citizen science. The ancestor site Kusbank holds 80.000 bird records collected by 450 birdwatchers between 2000 and

2017 (<https://ebird.org/turkey/news/turkish-breeding-bird-atlas-published>). On the other hand citizen science history has also some failures. For instance, Common Bird Monitoring is an interesting case. In global perspective it is one of the most successful examples of citizen science projects (Stephens et al., 2016). However in Turkey, the number of volunteers providing data for the project has trickled down to one or two in its third year and the project practically came to an end.

Enthusiasm is an intrinsic motivation behind citizen science. To sustain the motivation of people and quantity of data produced depend on keeping enthusiasm, whereas commanding strict rules would destroy this feeling (Foster, 2015). Understanding the interests, motivations, skills and needs of different contributors would increase the efficiency of citizen science (Pocock et al., 2015, Sutherland et al., 2015). One disadvantage is the uneven distribution of citizen scientists, which leads to their survey locations being highly biased (such as nearer to hometown). Therefore, there is a compromise between citizen science effort and systematic sampling (Pocock et al., 2015).

The active monitoring programs highlighted that NGOs benefit more from voluntarism (i.e. Mid-winter Waterfowl Survey) than citizen science. The reasons might be:

- The limited human resources of NGOs cannot manage citizen science.
- Citizen science requires quite an effort in training, data storage, management and validation. On the other hand NGOs choose volunteers among highly skilled birdwatchers

The active monitoring programs are mostly executed by NGOs, whose enthusiasm in sustaining monitoring is often higher than the academia and the government.

Looking at the historical development of civil societies, their role is much more a tracker role for governmental implications, create awareness, and provide necessary technical skills. Dixon et al. (2019) highlighted that monitoring and evaluation are accomplished better by NGOs compared to by governmental organisations. According

to the authors the reasons may be: (1) NGOs employ scientists and highly skilled employees, (2) NGOs report and evaluate the monitoring outcomes to the funders and stakeholders, (3) governmental organizations execute monitoring for legislative requirements, and even though commitments are not met they claim the credit.

In the nature conservation dimension, national NGOs in Turkey often import international agenda and trend topics, they collaborate with international partners and bring international funds. The movement has been supported (but not only) by BirdLife, RSBP, Tour de Valat, WWF, etc. In parallel to these developments, in 1996 the UN Habitat II İstanbul Conference was held in İstanbul. The Turkish Government, like other parties, committed to enlarge the legitimacy of non-governmental organizations and civil movements, and also to associate with civil organizations while performing civil services (Tekeli, 2012). The NGOs visibility and participation has accelerated with political stability. Until 2010 NGOs and governmental agencies had performed very successful projects (examples are presented in Kesmez et al., 2016)). In 2010, the general director of Nature Association which was one of the most influential NGOs that time, called the former Minister of Environment and Water Affairs as “*serial killer of nature*”. After this event, the ministry refused to cooperate not only with Nature Association but also with any other NGOs. They choose to collaborate with private sector through tender processes. Although the work completion certificates for specific tasks are demanded in tender application, at the end of the day the lowest bidder secures the tender. Many companies competed to decrease the bid cost of SAPs and UBENIS province tenders. Because of this reason the quality of these projects are highly suspicious since the sampling effort would be the first compensation measure in order to decrease the cost. The change of attitude towards NGOs is also visible in NBDSAPs. In the last NBDSAP (2018) only governmental projects took place, and the accomplishments of NGOs are ignored in reporting.

3.4.2.4. Financial

The early stages of monitoring is more expensive because of technical trainings, awareness creation and the capital cost of required equipment (Stephenson et al., 2017). On the other hand receiving reliable data requires also time. To keep consistency and stability is quite dependent on the financial constraints.

Peterson and Soberón (2018), reported the variability in the generation of biodiversity information. The unit cost of acquiring biological data can change from 1\$ to 1000\$ per record. To conduct a cost-benefit analysis, we need to derive the total cost of different type of monitoring efforts including the fixed costs (equipment, labor etc.) also variable costs (travel cost etc.). Targetti et al (2014) compared the cost of monitoring in different sites in Europe. The total cost changed at a ratio of one to twelve in accordance with sampling environment and geographical variances. Considering the vast size of Turkey, certainly we may face similar differences.

The donors' interests change by global policy, regional priorities etc. To update monitoring outcomes with the trend topics may influence the sustainability of a donor's interest. For example, ecosystem services topic has diverse sectoral interest, if any monitoring program can provide information about the correlation between per unit conservation effort with the per unit ecosystem services, then the monitoring question transforms into a societal issue.

Danielsen et al. (2003) highlighted that many monitoring programs suffer from being unrealistically large, complicated and impossible to sustain with the locally available funds and human resources. The programs can immediately collapse when the donor funding stops. A solid and long-term financial income seals the future of monitoring (Schmeller et al., 2015)

This metaanalysis shows a similar outcome for the active monitoring programs. Despite they are planned to be executed annually, half of them has interruptions in their history. For example Mediterranean Monk Seal Monitoring do not have a constant fund. Therefore, such monitoring was absorbed into other project activities

such as coastal zone management plans. Thus the monitoring is carried out whenever it can be. The GDNCNP supported two SAPs in Mersin and Muğla for the protection of monk seal whereas the breeding caves distributed among Mediterranean coast. As aforementioned the SAPs were prepared by private firms and the historical knowledge and experience of local NGOs were ignored in the process.

3.4.2.5. Technology

Technology will ease the solutions in three aspects (Kissling et al., 2018b);

1. Enhanced data acquisition would fill data gaps taxonomically, spatially and various aspects (not only species level),
2. Big data issues: standardizing existing data and metadata increase availability and accessibility,
3. Sustainable electronic infrastructures support discovery, access, analysis, storage and dissemination,

Advances in data acquisition such as remote sensing capabilities, radio tracking animals, camera trap networks, soundscaping, molecular based method streamline data collection, automate data collection, decrease the cost of long-term monitoring (Schmeller et al., 2015). Accumulation of geotagged species records enhance also the capabilities of modelling. Sensor networks both audio and imagery offer detection of species in a systematic way and enable data acquisition in large areas, e-DNA is a rapid and comprehensive method for identification of hundreds or thousands of organisms. The airborne and spaceborne spatial imagery is frequently used in diverse habitats and biomes. The temporally and spatially consistent and contiguous data offered by remote sensing is very beneficial compared to in-situ measurements (Kissling et al., 2018b). Especially for Turkey we need to prioritize the utilization of remote sensing and set up a consistent national scale ecosystem monitoring program.

A key challenge for the future is the development of tools for aggregating local studies to generate broader-scale patterns. Data share increases the collective benefit. Biodiversity data is diverse, dispersed and disparate. Standardization of data formats, increase interoperability of various sources and different temporal and spatial scales. Adopting global standard such as Darwin Core (TDWG, 2009) standards and ontologies make data harmonization easier. In addition to Darwin Core, Kissling et al. (2018b) listed the possible standards which supports EBVs as; Humboldt Core, Biocollections Ontology (BCO), Ecological Metadata Language (EML), Extensible Observation Ontology (OBOE) and Observations and Measurements (O&M), ISO 19115, ISO 19157 and PROV.

Datasets such as GBIF, MoL standardized the biodiversity data. Also community platforms such as iNaturalist increase the public awareness.

Biodiversity data should be more discoverable, accessible and digestible (Wetzel et al., 2018). The contribution can be increased by designing a system which makes data-holders visible and data transparent. Kissling et al. (2018b) suggested CCo (No Rights Reserved) and CC BY (Attribution) licenses form Creative Commons (CC) licenses and designations (<https://creativecommons.org/>).

The data restriction policy of Noah's Biological Diversity Database is a barrier. The governmental policy should embrace the other agents (academia, NGOs) and increase cooperation between stakeholders. All agents should develop tools and approaches about data harmonization and build a consensus on transparency between data holders.

CHAPTER 4

A FEASIBILITY ANALYSIS ON EBVS PERSPECTIVE FOR TURKEY

A primary challenge in biodiversity conservation is to establish a standardized and uniform system of monitoring globally. Providing a “minimum set of core tasks” agreed globally on robust objectives and approaches would increase the performance of monitoring, especially in developing countries where biodiversity is essential and the resources are limited (Teder et al., 2007). EBVs could form the basis of efficient and well-coordinated monitoring programs worldwide and this would help optimize the monitoring (Proença et al., 2017).

Optimization means that monitoring reaches the objectives of the program in a scientifically and statistically sound and permanent way (De Blunst et al., 2013). The durability, thus cost-effectiveness, is a major challenge in this equation. The EBONE project, in which the European level cost efficiency was investigated, defines efficiency as “the balance between the resources used and the output realized (‘doing things right’, ‘the route to the goal’)” while effectiveness is defined as “the capability of producing the desired results, the degree in which a target is achieved (‘doing the right things’, ‘scoring a goal’) (Figure 4.1)”. The optimum is the best, most desirable outcome, especially under some restrictions.

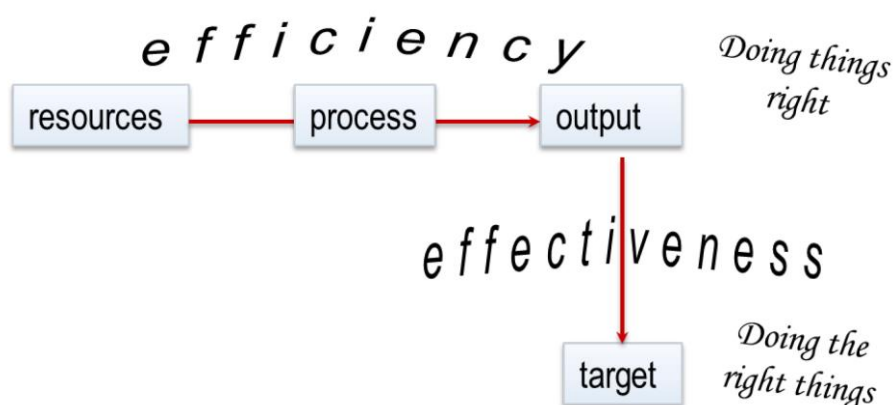


Figure 4.1. The relation between efficiency and effectiveness (De Blunst et al., 2013)

Before discussing effectiveness of any monitoring effort, it is necessary to define the feasibility as a measure of the possibility of which way to do it, or whether to do it at all or some. The EBV approach provides a condensed list presenting various aspects of biodiversity, and considering each item in that list is certainly both beneficial and practical. However, the state of our institutions and our level of knowledge in monitoring and evaluation are far from perfect, as presented in Chapter 4. Currently species level which uses presence data is the most favored aspect of biodiversity monitoring. Here, I present a feasibility analysis of biodiversity monitoring in Turkey by screening out the infeasible items in EBV list according to a set of criteria.

Feasibility is commonly used in project assessments. The goal is simply to evaluate the attained output considering the existing constraints. It covers five topics: technical, economic, legal, operational and scheduling (TELOS) feasibility studies (Bause et al., 2014).

Here, feasibility is regarded as technical, political and economic feasibility. This chapter's goal is not presenting the optimum solution. The optimum solution is achievable only when a solid and well-structured problem is defined. In 'section 2.6. What Makes Biodiversity Monitoring Efficient', I have presented some examples that aim to answer such questions. Here I rather define some accepted criteria at the

national level, without focusing on a particular ecosystem. A generic monitoring approach which promises “one size fits all” cannot be achievable (Lindenmayer and Likens, 2010). However considering Turkey’s institutional and scientific capacity (findings of Chapter 3), and accepting the practical use and universality of EBVs, some EBVs could be prioritized over others.

4.1. Feasibility Question

Monitoring has three major phases, and in an ideal adaptive monitoring scheme, these steps show iterative relation. Each step has its own constraints in labor, technological advances and design considerations (space, time and taxonomy), and relevance defines the support of monitoring activity to the target audience and provide benefits to users. Here, I developed a scoring methodology to assess the feasibility of EBVs with current knowledge. In case the conditions might improve in the future (sampling technique, decrease in cost, availability of technical expertise etc.), then the scores would change. To generate a simple algorithm, I normalized each criterion and assigned a weighting score. To prevent subjectivity, I only scored criteria that I can assign numerical values derived in this study or from the literature. By conceptualizing the future, in formulazing the question the utilization of remote sensing is accepted as a criterion since its benefits to several EBVs and cost-effectiveness is proven by several authors (O’Connor et al., 2015; Skidmore et al., 2015; Lausch et al., 2016; Vihervaara et al., 2017).

4.2. Usefulness

All of the EBVs are already screened according to their scientific soundness. Thus, I used Turak et al. (2017) scores for the usefulness of EBVs for societal benefits in terrestrial realms. Turak et al. (2017) suggest EBVs for national scale and explore the suitability of EBVs in Australia by a workshop (experts, decision maker and practitioners). The values presented in Table 4.1.

Table 4.1. *Usefulness of EBVs (Turak et al. 2017)*

EBV Class	EBV	Score
Genetic Composition	Co-ancestry	5
	Allelic diversity	0
	Population genetic differentiation	3
Species populations	Species distribution	100
	Population abundance	100
	Population structure by age/size class	28
Species traits	Phenology	41
	Body mass	0
	Natal dispersal distance	0
	Migratory behaviour	8
	Demographic traits	31
	Physiological traits	100
Community composition	Taxonomic diversity	100
	Species interactions	100
Ecosystem Function	Net primary productivity	59
	Secondary productivity	0
	Nutrient retention	67
	Disturbance regime	100
Ecosystem Structure	Habitat structure	92
	Ecosystem extent and fragmentation	100
	Ecosystem composition by functional type	100

4.3. Constraints

This assessment relies on the system requirements and limitations of monitoring program and evaluated by considering the outcomes derived from Chapter 3, or literature. These criteria define the ease of monitoring, some of them decrease the cost and some of them increases efficiency, thus impact the selection of EBV.

4.3.1. Human Resources

Human resources are the most descriptive attribute of monitoring programs. The abundance and distribution of experts limit the scope and extent of monitoring. One way to overcome this limitation is to benefit from citizen science. For scoring technical expertise, the Chapter 3 outcomes were used as proxies and for citizen science I derived the values from Chandler et al (2017).

In Turkey citizen science input is only valid for bird species distribution. Chandler et al (2017) assessed the utility of citizen science and community based monitoring projects on a global scale in accordance with EBVs. By using supplementary material of Chandler et al. (2017). I filtered the terrestrial realm studies and count the EBVs. For each criteria normalized values are used and converted into a 0-3 scale. The scale defines 3: abundant, 2: moderate; 1: scarce. (Table 4.2)

Table 4.2. *Scoring human resources*

EBV Class	EBV	Technical expertise availability	Suitability for citizen science
748Genetic Composition	Co-ancestry	0	0
	Allelic diversity	1	0
	Population genetic differentiation	2	0
Species populations	Species distribution	3	3
	Population abundance	3	3
	Population structure by age/size class	1	1
Species traits	Phenology	1	3
	Body mass	0	1
	Natal dispersal distance	0	0
	Migratory behaviour	1	2
	Demographic traits	1	2
	Physiological traits	0	0
Community composition	Taxonomic diversity	1	0
	Species interactions	0	1
Ecosystem Function	Net primary productivity	0	1
	Secondary productivity	0	1

Table 4.2. Scoring human resources (continued)

EBV Class	EBV	Technical expertise availability	Suitability for citizen science
Ecosystem Structure	Nutrient retention	0	0
	Disturbance regime	1	2
	Habitat structure	1	2
	Ecosystem extent and fragmentation	1	1
	Ecosystem composition by functional type	0	0

4.3.2. Technology and Equipment

The requirements of specific instruments and equipments increase the fixed cost of monitoring. The column values represent; 3: No equipment, 2: Standard equipment, 1: Level-up field equipments, 0: Advanced laboratory equipments.

As automation increases efficiency, many EBVs could benefit from it. Specifically, camera trap networks, audio sensors or automatic identification algorithms would significantly reduce human time and effort. In this regard remote sensing contribution to monitoring is assessed as an option of technological improvements. I used the scores provided by O'Connor et al (2015). The scores show: 0: No adequacy, 1: Low adequacy, 2: Medium adequacy, 3: High adequacy (Table 4.3).

Table 4.3. Scoring technology and equipment

EBV Class	EBV	Equipment	Remote sensing
Genetic Composition	Co-ancestry	0	0
	Allelic diversity	0	0
	Population genetic differentiation	0	0
Species populations	Species distribution	2	2
	Population abundance	2	2
	Population structure by age/size class	2	0
Species traits	Phenology	1	2
	Body mass	1	0

Table 4.3. Scoring technology and equipment (continued)

	Natal dispersal distance	1	0
	Migratory behaviour	1	0
	Demographic traits	1	0
	Physiological traits	2	0
Community composition	Taxonomic diversity	2	0
	Species interactions	1	0
Ecosystem Function	Net primary productivity	2	2
	Secondary productivity	2	3
	Nutrient retention	0	3
	Disturbance regime	3	2
Ecosystem Structure	Habitat structure	3	2
	Ecosystem extent and fragmentation	3	3
	Ecosystem composition by functional type	2	3

4.3.3. Design Limitations

Time bound and space bound characteristics of EBVs can guide the monitoring scheme. Also the existence of baseline information would be an advantage. For time limitations I used the temporal sensitivity values used in EBV assessments (GEO BON, 2013). I assume that a plausible policy time frame is 10 years, and longer periods would not meet the policy needs and management targets. The scores shows 1: Annual, 2: 1-10 years, 3: more than 10 years. Space limitations are defined by the sensitivity of EBV in spatial scale. I used the values assigned in the portfolio (local, regional and countrywide). A scalable EBV should be more beneficial not only to estimate local changes but also to combine national and regional assessments. For example, a score of 3 shows that this EBV is applicable at three different scales, 2 for two scales, and 1 represents just one scale. I used the portfolio values to assign the exact situation in Turkey.

Another frequently mentioned criterion is the existence of baseline data. For this I only used the active monitoring portfolio results and applied 5 year and 20 year filters. The scores show "0: No historical data exist, 1: Historical data available for the last 5

years, 2: Historical data available for the last 20 years, 3: Historical data available for previously than 20 years" (Table 4.4).

Table 4.4. *Scoring design limitations*

EBV Class	EBV	Time bound	Space bound	Baseline
Genetic Composition	Co-ancestry	3	1	0
	Allelic diversity	3	3	0
	Population genetic differentiation	3	3	1
Species populations	Species distribution	1	3	3
	Population abundance	1	2	3
	Population structure by age/size class	1	1	0
Species traits	Phenology	1	2	0
	Body mass	2	2	0
	Natal dispersal distance	3	0	0
	Migratory behaviour	2	3	0
	Demographic traits	2	2	0
	Physiological traits	2	2	0
Community composition	Taxonomic diversity	2	2	0
	Species interactions	3	2	0
Ecosystem Function	Net primary productivity	1	3	0
	Secondary productivity	1	0	0
	Nutrient retention	1	2	0
	Disturbance regime	1	2	0
Ecosystem Structure	Habitat structure	1	3	2
	Ecosystem extent and fragmentation	2	3	0
	Ecosystem composition by functional type	2	1	0

I weighted the scores for human resources with 0.50, for technology and equipment with 0.25, and for design limitations with 0.25, and standardized the outcome into a 0-100 scale.

The output score table is presented in Table 4.5 and Figure 4.2. In the figure EBVs abbreviations were labelled. They are shown on table with the color codes.

Table 4.5. *The cumulative analysis*

EBV Class	EBV	Label	Usefulness	Feasibility
Genetic Composition	Co-ancestry	CoAn	5	12.5
	Allelic diversity	AlDi	0	50
	Population genetic differentiation	PGD	3	50
Species populations	Species distribution	SpDi	100	100
	Population abundance	PoAb	100	100
	Population structure by age/size class	PSAS C	28	37.5
Species traits	Phenology	Ph	41	62.5
	Body mass	BoMa	0	37.5
	Natal dispersal distance	NDD	0	12.5
	Migratory behaviour	MiBe	8	75
	Demographic traits	DeTr	31	62.5
	Physiological traits	PhTr	100	12.5
Community composition	Taxonomic diversity	TaDi	100	37.5
	Species interactions	SpIn	100	50
Ecosystem Function	Net primary productivity	NPP	59	37.5
	Secondary productivity	SePr	0	25
	Nutrient retention	NuRe	67	12.5
	Disturbance regime	DiRe	100	62.5
Ecosystem Structure	Habitat structure	HaSt	92	75
	Ecosystem extent and fragmentation	EEF	100	50
	Ecosystem composition by functional type	ECFT	100	12.5

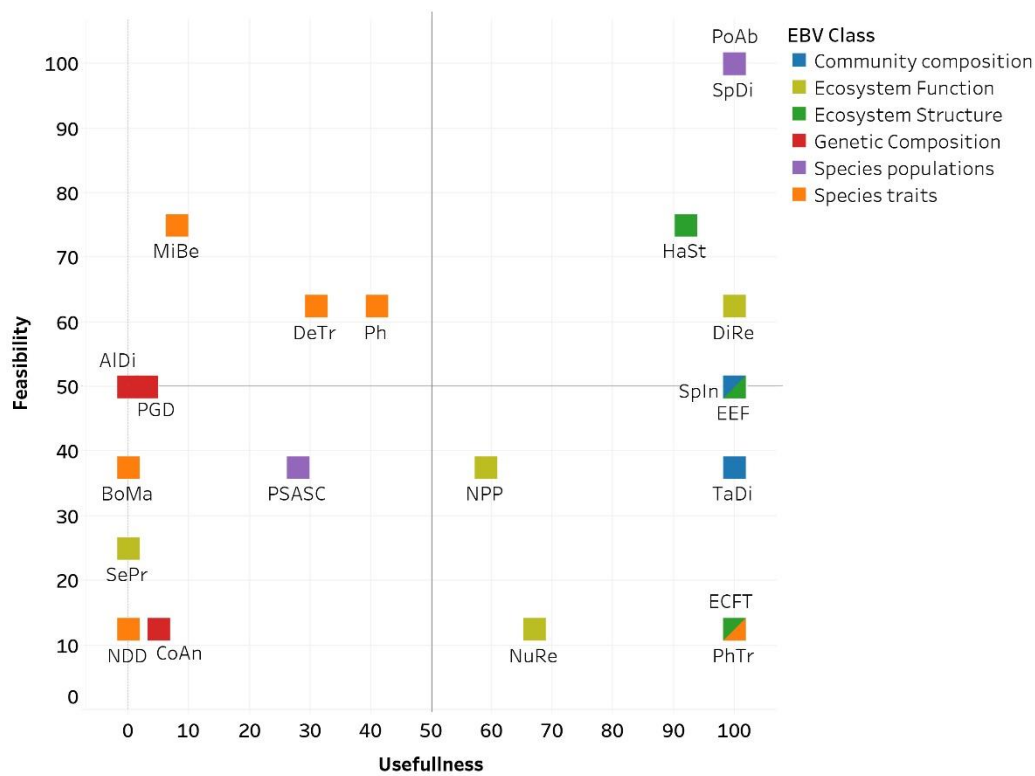


Figure 4.2. EBVs usefulness versus feasibility in Turkey's case

When divided into four quadrants with low/high values of feasibility or usefulness, there appears a clear differentiation of various EBVs. Monitoring Species Distribution and Population Abundance are both highly feasible and useful by a large margin, followed by Habitat Structure and Disturbance regime (upper right quadrant). Ecosystem Extent & Fragmentation, Species Interactions, Taxonomic Diversity are also highly useful but with increasingly lower feasibility (lower right quadrant). Most Ecosystem Function EBVs also fall here. In contrast, Species Traits EBVs such as phenology, demography and migratory behavior are moderate to high in feasibility yet rather low in usefulness (upper left quadrant) although this may be particular to the Australian workshop participants whose valuation was adopted. Finally, in the lower right quadrant we see a variety of EBVs with both low feasibility and low usefulness. Several of those latter EBVs are classified under Genetic Composition, an

EBV group with a fast improving technology, and often considered with prejudice by some practitioners.

As I have stated earlier, this is not a comprehensive and fully objective analysis or optimization. There are probably too many unknowns and multiple factors at work in such a complex issue.

The criteria used in this analyses can be extended by adding multiple aspects. Examples of similar works were presented in “2.6.1. Building Consensus in Indicators” section. Chapter 3 highlighted that monitoring decisions are taken by relative choices. Most active monitoring programs are part of a larger international or regional program, or are initiated by expert judgements. In general monitoring is done because it can be done (in specific areas, mostly at the species level). However EBVs show the necessity of multi-dimensional requirements in spatial, temporal and biodiversity levels. This ideal list cannot be sustained at a glance. Prioritizing the EBV list by considering the constraints and available resources enable comprehensive and successful monitoring schemes. Yet the approach I have outlined and provided an example can be used to help decision makers select which particular EBVs are most suitable to start monitoring with in a country.

I chose remote sensing as the most feasible technology for current conditions. However this decision might change in favor of other technological options. For example the applicability of e-DNA and soundscape ecology might improve in the future (increase in cost-efficiency or available equipments, donor interest etc.), then this option and its contribution to EBV measurements should be added to analyses. Then the results would reflect what is most useful and most feasible considering this particular technology. Similar analyses can be repeated in other countries considering their technical expertise and changing relevant criteria.

CHAPTER 5

A TRIAL ON PERFORMANCE OF REMOTE SENSING FOR ECOSYSTEM MONITORING: MAPPING THE DISTRIBUTION OF MEDITERRANEAN MAQUIS

This chapter presents a trial on the capacity of remote sensing in a complex ecosystem. In this section the usefulness of available open source Sentinel-2 gallery, and machine learning algorithms were tested and their contribution to mapping the distribution of vegetation are assessed in Mediterranean sparse forests where maquis formations. This study was published as the title “Species Level Classification of Mediterranean Sparse Forests-Maquis Formations Using Sentinel-2 Imagery”³⁴ in Journal of Geocarto International.

5.1. Introduction

Sustainable Forest Management (SFM), which encompasses a wide spectrum of concerns, from timber to non-timber forest products, and further towards forest related ecosystem services and functions (Wang and Wilson, 2007), requires management of the regenerative capacity of forests for an array of demands of goods (i.e. timber, food) and services (i.e. water regulation, soil protection) for current and future generations (MacDicken et al., 2015). To fulfil these requirements, it is important to understand the diversity of forests for three reasons. First, the compositional and structural diversity of forests serve multiple ecosystem services (Lindenmayer et al., 2000; Burrascano et al., 2011). Second, the composition and structure of forests are

³⁴ This chapter was published as Demirbas Caglayan, S., Leloglu, U. M., Ginzler, C., Psomas, A., Zeydanli, U. S., Bilgin, C. C., Waser, L. T., 2020. Species Level Classification of Mediterranean Sparse Forests-Maquis Formations Using Sentinel-2 Imagery. Geocarto International, 1-20. DOI: 10.1080/10106049.2020.1783581. Reprinted with permission of Taylor & Francis

important indicators to be monitored for guiding the adaptive management imposed by SFM (Rist and Moen, 2013). In this context, the composition and structure of maquis (defined here as a dense evergreen sclerophyllous cover of small trees and shrubs at various heights and densities) correspond to various stages of regressive succession and degradation (Tomaselli, 1977; Scarascia-Mugnozza et al., 2000). Third, diversity contributes to the resilience of the system (Ciancio and Nocentini, 2004), and it is important to identify the ecologically vulnerable and resilient sites, a crucial topic in Mediterranean because of its susceptibility to fire, degradation, and desertification, as a direct consequence of climate change (Peñuelas et al., 2010).

Despite management shifts towards a SFM perspective, the planning process and inventory principles largely continue to be tied to the conventional methods. National Forest Inventories (NFI) and derived management maps are still dependent upon timber increment interest (Laamanen and Kangas, 2011) and only partially meet the requirements of a sustainable management perspective (Siry et al., 2005; Groot et al., 2015). This is especially evident in Mediterranean sparse forests characterized by tree canopy closure of less than 10% while maquis generate a dense vegetation layer underneath. To classify, plan and manage such ecosystems considering only the sparsely distributed tall trees but ignoring the shrub/small tree layer causes a serious shortcoming due to several reasons: (1) maquis play an important role in ecosystem functioning since they prevent soil erosion (Gabarrón-Galeote et al., 2013), (2) enhance soil quality (García-Orenes et al., 2012), (3) control surface runoff (Casermeiro et al., 2004) (4) create a microclimate for further vegetation generation (Tomaselli, 1977), (6) enhance overall biodiversity (Goberna et al., 2007) and (7) provide indispensable economic resources to local livelihoods, i.e. non-timber forest products such as seeds, fruits, gums, resins, dyes, medicines and aromatic plants (Öztürk, 1995; Palahi et al., 2008).

Forests in the Mediterranean basin cover approx. 88 million hectares (FAO and Plan Bleu, 2018) and according to Bontemps et al. (2011) sparse trees (including shrublands and grasslands) cover across 17.7 % of the Mediterranean basin. Turkey's

Mediterranean region covers 5.7 million hectares of forest where 41.85% belong to “sparse forest” and are managed as if only tall trees (e.g. *Pinus brutia*) exist (GDF, 2019). However, according to the SFM principles, it is necessary to map the maquis distribution and incorporate their compositional diversity into management practices. Since recreating the maps that reflect the complex structure of maquis via surveys is impossible, remote sensing should be employed for this purpose.

The use of remote sensing techniques to delineate maquis is not a novel attempt for the Mediterranean region. Earlier efforts comprise: (1) land use change detection (Sluiter and de Jong, 2007; Tzanopoulos and Vogiatzakis, 2011), (2) vegetation mapping (de Jong and Burrough, 1995; Grignetti et al., 1997), (3) assessing vegetation dynamics (Kadmon and Harari-Kremer, 1999) particularly during recovery from fire (García and Caselles, 1991; Laurin et al., 2018), (4) detection of the flammability for fire management (Koutsias and Karteris, 2003; Bajocco et al., 2017), (5) biomass estimation (Calvão and Palmeirim 2004, Meer et al., 2001) and (6) monitoring land degradation and restoration management (Fava et al., 2016). However, in all previous studies in our knowledge, maquis were treated as a single group (Telesca and Lasaponara, 2006; Bajocco et al., 2012) or they were classified into maximal three categories on the basis of height (Maselli et al., 2000), density/coverage (Laurin et al., 2018) or physiological classes (*maquis/garrigue/phyrgana*) (De Jong and Burrough, 1995; Esbah et al., 2010). Only Manevski et al. (2011) applied a species level classification scheme based on field spectrometry that requires costly fieldwork.

This study introduces a detailed species level classification scheme for the dominant maquis species (*Genista acanthoclada*, *Erica* spp., *Phillyrea latifolia*, *Quercus* spp., *Olea europea* and *Arbutus andrachne*) based on Copernicus Sentinel-2 time series and a machine learning approach. As a multi-spectral satellite constellation Sentinel-2 provides an opportunity for heterogeneous forests with its 10 m resolution and the short revisit cycle of five days. Applying a multi-temporal methodology helps to catch the spectral variances in phenology and thus increase accuracy in vegetation mapping (Grabska et al., 2019). Due to these reasons Sentinel-2 imagery has been widely used

in the forestry sector to classify tree species composition (Immitzer et al., 2016, Persson et al., 2018; Kampouri et al., 2019), quantify forest extent (Suresh and Hovenbitzer, 2018), estimate above ground biomass (Chang and Shoshany, 2016; Laurin et al., 2018), and monitoring forest disturbances from fire (Colson et al., 2018) or logging (Lima et al., 2019).

The main objective of this study is to map the compositional diversity in complex Mediterranean maquis ecosystems with high accuracies based on Sentinel-2 images, and ancillary data. The specific aims comprise:

- (1) to create a species level classification for maquis in order to increase our knowledge in compositional data, especially for the relevant formations “sparse forests” in forest stand maps, although they are maquis from an ecological perspective,
- (2) to present a semi-automated approach based on open software and freely available global remote sensing data to guarantee that the method can be applied to similar formations over large areas in the Mediterranean region and easily be repeated for monitoring purposes,
- (3) to assess the explanatory power of remote sensing and ancillary features in the context of the present mapping task.

The contributions of this paper to the state-of-the-art are as follows:

- (1) It is a pioneering study that shows the feasibility of remote sensing methods to species level maquis classification using machine learning techniques and ancillary data in addition to satellite multi-temporal images,
- (2) It introduces new features designed to accentuate the subtle spectral differences among maquis species,
- (3) It determines the remote sensing variables along with ancillary variables that has a significant effect on species distribution in maquis.

5.2. Materials and Methods

5.2.1. Overview

In this study, a workflow (Figure 5.1) to produce an accurate and detailed composition map for Mediterranean woodlands, which distinguishes six dominant maquis species was developed. Since no detailed information about maquis distribution at the species level exists, a field survey was carried out to collect Ground Truth (GT) data. The main focus of the field survey was laid on “sparse forests” in NFI where the tree canopy cover is marked as less than 10%. Then, based on orthoimages, GT polygons were delineated around the sampling points. Finally, Sentinel-2 imagery Level 1C products for the time period between 01-01-2016 and 30-05-2019 were acquired via Google Earth Engine (GEE), which is a cloud computing platform for geospatial analysis which has been widely used to monitor deforestation, disaster risk, food security, etc. at the global, regional and local scales (Gorelick et al., 2017).

In addition to remote sensing features such as original spectral bands and spectral indices, also ancillary data such as soil type, geological information, bio-climatic surfaces and topographic variables were prepared and in total, a set of 44 features were used. Multi-collinearity was reduced by applying a feature selection procedure that identified the 20 most important variables. We applied a Random Forest (RF) classifier (Liaw and Wiener, 2002) with 10-fold cross-validation using R 3.3.2 (R Core Team, 2017) and Caret Packages (Kuhn, 2008).

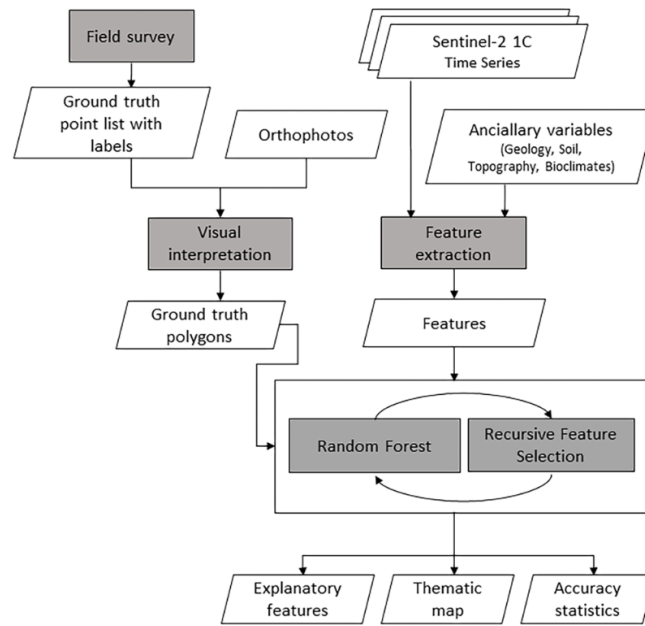


Figure 5.1. Workflow for the classification (Grey rectangle denotes process and rhomb denotes data)

5.2.2. The Study Area

Köyceğiz Forest Management Unit is located between 36.77 - 37.12° E and 28.41 – 29.07° N in the southwestern part of Turkey (Figure 5.2a) and covers 118,081 hectares. Elevation starts from sea level and reaches up to 2296 m above sea level (a.s.l.). 44.9 % of the unit is under various protection status (National Park, Specially Protected Area and Wildlife Reserve) due to the region's ecological significance for threatened species. A mosaic of freshwater, coastal, and woodland habitats contributes to the exceptional biodiversity of the region. The mean annual temperature is 18.3 °C, while the absolute minimum and maximum temperatures are -7.0 °C and 43.0 °C, respectively, and the annual mean precipitation is 1032 mm (Turkish State of Meteorological Service, 2016). Wooded vegetation covers 74.7% of the area and are composed mainly of *Pinus brutia* (81.8%) and *P. nigra* (19.5%) woodlands, of which approximatively a quarter is managed under the “sparse forest” label (GDF, 2013). The maquis vegetation starts from the sea level and reaches up to 1000-1200 m. a.s.l.

(Davis, 1965). A heterogeneous composition of maquis forms a multi-layered vegetation structure in the region. The study area hosts many maquis species in diverse physiognomic stages: dense and open shrublands (<2m) of *Genista acanthoclada* and *Erica* spp.; low tree formations (>5m) of *Olea europea*, *Arbutus andrachne*, *Phillyrea latifolia* and *Quercus* spp. Apart from these dominant species other characteristic species include *Juniperus*, *Cotinus*, *Ceratonia*, *Cistus*, *Daphne*, *Laurus*, *Myrtus*, *Pistascia* and *Sarcopoterium* spp.

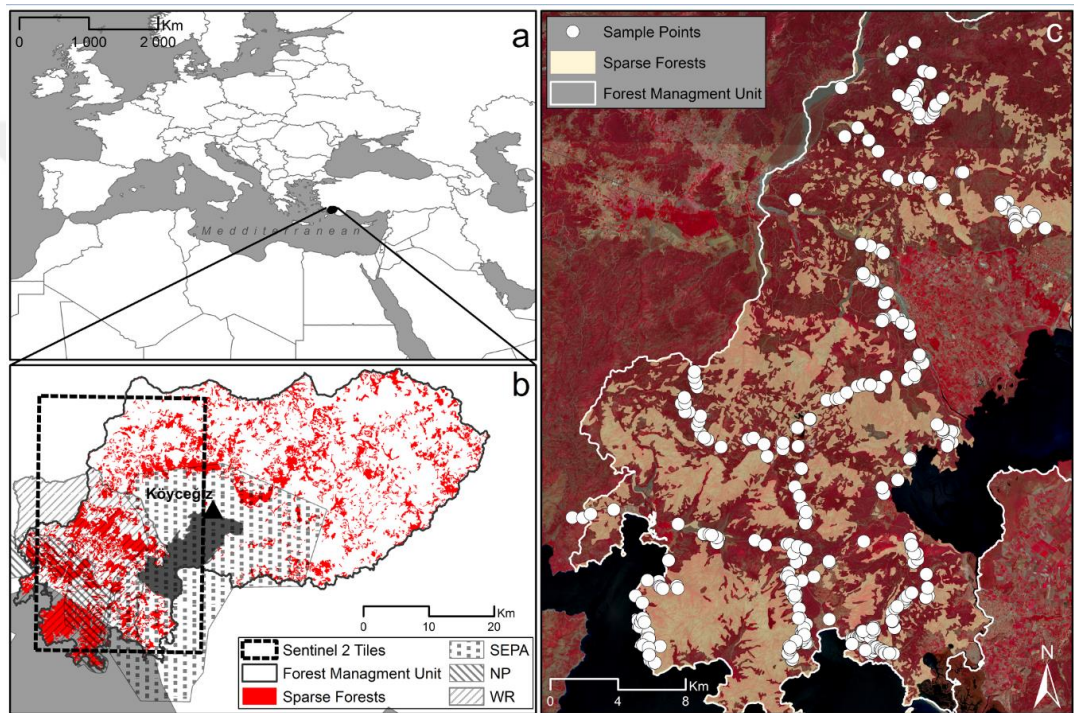


Figure 5.2. The study area and the sampling points within the “sparse forests” a) The location of the study area, b) Dark grey polygon: Köyceğiz Forest Management Unit. Red polygons: “sparse forest” stands identified in stand management maps. Dashed lines: various protection status (SEPA: Specially Environment Protection Area, NP: National Park, WR: Wildlife Reserve. c) White dots: sampling points.

5.2.3. Material

5.2.3.1. Field Survey and Ground Truth Polygon Drawing

The field survey was carried out to collect the GT reference data in August 2018. Prior to the survey, the canopy closure information of the study area was derived from forest management maps produced by the GDF (2013). Sparse forests with less than 10% canopy closure were marked and the fieldwork was carried out within this boundary (Figure 5.2b-c). If any maquis species covered more than 60 % of the patch and with a minimum radius of 10-15 m, then the centre of the vegetation cluster was geolocated by GPS and the maquis patch's radius was recorded for further polygon drawing. Habitat and specimen photos were taken at each location. Considering the time and labor constraints, we decided to collect a high number of samples that represent all dominant formations of the study area instead of only using few samples from a completely random design. Kadmon (2004) states that if a geographically biased (i.e. roadside) dataset is relatively unbiased as far as it reflects the environmental gradients of the study area, then accurate results are achievable. When we plot histograms of elevation as a major environmental gradient for the ground truth points ($n = 375$) and sparse forests, we assume except for the highest elevations, our sampling adequately reflects the present environmental heterogeneity (Figure 5.3).

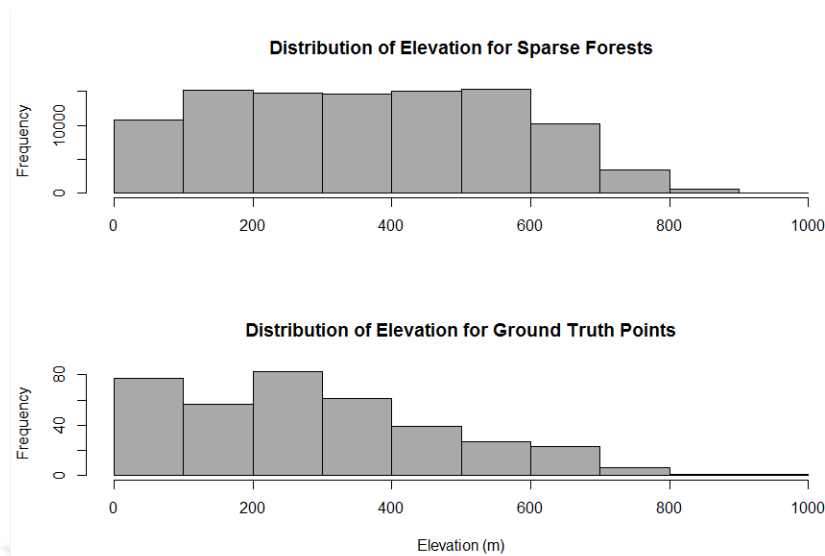


Figure 5.3. Histograms of elevation classes for sparse forests (upper) and 375 ground truth points (lower).

Following the fieldwork, GT polygons were drawn by visual interpretation by means of RGB orthophotos of the year 2013 with 90 cm resolution and the photographs taken during the survey. Species classes with samples less than 10 polygons were eliminated from the sample set (e.g. *Laurus nobilis*, *Myrtus communis* and *Cistus sp.*). Figure 5.4 shows the eight different maquis species used in the classification scheme. Their abundance and coverage reflect the dominance of each species within the studied stands.

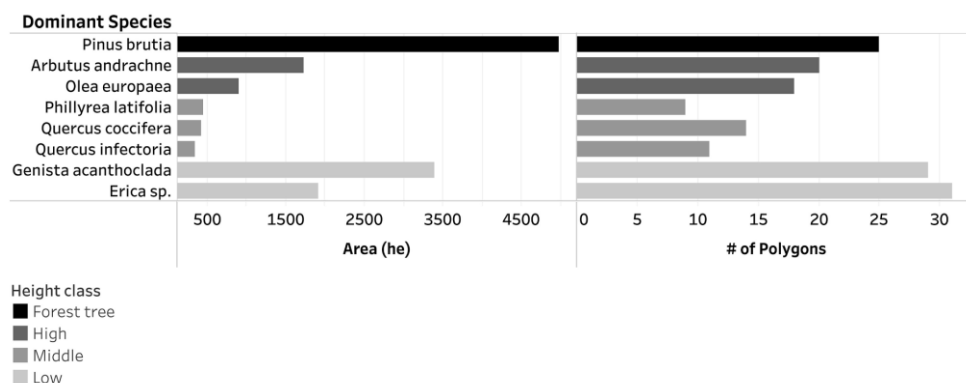


Figure 5.4. Distribution of ground truth polygons among the eight species classes

5.2.3.2. Remote Sensing Data

Sentinel-2 Level 1C images between 01-01-2016 and 30-05-2019 were acquired from GEE. The images more than 20% cloud coverage were eliminated from dataset. Totally 167 distinct days were derived for two Sentinel-2 tiles (T35SPA and T35SPB) (Figure 2b). A further cloud mask and shadow mask were applied at the pixel level (Chastain et al., 2019). Sentinel-2 bands B2, B3, B4, B6, B8, B9, B11, B12 (corresponding to blue, green, red, red edge 2, NIR, water vapour, SWIR1 and SWIR 2 respectively) were used in the analysis.

5.2.3.3. Ancillary Features

Apart from RS features, 25 environmental features in total (Soil-1, Geology-1, Bioclimates-19, Emberger-1, Topographic-3) were prepared to precisely model the distribution of maquis. This type of environmental features are frequently used in species distribution models (Morin et al., 2007). Several studies revealed the usefulness of combining remote sensing features with the environmental features at species level vegetation mapping (Zimmermann et al., 2007), especially in larger scales where the characteristics of the study area cannot be distinguished by moderate scale RS images alone (Engler et al., 2013). In Mediterranean region, many studies reveal the limiting factors of plant growth as the precipitation, the soil depth and formation (Di Castri, 1981; Sluiter and De Jong, 2005).

Table 5.1 lists the potential features used in this study. Soil and geology polygons were rasterized and other raster layers were resampled to 10 m resolution, which is the highest spatial resolution of Sentinel-2.

Table 5.1. List of ancillary features

Category	Feature Name	Data Source	Usefulness in vegetation mapping
1/25.000 Soil Map	Soil type	Turkey Ministry of Agriculture and Forestry	Sluiter and De Jong, 2005; Corcoran et al., 2013
1/25.000 Geology Map	Formation category	General Directorate of Mineral Research and Exploration	Sluiter and De Jong, 2005
Bioclimatic features	Bio1: Bio19	CHELSA bioclimatic surfaces (Karger et al., 2017)	Zimmermann et al., 2007
Emberger Index	Calculated from bioclimatic features	Emberger, 1955	Dufour-Dror and Ertas, 2004
Topographic Variables	Elevation (m) Slope (°) Northness	ASTER GDEM ³⁵	Sluiter and De Jong, 2005; Gislason et al., 2006

5.2.4. Method

5.2.4.1. Feature Extraction

The pixel values of each raster layer were computed for each GT polygon. Since the digestible Sentinel-2 library in Level 2A was limited in GEE, we used Level 1C images. These images are neither atmospherically nor radiometrically corrected, so a $\pm 3\sigma$ outlier removal algorithm was applied to remove extreme radiometric effects in the daily time series image dataset. Then, polygon spatial means of original image bands (B2, B3, B4, B6, B8, B9, B11, B12) and representative subset of Spectral Indices (SI) (Table 5.2) were computed. Spectral indices are frequently used for vegetation, soil and water body mapping and comprise band ratios, where confounding issues such as atmospheric effects or soil background reflectance are

³⁵ <https://asterweb.jpl.nasa.gov/gdem.asp>

reduced (Meyer et al., 2019).

The phenological traits such as leaf senescence, colouring, flowering, etc. of each species might enable to filter ideal dates or seasons for remotely sensed data acquisition (Gärtner et al., 2016). This is particularly challenging since the focal species are evergreen sclerophylls and some of them present similar morphological features and biomass accumulation (*Quercus coccifera*, *Q. infectoria*, and *Phillyrea latifolia*). To perceive the reflectance behaviour of the target species and understand the subtle differences among each other, the time series of indices are plotted on a monthly basis (Figure 5.5). In this step, after assessing the distributions visually, and considering their relatively smaller representations in the GT, we grouped the above three species into a single class named “mix”, hence the final classification is based on six maquis species classes. Furthermore, seven additional spectral features were calculated (Table 5.2) to accentuate the phenological differences between certain species. In total, 21 features were extracted for each GT polygon: annual median values for eight basic spectral bands, annual mean values for six spectral indices, and seven newly computed indices inferred from time series graphs of spectral indices.

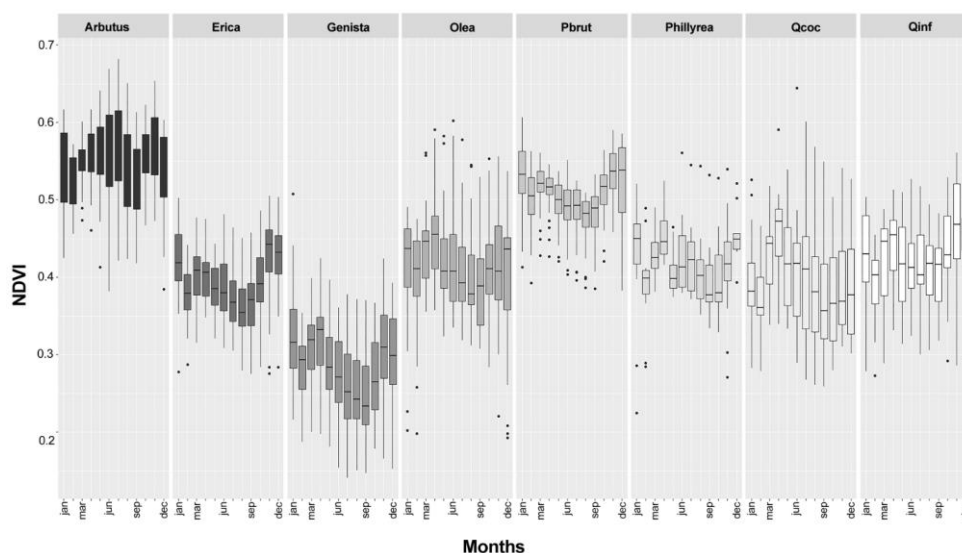


Figure 5.5. NDVI values distribution per month for each of the eight vegetation classes

Table 5.2. List of spectral indices and re-computed features from SIs to delaminate vegetation classes

Spectral Indices (SI)	Formula	Reference
NDVI	$(B8 - B4)/(B8 + B4)$	Rouse et al., 1974
NDWI	$((B8 - B11))/((B8 + B11))$	Ceccato et al., 2001
SAVI	$((B8 - B4) * 1.5)/((B8 + B4 + 0.5))$	Huete, 1988
EVI2	$((B8 - B4) * 2.5)/((B8 + 2.4 * B4 + 1))$	Jiang et al., 2008
GDVI2	$\frac{(B8^2 - B4^2)}{(B8^2 + B4^2)}$	Wu, 2014
GVI (Tasselled Cap vegetation)	$(-0.283 * B2) + (-0.2453 * B3) + (-0.5436 * B4) + (0.7243 * B8) + (0.0840 * B11) + (-0.18 * B12)$	Thenkabail et al., 2002
Computed Features	Formula	
Feat ₁	$\frac{NDVI_{std}^1 + NDVI_{std}^2}{2}$	Inferred from SI monthly graphs (e.g. Figure 5) for to distinguish species phenological differences
Feat ₂	$\frac{NDVI_{mean}^4 - NDVI_{mean}^9}{NDVI_{mean}^{1:12}}$	
Feat ₃	$\frac{NDVI_{mean}^{11} - NDVI_{mean}^6}{NDVI_{mean}^{1:12}}$	
Feat ₄	$\frac{NDWI_{mean}^2 - NDWI_{mean}^4}{NDWI_{mean}^{1:12}}$	

Table 5.2. List of spectral indices and re-computed features from SIs to delaminate vegetation classes
(continued)

Computed Features	Formula	
Feat ₅	$\frac{GVI_{\text{mean}}^7 - GVI_{\text{mean}}^{12}}{GVI_{\text{mean}}^{1:12}}$	
Feat ₆	$\frac{SAVI_{\text{mean}}^{11} - SAVI_{\text{mean}}^9}{SAVI_{\text{mean}}^{1:12}}$	
Feat ₇	$\frac{GVI_{\text{mean}}^6 - GVI_{\text{mean}}^4}{GVI_{\text{mean}}^{1:12}}$	

5.2.4.2. Random Forest Classification

Random forest (RF) (see e.g. Breiman, 2001) is a fast and powerful machine learning algorithm that successfully overcomes high dimensionality and multicollinearity, thus intermittently used in both regression and classification problems (Colditz et al., 2015; Räsänen et al., 2013). The RF model was run in R software (R Core Team, 2017). Major RF tuning parameters have been set to default values as suggested by Belgiu and Drăguț (2016). Such that; *mtry* (Number of variables randomly sampled as candidates at each split) is equal to the square root of the total number of features, and *N* (number of trees to grow) is set at 500.

5.2.4.3. Feature Selection

RF's variable importance approach is highly beneficial for ranking features, applying stepwise approaches, and setting certain thresholds to feature space. By means of these, it is possible to find out (1) respectively correlated variables, (2) explanatory

features for the prediction, and (3) to optimize the feature space with the minimum number of variables (Genuer et al., 2010). Feature selection is an important step for machine learning applications (Kohavi and John 1997). In total, 46 remote sensing and environmental features are computed. Inherently some of them might be highly correlated with each other, so to highlight the indispensable features, feature selection algorithm was applied. In this study, we applied a wrapping approach, i.e. Recursive Feature Selection (RFE) as described in Gregorutti et al., (2017). RFE uses a backward iteration approach and it is highly capable of removing noisy and highly correlated features. The RF classifier is trained and feature ranking is computed by permutation importance. As a consecutive step, the least important features are eliminated and this recursive process is repeated until all the features contribute significantly to the model (Gregorutti et al., 2017).

5.2.4.4. Accuracy Assessment

We applied 10-fold cross-validation to provide an unbiased estimation of RF model performance based on the entire sample of the limited GT set. To assess the accuracy of the output classification a further independent validation was applied by placing 500 random points within sparse forest stands. By visual interpretation we categorized each point by means of orthophotos. However due to the limitations in delineating maquis we labelled these points as either trees or shrubs, thus a physiognomic ontology was produced (tree and shrub) which is also highly beneficial in understanding the dynamics of various vegetation stages. The classification map was also grouped namely, shrubs (*Genista* ssp., *Erica* ssp., Mix) and trees (*Olea europea*, *Arbutus andrachnea*, *Pinus brutia*). The classification map predicted by the model were compared to these independent random set and assessed with the accuracy statistics aforementioned above.

5.3. Results

5.3.1. Classification map

The species level classification map of the maquis is presented in Figure 5.6. The most widespread species is *Genista acanthoclada* (34.4%), followed by the “mix” class (26.6 %), *Erica sp.* (15.9%), *Arbutus andrachne* (7.9%) and *Olea europaea* (3.3 %). Although these vegetation types are labeled as “sparse *Pinus brutia* forests” by the foresters, our study reveals that pines only cover 11.8% of the masked area.

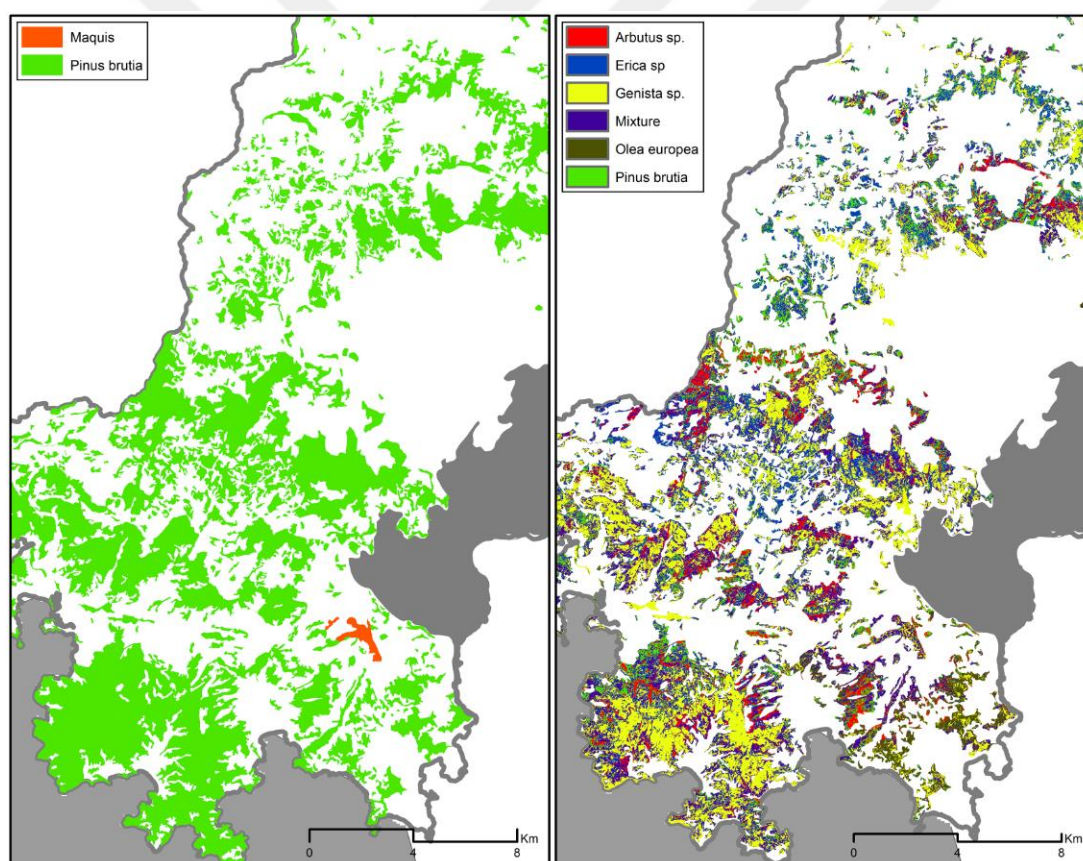


Figure 5.6. (left) “Sparse forest” mask; green polygons show stands labelled as “sparse *Pinus brutia* forest”, only orange polygon labelled as “maquis”. (right) Classification representing the dominant maquis species and *Pinus brutia*

5.3.2. Classification Accuracy

5.3.2.1. Species Level Classification Accuracy

Overall accuracy (OA) of the model is 0.78 and Cohen's kappa coefficient (K) is 0.73 (Table 5.3). For each class, the accuracies are greater than 0.70. The classes *Genista acanthoclada* and *Pinus brutia* achieved highest accuracies indicating a successful classification. Commission errors are in the range of 0.0% to 28%, with the largest error for *Pinus brutia* and the smallest for *Olea europea*.

Table 5.3. Confusion matrix of species classification

CLASSES	Arbutus	Erica	Genista	Mix	Olea	Pbrut	Row Total
Arbutus	14	0	0	1	0	4	19
Erica	0	24	3	4	0	0	31
Genista	0	2	25	2	0	0	29
Mix	2	1	4	24	0	3	34
Olea	2		1	1	14	0	18
Pinus	0	2	1	1	0	21	25
Column Total	18	29	34	33	14	28	156
Omission Error	0.26	0.23	0.14	0.29	0.22	0.16	
Comission Error	0.22	0.17	0.26	0.27	0.00	0.28	
Overall Accuracy: 0.78				Cohen's Kappa: 0.73			

5.3.2.2. Physiognomic Classification Accuracy

The species level classification can be easily adapted into a physiognomic classification which is a basic way of describing the vegetation condition. This scheme is useful for various application areas in forestry and restoration ecology. Furthermore, with this generalized categorization, we produced an independent sample set that enables further validation. To assess map accuracy at the physiognomic level, an independent validation set was generated that is based on 500 randomly selected points and labelled by image interpretation. Table 5.4 shows the accuracy metrics of this independent validation set on physiognomic level. OA is 0.93 and the K value is 0.86. These results confirm that this classification is highly capable to discriminate the physiognomic (shrub-tree) stages of the maquis.

Table 5.4. Confusion matrix of the physiognomic classification

CLASSES	Shrub	Tree	Row Total
Shrub	287	8	295
Tree	25	180	205
Column Total	312	188	500
Comission Error	0.08	0.04	
Omission Error	0.03	0.12	
Overall Accuracy:0.93		Cohen's Kappa:0.86	

5.3.3. Explanatory Features

The RF classification for six species of the maquis enables to assess the power of the predictor features. The total number of features used in the final RF model generation is assessed by RFE performance. To reduce the effect of fluctuations in the

performance of the RF caused by the random nature of the algorithm, the model is run 12 times with different seed values and the results are averaged. Figure 5.7 represents the relative contribution of features to the model accuracy. Trend lines are depicted on the curve and the first intersection is observed around 20 features. The intersection point illustrates that the first 20 features seem to be highly important (steep trend line). Using more than 20 features results in an almost horizontal trend line and feature importance even begins to decline.

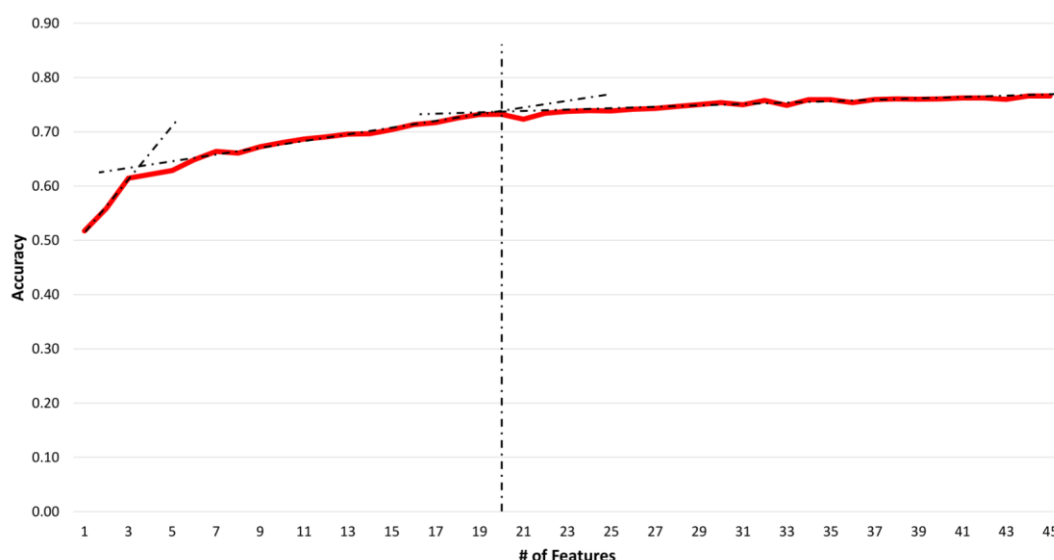


Figure 5.7. Number of features versus overall accuracy (Red line: change in accuracy with the additive random features. Dashed lines: the trend in the accuracy change)

As for variable importance, spectral indices appear to be the most important features with the blue band (B2). Visible (red, green and blue bands), NIR and SWIR spectrum of Sentinel-2 also contribute to the model. On the other hand, red edge spectrum is eliminated. With respect to characteristics of the evergreen species, the mean annual indices are more descriptive than specific seasonal features such as Feat 2, 4 and 1. Among the ancillary variables, geology, soil, BIO19 (Precipitation of Coldest

Quarter), BIO12 (Annual Precipitation) and DEM (elevation) are prominent (Figure 5.8).

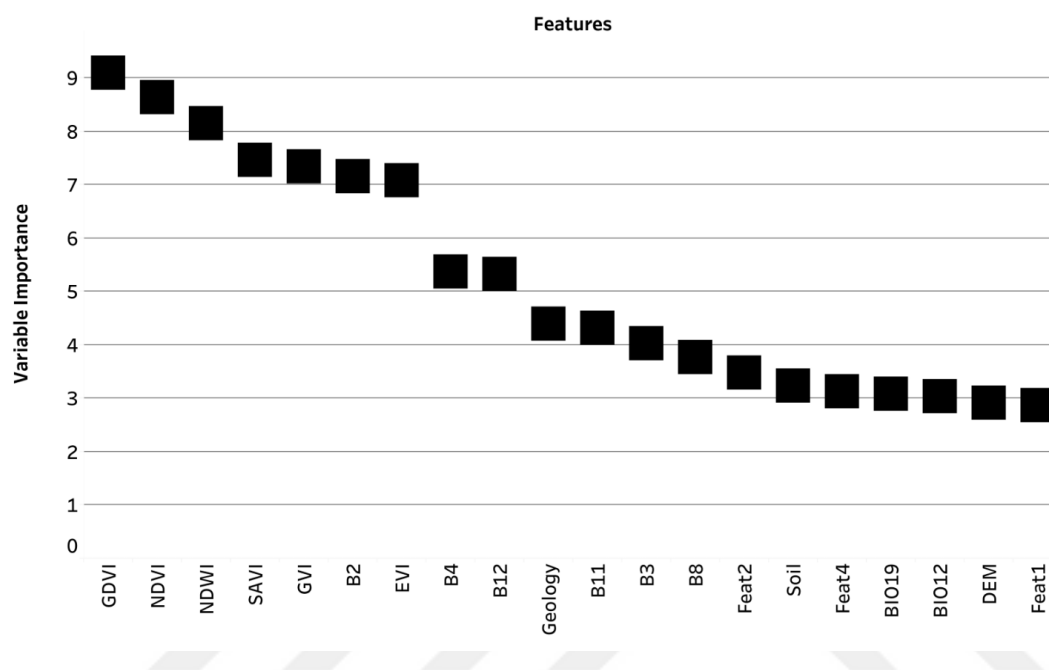


Figure 5.8. RF Variable importance of the 20 input features

5.4. Discussion

5.4.1. Utility of the Classification Map

This study presents an algorithm to classify six species of maquis and contributes to a consistent solution to the problem of classifying complex woody vegetation in the Mediterranean ecoregion. Thus, the output of this research is of great importance and will enable to develop an enhanced ecosystem management and policy, in particular SFM at stand level in Turkish Mediterranean region. Moreover, the use of freely available and high-quality multi-temporal Sentinel-2 images offers new perspectives

to discriminate maquis vegetation down to the species level. The spatial resolution of the map (10 m) is sufficient to discriminate the composition of most maquis types. Although higher spatial resolution might produce even better classification results at the species level, the current resolution is absolutely sufficient for forest management units to infer management decisions. The potential utility areas of species and physiognomic level maps are suggested in Table 5.5.

Table 5.5. Potential utility of produced species maps in Mediterranean maquis

Utility	Species level map	Physiognomic level map
Monitoring land use land cover (LULC)	X	X
Monitoring land degradation	X	X
Landscape restoration	X	X
Vegetation mapping	X	X
Vegetation dynamics	X	
Fire management	X	
Biomass estimation	X	X
Managing non- timber forest products	X	
Mapping ecosystem services	X	X

RS based classification is more successful when most pixels are pure, i.e., composed of one single class only. However, even for tree species classification, it remains challenging to find pixels consisting of a single tree species and/or single age class (Fassnacht et al., 2016). Also in our study, obtaining pure sample points consisting of a single maquis species was not always feasible due to the heterogeneous and inherently mixed maquis vegetation with varying heights. To overcome this problem, we focused on patches dominated by a single species (>60% cover of a single type of

vegetation) and generated target classes accordingly. Although canopy closure for each class is even, the height of target species varies significantly for some of the classes. The greater variance occurred for oak species (between 1 and 10 m), probably due to their specific management (coppice regime or grazing pressure) in the past. *Phillyrea latifolia* also vary substantially in their height (between 0.6 m and 5 m). The vertical leaf area density of those species changed during their life cycle and thus might affect classification performance.

Another issue is the spectral inter class variability due to the clutter caused by the bare soil or other plants underneath the target species (Fassnacht et al., 2016). In our case, presence of bare soil causes problems for the classes *Genista acanthoclada* and *Erica* spp. However, other maquis plants and herbs contributing to the mixture in the sampling locations of other classes (i.e. *Arbutus*, *Olea*, *Quercus* etc.) are the major challenge and increase intra-class variability. In order to reduce the background signal (clutter) caused by bare soil, we chose sampling locations with canopy closure higher than 75%. We tolerated the natural variability caused by species heterogeneity as typical characteristics of the Mediterranean region and did not further categorize or eliminate species classes to remove this effect. Similar to the findings of Manevski et al. (2012) obtained with field spectrometer, VIS and SWIR are highly prominent for the maquis species. This is especially evident for *Olea europea* in our study. Similarly *Genista* and *Erica* classes are well distinguished (Table 5.5).

5.4.2. Classification Accuracy

Our classification for both species and physiognomic levels are highly accurate. In general, the accuracies are higher in biomes which have lower biodiversity (Fassnacht et al., 2016). As Mediterranean maquis has high biodiversity, we found it more applicable to compare our results with the similar studies conducted in the Mediterranean region. The classification schemes, spectral and spatial resolutions of imagery used and classification algorithms vary greatly in previous literature.

Nevertheless, Table 5.6 presents a comparison, with an emphasis on the accuracy statistics.

Table 5.6. Accuracy statistics and classification scheme. We listed only classes related with maquis.

Classes (Maquis related class labels mentioned)	Predictors	Classification/ discrimination technique	Accuracy	Reference
Maquis and three other classes	Aerial Photographs	Object based	OA: 0.83, Kappa: 0.77	Fava et al., 2016
Low maquis High maquis Maquis with open canopy forest sp. and other 11 classes	Landsat TM SPOT	Maximum likelihood	OA: 0.85	Grignetti et al., 1997
Species level discrimination; <i>Ceratonia siliqua</i> , <i>Olea europaea</i> , <i>Pistacia lentiscus</i> , <i>Calicotome villosa</i> , <i>Genista acanthoclada</i>	Hyperspectra l air and spaceborn sensors / Field spectrometry	Parametric and non-parametric tests	99% confidence level results highlights the spectral discriminati on in certain wavelengths	Maneski et al., 2011
Shrublands, Oak Grove and 12 other classes	Landsat TM geostatistical textural features	RF / Maximum likelihood	OA: 0.83- 0.92	Rodriguez- Galiano et al., 2012
6 dense matorral classes (3 of them directly related with maquis: scattered <i>Pinus</i> , <i>Quercus ilex</i> dominant by undergrowth species) 4 middle matorral classes (dominated by <i>Quercus cocifera</i> , <i>Erica arborea</i> , <i>Cistus</i> spp) 3 low matorral and 13 other classes	HyMap & Some ancillary variables	Spectral angle mapper & Ancillary data classification Model	OA: 0.51- 0.69	Sluiter and De Jong, 2005

To increase the accuracy and usefulness of the classification map we recommend three issues regarding the sampling set. The acquisition of sampling set is a time and money consuming process and a relatively subjective task (Belgiu and Drăguț, 2016). We collected 382 samples from 11 different maquis types. However, as aforementioned above, we could not draw polygons for every sample point and include that number (382) of training samples in the classification scheme. Recording the locations of cluster centres just as points is not a good sampling methodology for the Mediterranean region where the spatial heterogeneity is high. For some of the target species visual interpretation is hardly possible at the inter-specific level (e.g. between *Quercus* and *Phillyrea*, or between *Erica* and *Genista*). The easiest case of discrimination by photo interpretation is between *Olea* and *Arbutus* due to different hues of their leaves. Also, the shadows generated by the taller trunks of *Olea* and *Arbutus* are easily discriminated from shrub formations.

A further limitation is in the evenness of the remaining samples. RF classifier is less sensitive to imbalance in training, noise in the training set or overfitting problems (Belgiu and Drăguț, 2016). However, the distribution of samples within the training set might improve the performance of the model. Colditz (2015) suggested that the best accuracy was reached by the generation of area-proportional allocation of training samples over classes, i.e. more samples allocated for commonly occupied classes. On the other hand, Jin et al., (2014) showed that the area-proportional allocation reduced the commission error and the equal allocation of classes reduced the omission error for low- represented classes. While noting these findings, we again underline the complex vegetation patterns in our study area. Given in Figure 4, the widespread species are *Genista acanthoclada*, *Erica sp.* and the rare ones are *Phillyrea latifolia*, *Q. coccifera* and *Q. infectoria*. On the other hand, due to the species community traits, some of them generates wide clusters (*Genista acanthoclada*, *Erica sp.*) on the other hand for some species it was hard to find even 100 m² coverage (*Q. infectoria*). We followed the area-proportional allocation guides, our sampling scheme reflects the plants' occurrences.

However, there are several other species such as *Laurus nobilis*, *Myrtus communis*, and *Pistacia terebinthus* in the study area but they do not cluster explicitly or show dominance and also they are very rare in the study area. Since, we note these species as minorities or odd distributions during the field survey, we dismiss their representation in the sample set. In further studies detection of these rare species should be targeted as they have a potential to contribute to the local livelihoods as non-timber forest products. These shortcomings in the sampling set might be improved with more intensive fieldwork.

5.4.3. Explanatory Features

Although RF is insensitive to high dimensionality, an iterative backward selection is highly recommended (Belgiu and Drăguț, 2016). With the optimization of feature space, the predictors with substantial importance were identified, so we can understand the main drivers of the species distribution and prevent the overfitting problem caused by a limited number of samples in relation to the number of predictor features, as well as prevent multicollinearity.

5.4.3.1. Remote Sensing Features

The important wavelength regions are VIS and SWIR which explains the reaction of plant pigments and water content (Schmidt and Skidmore, 2003; Fassnacht et al., 2016; Manevski et al., 2011). Similar to Pu and Liu (2011) and Waser et al. (2011)'s findings, the blue wavelength region is remarkable to the construction of the model. This might be related to the lower photosynthesis in the blue light. The least important portion of the wavelength is red edge spectrum which is also noted in the study of semi-arid woodlands' tree classification (Peerbhay et al., 2014).

Grignetti et al. (1997) highlighted the autumn and winter periods as the best seasonal descriptors for maquis. On the other hand, Calvão and Palmeirim (2004)

recommended the summer period to better discriminate between sclerophylls and semi-deciduous scrubs. Our results revealed that the annual mean features are more descriptive than specific seasonal descriptors, i.e., Feat 1-7 inferred from time series graphs in our case.

5.4.3.2. Ancillary features

In this study, the use of ancillary features substantially increases model performance. Single use of spectral features is not able to reflect the high environmental heterogeneity of the study area. These findings support Sluiter and De Jong (2005); they also suggested that the spectral confusion in heterogeneous vegetation patterns can be overcome by adding ancillary data. The depth and type of soil bounds the niche for particular maquis species (e.g. Rundel et al., 2016). Another limitation in plant growth is the precipitation (Pausas, 1999). Thus, geology, soil type, annual precipitation (BIO12), the precipitation of coldest quarter (BIO19) and elevation appear as important features in Figure 8 in terms of variable importance.

5.5. Conclusions

As an important ecological formation, maquis provide substantial services such as soil protection, runoff control or the provision of non-timber forest products to Mediterranean communities. Therefore, maquis ecosystems should not be ignored in the context of climate change because the forest trees are highly prone to climate change and interlinked to land degradation and desertification process. Their high biodiversity, various fire and drought prone traits may enhance resilience of Mediterranean region.

In the present study a detailed classification for Mediterranean maquis was developed based on a machine learning approach and freely available multi-temporal Sentinel-2 images that meets the requirements for a future Sustainable Forest management. The classification approach enabled to distinguish between six maquis classes and

produced 78% overall accuracy. An additional output of the approach was the identification of required spectral indices, spectral bands and environmental factors a successful classification for typical Mediterranean maquis region. Our results demonstrate that several prominent maquis species can be successfully discriminated with remote sensing.

Based on the promising results, we anticipate that increasing the number of samples in low represented classes will further improve the accuracy of the classification product. Existing forest inventories, focusing only on the presence of a few woody tree species in Turkey, have to be improved and adapted by better reflecting the diversity of maquis ecosystems,

The increasing availability of remote sensing products and the launch of user-friendly data downloading and processing tools such as the cloud sourcing platforms (Google Earth Engine) will provide a common basis to improve our knowledge on understanding the complex ecosystems and will enable us to test the performance of the model in the wider Mediterranean Basin. Also the ingestion of Sentinel-2 Level 2A images, when available, into GEE may increase accuracy of species classification.

5.6. Linkage the Ecosystem Level Monitoring

This study highlighted the great potential of remote sensing in ecosystem level monitoring. Even in a complex ecosystem this method provides an accurate tool to map the compositional diversity in ecosystem level. This approach is spatially comprehensive and temporally consistent. Thus, it presents an opportunity to set up a systematic long term monitoring program by utilizing Sentinel-2 imagery. The open and freely available image archive increases the cost effectiveness of the monitoring compared to other information resources.

National monitoring programs highly differ in temporal, spatial and taxonomic extents. Developing a national scale ecosystem level monitoring is necessary to link the drivers of ecosystem change with other levels of biodiversity. The benefits of satellite based remote sensing in monitoring and potential to feed EBVs approach) has been

highlighted by several authors (O'Connor et al., 2015; Skidmore et al., 2015; Lausch et al., 2016; Vihervaara et al., 2017). And O'Connor et al. (2015) listed these benefits as follows;

1. Wide swaths of satellites scan large portions of land surface at a glance.
2. These images provide consistent and systematic observations of Earth.
3. More stable and continuous satellite missions enables multi-annual time series information.
4. Remote sensing is the most cost-effective way monitoring remote and inaccessible areas (except extreme Polar Regions).

The promising improvement in automated data acquisition techniques (such as camera traps, soundscape capturing sensors etc.) still come with economic limitations. The most beneficial attribute of remote sensing is its long term accurate and reliable data stream and free of charge structure of some galleries. Thus, establishing a nationwide program relying on remote sensing data would improve the current situation by increasing geographical coverage and providing repeated measurements. To automatize the process we need to generate the nomenclature of habitats and ecosystems, collect validation and calibration ground truth points, set up the model. Once the model would be built, the automation would increase the economic returns of scale by its applicability, feasibility, scalability and continuity (Vihervaara et al., 2017).

CHAPTER 6

CONCLUSION AND FUTURE WORK

Monitoring is essential for halting biodiversity loss, understanding the driving forces of biodiversity decline and extinction, and regulating human activities. We face the consequences of biodiversity loss at unprecedented rates in unexpected ways, and we recognize its importance only when its essential benefits disappear. As climate change and other environmental challenges affect society, awareness of such issues and concerns about the future of our planet increase among many people. During these days, we try to save our health from the COVID19 virus that globally infected over twenty nine million people and caused nine hundred thousand people to die. While I was writing this dissertation, I have listened politicians, journalists, scientists, and ordinary citizens talking about the importance of biodiversity daily on popular media. Biodiversity monitoring is not a fashion or an action for taking an advantage on the policy arena. It is a vital issue that we need to tackle in a smart way.

6.1. Assessment of Monitoring in Turkey

This dissertation has focused on the monitoring of biodiversity in Turkey's terrestrial realms. It is a snapshot in time and space, and surely has room for improvement. Biodiversity monitoring is a vast topic that covers many agents, entities and extents.

I conducted a meta-analysis of the status by generating comprehensive metadata. Despite the abundance of electronic databases (Noah's Ark, e-Bird, GBIF etc.), spatial, temporal and taxonomic extents of data are limited. This study revealed those gaps. Although enormous progress have been achieved in monitoring biodiversity, what to monitor is still a big argument. Most of the time decisions are taken either politically or based on the availability of the human resources. Here I present the gaps

and opportunities derived in this study based on our biodiversity monitoring history in the hope that it will help to guide us in this new era of knowledge.

There has been little biological knowledge to form a baseline data except for birds and some charismatic animals such as the Mediterranean Monk Seal and the Loggerhead Turtle for Turkey. However, with species action plans and biodiversity inventories, Turkey is now approaching a new level of baseline data accumulation. Successful monitoring programs involve multi-step, multi-scale systems, stratified spatially and sequentially. Long term monitoring should be based on inventories and systematically recorded data produced by dedicated teams or agencies in strong cooperation. The constraints on human and financial resources challenge us. We can overcome this problem with a dedicated leadership and by forging well developed partnerships between the government, academia and NGOs.

6.1.1. Design and Implementation

In this new generation of knowledge, it is important to ensure the persistence of “willingness to monitor” / “monitoring dedication” in Turkey. Identifying huge areas for monitoring in 81 province would not make the process easier, considering the limited financial resources. Thus conceptualizing a sustainable scheme is highly important for covering all ecoregions, and all levels of biodiversity (ecosystems, species, genes). To prioritize the monitoring in spatial extent it would be wise to use optimization algorithms that consider constraints such as 1) threats and pressures, 2) financial and human resources, and 3) representative targets. These targets should span various aspects of biodiversity (i.e. different taxonomic groups as well as various EBV classes). Systematic change would be captured only through wise area selection. In cases where such decisions are taken by experts, there will be a certain bias towards some geographical areas or some species groups due to the taxonomic chauvinism.

It is important to limit the aim of the monitoring. Will monitoring particularly focus on one impact (such as climate change, fragmentation, pollution etc.) or a single management action (clear cut logging, plantation, landscape restoration), or is it for

detecting broad scale change in an ecosystem (wetlands, forests etc.)? Below questions are ideal goals for shaping a monitoring scheme: (1) How does biodiversity change? (2) Why is biodiversity changing? (3) What are the consequences for human well-being? (4) Are responses being taken effective? But these questions are not precise enough. An ideal question might rather be “How can we detect a 5% change in population, community, ecosystem with 10% confidence interval in a defined area within defined period?” None of the monitoring programs in Turkey has descriptive monitoring questions in their portfolio. Such thresholds are important to trigger policy making and management into action.

Ecosystem level monitoring should be carried out at the national level. An interval of 5 years would be frequent enough for most ecological processes but separated enough in time to sustain limited resources. The nomenclature of the land cover map should reflect the diversity of ecosystems. Imported ontologies such as CORINE often do not represent this diversity. Moreover the minimum mapping unit size of such large scale products lead to missing rare and unique habitats. The UBENIS project requires production of EUNIS habitat classifications for each province. Since these maps are not accessible yet, it is hard to argue about their sufficiency. It is also important to generate ecosystem level monitoring through remote sensing. In case a successful algorithm has been set up once, the analyses can be repeated even at monthly intervals. In this way an early warning detection system would be established at the national level by incorporating thresholds for ecosystems such as “10 hectares or more of change in a region within a month”. These changes might be natural such as due to forest fires, droughts or they may be man-made. Autonomous detection of change raises our capacity to intervene whenever necessary.

At the ecoregional level, common generalist species should be monitored at 1-3 years intervals. Birds are most suitable for this purpose, thanks to the higher citizen science potential across the country.

Particularly some ecosystems (forests, wetlands, grasslands, etc.) should be monitored within ecoregions with defined targets. The selection should be done wisely by using spatial optimization tools.

Developing common processes and methodologies to monitor the status and trends in ecosystem services is of high interest for many practitioners. However many services cannot be monitored at the moment. Although the society increasingly realizes the importance of ecosystem services day by day, currently many ecosystem services are evaluated via rough models because of our knowledge deficit on ecosystem functions. Long-term monitoring would definitely improve our knowledge on functioning of ecosystems. It is particularly urgent to generate targeted monitoring programs focusing on soil biotic communities and pollinators to better understand pollination ecology and soil conservation. In relevance with ecosystem services, it is important to design long-term monitoring activities in human modified landscapes (urban, rural, agricultural). These landscapes are fragile to extreme events and at the same time host millions of people. It is important to highlight how biodiversity increase or decrease impacts the acquisition of ecosystem services and whether that makes these areas more vulnerable or resilient.

Another highlight is the urgency of monitoring of protected areas. These areas constitute a baseline where human interference is limited and controlled, and could act as reference ecosystems against which utilized ecosystems are compared with. Unfortunately, there is no ongoing monitoring of them at the moment.

6.1.2. Data Management and Storage

This dissertation shows one bad, one good and one ugly thing about biodiversity data across Turkey. The good thing is “there is data”, in various forms and covering a relatively wide range of species groups, geographical regions and levels. The bad thing is “data is highly dispersed through not only temporal, spatial and taxonomic extents but also amongst a multitude of individuals and organizations”. The ugly thing is

“unwillingness to share data”, a behavior or attitude that runs across the whole spectrum of government or academia. I faced many troubles while even compiling metadata. We need to harmonize the existing data and construct a basis for future monitoring. EBVs are located between raw data and indicators. Thus a harmonization policy at this stage would meet the needs of all users.

Two issues arise with the existing data: (1) *digitalization of historical data*: Even though the data was collected by several projects run by several organizations, due to the lack of organizational memory, most data is only in personal archives. Therefore, the available data is more dispersed than it really should have been. (2) *harmonizing existing digital data*: This is mostly at the species level. However, data collection methodologies and type of sampling vary enormously, and no metadata structure exists. It is important to generate metadata tags and use global data formats for data storage.

For future studies, the most important step would be to activate the Noah’s Ark Biological Diversity Database, and to remove data restrictions at least for the data provider community. In case this cannot be achieved, then the biodiversity community should generate a new open source database which meets the FAIR principles (Findable, accessible, interoperable, reusable) and globally accepted data and metadata standards (EML, OGC, etc.) (Hardisty et al., 2019).

Unfortunately the contribution of global databases is yet quite low (i.e. GBIF). Biodiversity is a global common, considering the global catastrophes such as vector based diseases or spread of invasive species require a cross border assessment. Thus, the biodiversity data acquired by monitoring efforts should be shared with the global community.

6.1.3. Analysis and Reporting

Collective and automated data strengthens other automated tools such as models, estimates and future projections. Ecology is a vast discipline and in general modelers build models and taxonomists collect samples, but they rarely work together.

Combining these expertise in a platform with automated tools will increase our understanding of the issues, and will provide improved interpretation and visualization.

The volume of monitoring is meaningless unless the quantification of change is presented in the reports. Reporting frequency should match with the policy plans (development plans, management plans, etc.). Moreover the reports should also integrate a section on corresponding loss or degradation of ecosystem services or SDGs.

6.2. Feasibility Analysis

The condensed framework of EBVs is very useful to harmonize biodiversity data knowledge globally. Monitoring every aspect of biodiversity and covering several taxa is scientifically ideal. But it is highly arguable to reach that utopic wishlist considering the uneven distribution of expertise, financial resources etc. worldwide.

Here, my motive is not to offer a set of EBVs, but rather to present a basin for vision change. Current tendencies are often constricted by customary practices and habits. Monitoring is an inherently expensive and resource demanding activity. By assessing their usefulness (as benefits) and feasibility (as a derivative of cost), future monitoring actions can be wisely selected.

For this reason I also conduct a robust comparison of the feasibility of EBVs by using meta-analysis results (expert numbers, etc.). This assessment is not based on solid cost values but rather an interactive scoring. It is possible that the relative rankings of scores may shift as sampling methods improve, further taxon-specific survey experience is gained (especially for currently disadvantaged taxa), some EBVs become better understood in the future, or the monitoring question (the target species, temporal and spatial extents, etc.) is better described – then this methodology will present more concise results. The irreplaceable set of monitoring should include the most useful and the most feasible EBVs. For the moment, at the national scale, the predominant EBVs are species population (Species Distribution and Population

Abundance), ecosystem structure (Habitat Structure) and ecosystem function (Disturbance Regime).

6.3. Remote Sensing

Ecosystem monitoring requires particular attention as it can reflect both biotic change and human disturbance. Consistent mapping of habitats reveals not only information about ecosystem integrity but also any instantaneous change. Thus future conservation and planning can be developed at the ecosystem level. Open source remote sensing galleries provide a big opportunity due to their broad spatial coverage, adequate spatial (10-30m) and temporal resolution (5-16 days). It is interesting that we do not have a national land cover map yet. Generating semi-automated ecosystem mapping on the basis of remote sensing and machine learning is necessary to reduce site-based effort. Even in a complex ecosystem, I was able to demonstrate the success of vegetation mapping by using open source Sentinel-2 gallery (see Chapter 5). For this task, first we need to identify the vegetations on both compositional and structural bases. Once the nomenclature is determined, then we need to complete ground truth points for training and testing the model. These points can be obtained from ongoing monitoring programs (ICP forests). Also if a data platform can be developed, volunteers and citizen scientists will fill the gaps. Remote sensing is the least expensive monitoring tool once a working model has been set. This shift in emphasis will develop our modelling skills, which will benefit from the technological improvements in drones, and availability of LIDAR and hyperspectral data. Such data sources provide information that any on-site study can generate (such as biomass calculations). Moreover, habitat maps provides necessary information about ecosystem services, SDGs, and natural resource management.

6.4. What I could not do?

As a conclusion remark I would like to discuss what I could not achieve during this study. I believe these limitations are as important as the positive outcomes. First of all, data accessibility has been a major obstacle. Collating data requires a collective spirit as sharing information makes us stronger. However, not only scientists but also governmental organizations keep data to themselves. They tend to use data ownership as a measure of power and this attitude is somehow contiguous over the community. Also as the ministry's work model often involves giving tenders to private companies, this moves the community towards the wrong vision that "Biodiversity data sells". Hopefully the citizen science community is expanding.

Considering the vast biodiversity in Turkey, "What to monitor?" is an important question but more urgently we need to answer "What to monitor, where, in the most cost efficient way?". Some monitoring items would be indispensable, but surely there would be some substitutional and complementary items. Comparing the cost of monitoring alternatives would rise the overall efficiency in the long-run. Conducting such an analysis requires the following data:

- Concrete monitoring question
- Species occurrence records and derived species distribution models
- Cost of monitoring actions per person/per unit time/per effort, consistent budget items
- Agreed list of indicators (target ecosystems/species/genes)
- Allocated budget for monitoring

The cost of monitoring would differ by location due to logistics and availability of expertise and volunteers etc. Thus, performing monitoring in İstanbul and Iğdır would be different in expenses. Therefore, inventory of costs should reflect such variables.

Ecologists hardly understand economists and vice versa. But money is a common value that everyone has the same kind of knowledge about. The marginality topic is a future discussion. How would information increase by performing one more unit of

monitoring? For example adding ecosystem level monitoring to ongoing species programs would bring enormous benefit in an ecological sense. Or conducting a genetic analysis would provide information for climate change resilience studies. In that regard, it is important to provide financial analysis not just by cost perspective but also for benefit perspective. The monitoring activity has many positive externalities.

Overall, one could state that although the necessity of biodiversity monitoring has been understood by most relevant bodies in Turkey, the lingering issues of insufficient data sharing and lack of a prioritization of types of monitoring continue to cause concern in the face of accelerating biodiversity loss. The adoption of EBVs as a framework on which to develop policies and methodologies, as well as the setting up of a dedicated unit for biodiversity monitoring might be valuable steps to remedy those concerns.

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APPENDICES

A. Questionnaire Form

Bu anket çalışması ODTÜ Yer Sistem Bilimleri Anabilim dalında yürütülen “TÜRKİYE’DE BİYOÇEŞİTLİLİK İZLEME ÇALIŞMALARININ TEMEL BİYOÇEŞİTLİLİK DEĞİŞKENLERİ ÇERÇEVESİNDE DEĞERLENDİRİLMESİ” isimli doktora çalışması kapsamında yapılmaktadır. Anket, ulusal çapta yapılan izleme çalışmalarının mevcut durumunu ortaya koymayı ve hangi düzeyde bilgilerin eksik olduğunu tespit etmeyi amaçlamaktadır. Anket çalışması ODTÜ İnsan Araştırmaları Etik Kurulu tarafınca 2018-FEN-023 protokol numarası ile onaylanmıştır. Anketimize katıldığınız için teşekkür ederiz.

Kişisel Bilgiler	
İsim	
Kurum	
Pozisyon	
İzleme çalışmasının adı	

İzleme Çalışması Raporlaması Hakkında Bilgiler (İlgili hücreyi işaretleyiniz) *Bu bölümde birden fazla seçeneği işaretleyebilirsiniz. **Lütfen raporlama yaptığınız kurumun adını belirtiniz.		
Raporlama zorunluluğu bulunmamaktadır.	☐	
Kamu kurumuna raporlanmaktadır.	☐	...
Uluslararası bir kuruma raporlanmaktadır.	☐	...
Diğer	☐	...

İzleme Çalışması Hakkında Bilgiler			
İzleme çalışması daha büyük bir programın parçası mı? (Evet/Hayır- Evet ise belirtiniz)	Evet	☐	...
	Hayır	☐	
İzleme çalışması hangi kurum tarafından yürütülüyor? (İlgili hücreyi işaretleyiniz)	Kamu kurumu	☐	
	Akademi	☐	
	STK (Yerel/Ulusal)	☐	
	STK (Uluslararası)	☐	
	Özel sektör	☐	
	Hükümetler arası kurumlar (FAO/GEF)	☐	
	Diğer (lütfen belirtiniz)	☐	
İzleme çalışması finansal olarak hangi kurum tarafından destekleniyor? (İlgili hücreyi işaretleyiniz)	Kamu kurumu	☐	
	Akademi	☐	
	STK (Yerel/Ulusal)	☐	
	STK (Uluslararası)	☐	
	Özel sektör	☐	
	Hükümetler arası kurumlar (FAO/GEF)	☐	
	Diğer (lütfen belirtiniz)	☐	

İzleme yöntemi hakkında bilgiler			
İzleme kapsamında veya örneklemede kullandığınız yöntem/ yaklaşımları işaretleyiniz. (İlgili hücreyi işaretleyiniz) *Bu bölümde birden fazla seçeneği işaretleyebilirsiniz.			
Uzaktan algılama	☐		
Hava fotoğrafları	☐		
Telemetry	☐		
Akustik yöntemler	☐		
Fotoğraf	☐		
Video	☐		
Arazi gözlemleri	☐		
Diğer	☐	...	
İzleme çalışması kapsamı hakkında bilgiler			

İzleme çalışması tür bulunma/ popülasyon büyüklüğü / tür çeşitliliği parametrelerinin hangilerini kapsıyor lütfen işaretleyiniz. (İlgili hücreyi işaretleyiniz) *Bu bölümde birden fazla seçeneği işaretleyebilirsiniz.		
Tür bulunma	☐	
Popülasyon büyüklüğü	☐	
Tür zenginliği	☐	
Diğer	☐	...
İzleme çalışmasının coğrafi kapsamı hakkında bilgiler (İlgili hücreyi işaretleyiniz).		
< 1km²	☐	
1-10 km²	☐	
10-100 km²	☐	
100-1000 km²	☐	
>1000km²	☐	
İzleme çalışmasının zamansal özellikleri hakkında bilgiler (İlgili hücreyi işaretleyiniz).		
İzleme çalışmasının ilk değerlendirildiği yıl nedir?	...	
İzleme çalışmasının son değerlendirildiği yıl nedir?	...	
İzleme çalışması halen devam ediyor mu?	Evet	☐
	Hayır	☐
	Bilmiyorum	☐
İzleme çalışmasının sıklığı nedir?	Aylık	☐
	Yıllık	☐
	Mevsimsel	☐
	Düzensiz (fırsat oldukça)	☐
	Tek seferlik	☐
	Diğer	☐ ...
İzleme çalışması belirtilen zaman diliminde düzenli olarak yapıldı mı?	Evet	☐
	Hayır	☐
	Bilmiyorum	☐
Belirtilen zaman diliminde çalışmanın atlandığı/yapılamadığı yıl/dönemler oldu mu?	Evet	☐
	Hayır	☐
	Bilmiyorum	☐
İzleme çalışması eforuna ilişkin ilgiler (İlgili hücreyi işaretleyiniz).		
İzleme çalışmasına kaç kişi katıldı?	1 kişi	☐

	2-10 kiři	☐
	>10 kiři	☐
	>100 kiři	☐
	Diđer	☐
İzleme alıřmaları aynı kiřiler tarafından mı gerekleřtirildi?	Evet	☐
	Hayır	☐
İzleme alıřmalarına gnlller dahil edildi mi?	Evet	☐
	Hayır	☐
İzleme alıřmalarına vatandaşlık bilimi kullanıldı mı? (Bu soruyu yanıtlarken vatandaşlık bilimini, bireylerin kendi motivasyon ve inisiyatifleriyle yrtę alıřmalar olarak ele alınız. alıřmanıza dahil olan gnlller sizin onlara sunduęunuz imkanlar dahilinde alıřmaya destek oluyorsa bu blm hayır olarak iřaretleyiniz)	Evet	☐
	Hayır	☐
Gnlllerin izleme alıřması kapsamında bilgilendirme alması saęlandı mı? (alıřmanıza gnll katılımı dahil edildiyse yanıtlayınız)	Evet	☐
	Hayır	☐
Gnlllerin izleme alıřması kapsamında eęitim alması saęlandı mı? (Bilgilendirmeden ziyade sistematik olarak ve daha kapsamlı bir řekilde alıřmanın amacı, yntemi vb konularda eęitimi saęlandıysa eveti iřaretleyiniz)	Evet	☐
	Hayır	☐

İzleme çalışmasının coğrafi dağılımı hakkında bilgiler (İlgili hücreyi işaretleyiniz)		
Tek bir alan	☐	
Birden fazla alan	☐	
Bir coğrafi bölge	☐	
Birden fazla coğrafi bölge	☐	
Çalışmanız hangi coğrafi bölge(ler)de yer alıyor?	Marmara	☐
	Karadeniz	☐
	Ege	☐
	Akdeniz	☐
	İç Anadolu	☐
	Doğu Anadolu	☐
	Güneydoğu Anadolu	☐
Ulusal ölçek	☐	
Diğer	☐	...
Çalışmanız herhangi bir korunan alanı kapsıyor mu?	Milli Park	☐
	Yaban Hayatı Geliştirme Sahası	☐
	Özel Çevre Koruma Bölgesi	☐
	Tabiatı Koruma Alanı	☐
	Diğer (Doğal Sit, Tabiatı Koruma Alanı)	☐
Çalışmanız hangi ekosistem(ler)i kapsıyor?	Orman	☐
	Bozkır	☐
	Sulakalan	☐
	Kıyı	☐
	Deniz	☐
	Dağ/alpin	☐
	Diğer	☐

İzleme çalışması veri deposu /arşivine ilişkin bilgiler (İlgili hücreyi işaretleyiniz (Evet/Hayır- Evet ise belirtiniz)).			
Veri ulusal bir veri merkezinde depolanıyor mu?	Evet	☐	...
	Hayır	☐	
Veri başka bir veri deposunda arşivleniyor mu?	Evet	☐	...
	Hayır	☐	
Veri kalitesi/doğruluğu kontrol ediliyor mu?	Evet	☐	...
	Hayır	☐	
Veri erişiminde kısıtlamalar var mı?	Evet	☐	...
	Hayır	☐	
Veri online paylaşıyor mu?	Evet	☐	...
	Hayır	☐	
Metaveri (veri künyesi) online paylaşıyor mu?	Evet	☐	...
	Hayır	☐	
Veri hangi ortamda saklanıyor?	Online veri tabanı	☐	
	Lokal veri tabanı	☐	
	Excel vb. çalışma dosyaları	☐	
	Rapor dökümanı	☐	
	Veri dijital halde saklanmıyor	☐	

B. List of Literature Survey- Academic Studies

The columns includes abbreviations as follows;

EBV column; Co-ancestry (CA), Allelic diversity (AD), Population genetic differentiation (PGD), Species distribution (SD), Population abundance (PA), Population structure by age/size class (PSA/SCs), Phenology (P), Body mass (BM), Natal dispersal distance (NDD), Migratory behaviour (MB), Demographic traits (DT), Physiological traits (PT), Taxonomic diversity (TD), Species interactions (SI), Net primary productivity (NPP), Secondary productivity (SP), Nutrient retention (NR), Disturbance regime (DR), Habitat structure (HS), Ecosystem extent and fragmentation (EEF), Ecosystem composition by functional type (ECFT)

Species Group column; Also includes Ecosystems (E), Bird (B), Herpetofauna (H), Invertebrate (I), Large Mammal (LM), Plant (P), Small Mammal (SM),

Habitat column: Agriculture (A), Coastal (C), Forest (F), Grassland (G), Multiple (M), Urban (U), Wetland (W)

Geographical Scale column: Local (L), Regional (R), Countrywide (C)

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
Ezer T.	2017	Epiphytic bryophyte communities and succession on <i>Platanus orientalis</i> trees in Kadıncık Valley (Mersin/Turkey)	SI	P	F	L
Ertürk A.	2017	Anadolu Canis lupus L. 1758 (kurt) türünün alansal ekolojisi ve populasyon yapısının araştırılması	PGD, SD	LM	M	C
Eşe S.	2017	Güney Ege bölgesinde gübrede bulunan Histeridae (Coleoptera) türlerinin fenolojisi ve vertikal dağılışı üzerine araştırmalar	SD, P	I	M	R
Oğul N. F.	2017	Genetic structure and hatchling behavior of sea turtle populations in the Eastern Mediterranean	PGD	H	C	R
Yelmen B.	2017	The effects of sex ratio in estimation of genetic differentiation in <i>Populus nigra</i> populations	AD	P	M	R
Tokdemir Y.	2017	Determination of genetic diversity in <i>Salix caprea</i> populations from the Coruh river watershed	PGD	P	M	R

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
Erşahin S. et.al.	2016	NPP of anatolian Fs in relation to climate, 2000-2010	NPP	E	F	C
Koleček J., et.al.	2016	Cross-continental migratory connectivity and spatiotemporal migratory patterns in the great reed warbler	MB	B	W	C
Çolak R., et.al.	2016	Genetic variations of Turkish bank vole, <i>Myodes glareolus</i> (Mammalia: Rodentia) inferred from mtDNA	PGD, AD	SM	F	R
Donmez C., et.al.	2016	Spatiotemporal modeling of NPP of eastern mediterranean biomes under different regional climate change scenarios	NPP	E	M	R
Sobierajska K., et.al.	2016	Effect of the Aegean Sea barrier between Europe and Asia on differentiation in <i>Juniperus drupacea</i> (Cupressaceae)	PGD	P	F	R
Alphan H. and Çelik N.	2016	Monitoring changes in landscape pattern: use of Ikonos and Quickbird images	EEF	E	M	L
Fırat S. and Sert O.,	2016	Faunistic and zoogeographical composition and preliminary evaluations of some ecological features of the subfamily staphylininae (Coleoptera: Staphylinidae) of the central anatolian region of turkey	TD	I	G	R
Baykal H. And Atamov V.,	2016	Floristic diversity in Başhemşin valley of Kaçkar Mountains National Park of Rize, Turkey	TD	P	F	R
Karakaş R.,	2016	Status and distribution of red-wattled lapwing <i>Vanellus indicus</i> (Boddaert, 1783) (Charadriiformes: Charadriidae) in Turkey	SD	B	W	R
Arslan Şahin N., et.al.	2016	Breeding biology of the red-backed shrike, <i>Lanius collurio</i> , in the Kizilirmak Delta in the north of Turkey	DT	B	W	L
Horns J.J., et.al.	2016	Geolocator tracking of Great Reed-Warblers (<i>Acrocephalus arundinaceus</i>) identifies key regions for migratory WL specialists in the Middle East and sub-Saharan East Africa	MB	B	W	R
Öztürk Y. and Tabur M.A.,	2016	Nesting habitat preferences and reproductive performance of griffon vultures <i>Gyps fulvus</i> (Hablizl, 1783) in Afyonkarahisar, Antalya and Isparta (Turkey)	DT	B	G	L
Ambarlı D., et.al.	2016	An overview of biodiversity and conservation status of steppes of the Anatolian Biogeographical Region	HS, SD	5G	G	C

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
Kaya Özdemirel B., et.al.	2016	Impact of large scale dam construction on movement corridors of mammals in Artvin, north- eastern Turkey	EEF, SD	LM	M	R
Çilingir F.G., et.al.	2016	Exceptional maternal lineage diversity in brown bears (<i>Ursus arctos</i>) from Turkey	PGD	LM	F	C
Yiğit N., et.al.	2016	Genetic differentiation of the <i>Meriones tristrami</i> (Mammalia: Rodentia) subpopulations in Turkey - Inferring allozyme variations	PGD, AD	SM	G	C
Demirbaş Y., et.al.	2016	Mitochondrial DNA control region variability of wild boar <i>sus scrofa</i> with various external phenotypes in Turkey	PGD	LM	F	C
Şabanoglu, B. and Şen İ.	2016	A study on determination of <i>Cerambycidae</i> (Coleoptera) fauna of Isparta Province (Turkey)	TD	I	F	R
Bayrakçı Y., et.al.	2016	Abundance of western caspian turtle, <i>mauremys rivulata</i> (Valenciennes, 1833) in gökçeada (Imbros), Turkey	PA	H	W	L
Çapar D. And Başkale E.	2016	Population size of endemic <i>Rana tavasensis</i> in its terra typica, Turkey	PA, DT	H	W	L
Altay V., et.al.	2016	Molecular and ecological investigations on the wild populations of <i>Glycyrrhiza L.</i> taxa distributed in the East Mediterranean Area of Turkey	AD	P	M	L
Werner Y.L. et.al.	2016	Bergmann's and Rensch's rules and the spur-thighed tortoise (<i>Testudo graeca</i>)	DT	H	M	L
Ambarlı H.	2016	Litter size and basic diet of brown bears (<i>Ursus arctos</i> , Carnivora) in northeastern Turkey	DT	LM	F	L
Geven F., et.al.	2016	Habitat classification and evaluation of the Köyceğiz-Dalyan Special Protected Area (Muğla/Turkey)	EEF	E	M	L
Azizoglu U., et.al.	2016	Phylogenetic relationships of insect-associated free-living rhabditid nematodes from eastern mediterranean region of Turkey	PGD	I	M	R
Veith M., et.al.	2016	Seven at one blow: The origin of major lineages of the viviparous Lycian salamanders (<i>Lyciasalamandra</i> Veith and Steinfartz, 2004) was triggered by a single paleo-historic event	PGD	H	F	R
Wilkins M.R., et.al.	2016	Phenotypic differentiation is associated with divergent sexual selection among closely related barn swallow populations	PGD, MB	B	M	L
Kuyucu A.C., and Çağlar S.S.	2016	Thermal Preference of the Bush Cricket <i>Isophya rizeensis</i> ; Testing the Effect of Countergradient Selection	PT	I	F	L
Ambarlı H., et.al.	2016	Current status, distribution, and conservation of brown bear (<i>Ursidae</i>)	SD	LM	M	C

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
		and wild canids (gray wolf, golden jackal, and red fox; canidae) in Turkey				
Yavasoglu S.I., et.al.	2016	Distribution pattern and genetic structure of <i>Aedes zammitii</i> (Diptera: Culicidae) along the Mediterranean and Aegean coasts of Turkey	SD, AD	I	C	R
Fidan E.C. and Sirin U.	2016	The changes related with altitudinal gradient and seasonal variation in the species composition of Carabidae (Coleoptera) in Türkmen mountain (Eskisehir, Turkey)	TD	I	F	L
Yaman İ.	2016	Kovada Gölü Milli Parkı (Isparta)'ndaki yer böcekleri (Coleoptera:Carabidae)'nin farklı habitatlara bağlı tür çeşitliliği	TD	I	F	L
Bulut Ş.	2016	Farklı habitat tiplerinde küçük memelilerin biyo-ekolojilerinin incelenmesi	PA, TD	SM	M	L
Kankiliç T., et.al.	2015	Allozyme variations in Anatolian populations and cytotypes of the blind mole rats (<i>Nannospalax</i>)	AD	SM	M	R
Abay G., et.al.	2015	Spatial variation, mapping, and classification of moss families in semi-arid landscapes in NW Turkey	HS	E	M	L
Elmas E. and Kutbay H.G.	2015	Plant functional types in Mediterranean enclaves in Western Black Sea Region of Turkey	PT	P	F	R
Altunışık A. And Özdemir N.,	2015	Life history traits in <i>Bufo variabilis</i> (Pallas, 1769) from 2 different altitudes in Turkey	DT	H	M	L
Göçmen B., et.al.	2015	Population size estimates of <i>Lissotriton vulgaris</i> (L., 1758) and <i>Triturus ivanbureschi</i> Arntzen & Wielstra 2013 (Caudata: Salamandridae) from Edirne, European part of Turkey	PA	H	W	L
Bergner A., et.al.	2015	Influences of F type and habitat structure on bird assemblages of oak (<i>Quercus</i> spp.) and pine (<i>Pinus</i> spp.) stands in southwestern Turkey	SI	B	F	L
Balkız O., et.al.	2015	Turkey as a crossroad for Greater Flamingos <i>Phoenicopterus roseus</i> : Evidence from population trends and ring-resightings (Aves: Phoenicopteridae)	PA	B	W	R
Erciyas-Yavuz K., et.al.	2015	Spring and autumn migration of the red-breasted flycatcher through the kizilirmak delta, Turkey	MB	B	W	R
Erdoğan N., et.al.	2015	Land use/land cover change detection for environmental monitoring in Turkey. A case study in Karaburun Peninsula	HS	E	M	R

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
Azgin S.T. and Dadaser-Celik F.,	2015	Spatial and temporal changes at Tuzla (Palas) Lake in Turkey	HS	E	W	L
Şen G., et.al.	2015	Spatiotemporal changes of land use patterns in high mountain areas of Northeast Turkey: a case study in Maçka	HS	E	F	L
Bozali N., et.al.	2015	Use of spatial pattern analysis to assess F cover changes in the Mediterranean region of Turkey	HS	E	F	R
Arslan A. and Zima J.,	2015	Chromosome banding pattern retrieves an independent origin of 2n = 50 chromosome populations of <i>Nannospalax xanthodon</i> from Turkey	PGD	SM	G	L
Olgun Karacan G. Et.al.	2015	Determination of genetic variations between <i>Apodemus mystacinus</i> populations distributed in Turkey inferred from mtDNA PCR-RFLP	PGD, AD	SM	F	C
Mutun S. and Karagözoglu H.,	2015	Investigation of genetic variation among Turkish populations of <i>Andricus lignicola</i> using mitochondrial cytochrome b gene sequence data	PGD, AD	I	F	C
Gümüş Özcan Ç. And Üzümlü N.,	2015	Body size and age in three populations of the northern banded newt <i>ommatotriton ophryticus</i> (Berthold, 1846) from Turkey	PSA/SCs	H	W	L
Perktaş U., et.al.	2015	Climate-driven range shifts and demographic events over the history of Kruper's Nuthatch <i>Sitta krueperi</i>	SD	B	F	C
Oskay D. and Altan Y.	2015	An investigation on habitat and population properties of local endemic <i>Erodium somanum</i>	PA, PSA/SCs	P	G	L
Aslan M.	2015	Succession of steppe areas after fire in the gap region of Turkey	DR	E	G	L
Gülci S. and Akay A.E.	2015	Assessment of ecological passages along road networks within the Mediterranean F using GIS-based multi criteria evaluation approach	EEF	E	F	R
Perktaş U. Et.al.	2015	Historical demography of the eurasian green woodpecker: Integrating phylogeography and ecological niche modelling to test glacial refugia hypothesis	PGD	B	F	R
Kart Gür M. and Gür H.	2015	Age and sex differences in hibernation patterns in free-living Anatolian ground squirrels	PT	SM	G	L
Itci N. Et.al.	2015	Range extension of four species of snakes (<i>Ophidia: Eirenis, Pseudocyclophis, Platycephalus</i>) in eastern Anatolia	SD	H	M	R

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
Chynoweth M.W., et.al.	2015	Conservation of a new breeding population of Caucasian lynx (<i>Lynx lynx dinniki</i>) in eastern Turkey	SD	LM	F	L
Türe C. And Ocak A.	2015	Habitats and distribution of fern species in Bilecik, Turkey	SD	P	M	L
Wielstra B., et.al.	2015	The distribution and taxonomy of <i>Lissotriton</i> newts in Turkey (Amphibia, Salamandridae)	SD, PGD	H	W	R
Aydemir M.	2015	Phylogenetic analysis of <i>Colchicum</i> L. species with chloroplast genome-specific markers	PGD	P	G	C
Bozkurt M.	2015	<i>Psephellus aucherianus</i> (DC.) boiss. (asteraceae) kompleksine ait tür popülasyonlarında genetik çeşitliliğin belirlenmesi	PGD	P	F	R
Karaköse M.	2015	Yaralıgöz Eğitim ve Gözlem Ormanı (Kastamonu) ile Finike Merkez Orman Planlama Birimi'nin (Antalya) florası, vejetasyonu ve habitat tiplerinin sınıflandırılması	EEF, TD	E	F	L
Pekşen Akın Ç.	2015	Molecular evolution and phylogeography of the Eastern Mediterranean water frog (<i>Pelophylax</i>) complex	AD, PGD	H	W	C
Osmanoğlu T.	2015	Isparta-Gölcük Tabiat Parkı ormanında meşcere yapısı ile kuş türü zenginliği arasındaki ilişkiler	TD, HS	B	F	L
Kocamanoğlu E. B.	2015	Çoruh havzasının bazı mikro havzalarında biyoçeşitlilik indisleri ve bunların üstüne etki eden faktörler	TD	P	M	R
Kurt P.	2015	Erzincan ilinde endemik olarak yetişen ve yok olma tehlikesinde olan <i>Sonchus erzincanicus</i> türünün popülasyon genetiğinin moleküler yöntemlerle araştırılması ve koruma stratejilerinin geliştirilmesi	PGD	P	G	R
Laz B.	2015	Kahramanmaraş ili Andırın ilçesinde 3 farklı orman tipinde bazı Coleoptera familyalarının çeşitliliği üzerine incelemeler	TD	I	F	R
Çetintürk D.	2015	Trakya ve Batı Anadolu'da yayılış gösteren <i>Microtus lydius</i> (2n=54) ve <i>Microtus hartingi</i> (2n=54) türlerinin filogenetik ilişkilerinin ortaya konulması	PGD	SM	G	R
Karasu N.	2015	Farklı alanlarda yaşayan <i>Eustigmaeus erciyesiensis</i> (Acari: Stigmaeidae) popülasyonlarındaki genetik polimorfizmlerin RAPD-PCR yöntemi ile belirlenmesi	AD	I	W	L
Karakaş Metin Ö., et.al.	2014	Use of fluorescent-based amplified fragment length polymorphism to	PGD	P	G	C

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
		resolve phylogenetic relationships of <i>Colchicum</i> species from Turkey				
Altunişik A., et.al.	2014	A skeletochronological study of the smooth newt <i>Lissotriton vulgaris</i> (Amphibia: Urodela) from an island and a mainland population in Turkey	DT	H	W	L
Kılıç Ç. and Candan O.,	2014	Hatchling sex ratio, body weight and nest parameters for <i>Chelonia mydas</i> nesting on sugözü beaches (Turkey)	PSA/SCs	H	C	L
İbiş O., et.al.	2014	Phylogenetic status of the turkish red fox (<i>Vulpes vulpes</i>), based on partial sequences of the mitochondrial cytochrome b gene	AD, PGD	LM	M	C
Üzüm N., et.al.	2014	The body size, age structure, and growth of Bosc's fringe-toed lizard, <i>Acanthodactylus boskianus</i> (Daudin, 1802)	PSA/SCs	H	G	L
Kint V., et.al.	2014	Ecological traits of Mediterranean tree species as a basis for modelling F dynamics in the Taurus mountains, Turkey	PT	P	F	R
Filiz E., et.al.	2014	Assessment of genetic diversity and phylogenetic relationships of endangered endemic plant <i>Barbarea integrifolia</i> DC. (Brassicaceae) in Turkey	CA	P	W	R
Bolat I.,	2014	The effect of thinning on microbial biomass C, N and basal respiration in black pine F soils in Mudurnu, Turkey	NPP, NR	E	F	L
Kadioğulları A.I., et.al.	2014	Analysing land cover changes for understanding of F dynamics using temporal F management plans	HS	E	F	L
Ambarlı D. And Bilgin C.C.,	2014	Effects of landscape, land use and vegetation on bird community composition and diversity in Inner Anatolian steppes	HS	B	G	R
Gökyer E.,	2014	Evaluating landscape changes and environmental threats in a Co landscape case study of Bartın Co area, Turkey	HS	E	C	L
Esetlili M.T., et.al.	2014	Relationship between highway constructions and natural habitat. a case study of izmir highway	EEF	E	M	L
Özdemir N., et.al.	2014	Molecular systematics and phylogeography of <i>Bufotes variabilis</i> (syn. <i>Pseudepidalea variabilis</i>) (Pallas, 1769) in Turkey	PGD	H	M	C
Avgan B., et.al.	2014	The first density estimation of an isolated Eurasian lynx population in southwest Asia	PA	LM	F	L
Uzun A. and Helli S.	2014	The activities of the little Egret (<i>Egretta garzetta</i>) and night Heron	PA	B	W	L

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
		(<i>Nycticorax nycticorax</i>) in their colonies during the breeding season				
Sağlam I.K., et.al.	2014	Diversification of montane species via elevation shifts: The case of the Kaçkar cricket <i>Phonochorion</i> (Orthoptera)	AD	I	M	R
Markov G. et.al..	2014	Intraspecific epigenetic polymorphism of the East European vole (<i>Microtus levis</i> Miller, 1908) in South-eastern Europe and Turkey	AD	SM	M	R
Akyildirim H., et.al.	2014	Determined aphid and ant associations from trabzon, rize and artvin provinces of the Turkey	SI	I	M	R
Eser O. and Erismis U.C.	2014	Research on the HF of baskomutan historical national park, Afyonkarahisar, Turkey	TD	H	M	L
Subaşı Ü.	2014	<i>Campanula tomentosa</i> lam. ve <i>C. vardariana</i> bocquet'nın koruma biyolojisi ve genetik çeşitliliği	PGD	P	G	R
Kırtıloğlu E.	2014	Hotamış gölü çevresinin arazi kullanımının uydu görüntüleri yardımıyla zamansal analizi	EEF	E	W	L
Öksüz P. D.	2014	<i>Poecilimon similis</i> (Orthoptera: Tettigoniidae)'in Doğu Karadeniz popülasyonları arasındaki genetik çeşitlilik-coğrafi dağılım ilişkisinin merkez-perifer hipotezi çerçevesinde sınanması	PGD	I	M	R
Demirci S., et.al.	2013	Mitochondrial DNA diversity of modern, ancient and wild sheep (<i>Ovis gmelinii anatolica</i>) from Turkey: New insights on the evolutionary history of sheep	AD	LM	G	C
Çoraman E., et.al.	2013	Phylogeographic analysis of Anatolian bats highlights the importance of the region for preserving the Chiropteran mitochondrial genetic diversity in the Western Palaearctic	AD	SM	M	R
Kabalak M. and Sert O.	2013	Faunistic composition, ecological properties, and zoogeographical composition of the Elateridae (Coleoptera) family in the Western Black Sea region of Turkey	SI	I	F	R
Gül S.,	2013	Ecological divergence between two evolutionary lineages of <i>Hyla savignyi</i> (Audouin, 1827) in Turkey: Effects of the anatolian diagonal	SD	H	M	R
Saygılı F. and Yiğit N.,	2013	<i>Passer hispaniolensis</i> subpopulations in Turkey: Allozyme variations and brief ecobiological notes	AD	B	M	R
Kirazlı C. and Yamaç E.,	2013	Population size and breeding success of the cinereous vulture, <i>Aegypius monachus</i> , in a newly found breeding	PA, DT	B	F	L

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
		area in western Anatolia (Aves: Falconiformes)				
Kıvanç E., et.al.	2013	Reproductive biology of <i>Acomys cilicicus</i> Spitzenberger, 1978 (Rodentia: Muridae) in Turkey	DT	SM	F	R
Kadioğulları A.I.,	2013	Assessing implications of land use and land cover changes in F Es of NE Turkey	HS	E	F	R
Alphan H.,	2013	Bi-temporal analysis of landscape changes in the easternmost mediterranean deltas using binary and classified change information	HS	E	C	R
Yavuz G., et.al.	2013	Investigations on the ecology of eurasian water vole, <i>Arvicola amphibius</i> (rodentia: Mammalia) in ankara province	PA, BM	SM	M	L
Saygılı F., et.al.	2013	Morphometric and allozymic differences between Bearded Tit <i>Panurus biarmicus</i> (Aves: Passeriformes) subpopulations in a large WL and a small pond in central Anatolia, Turkey	AD	B	W	L
Yücedağ C., and Gailing O.,	2013	Morphological and genetic variation within and among four <i>Quercus petraea</i> and <i>Q. robur</i> natural populations	AD	P	F	C
Kankiliç T., et.al.	2013	Genetic diversity and geographic variation of chromosomal races of <i>Nannospalax xanthodon</i> (Nordmann, 1840) and <i>Nannospalax ehrenbergi</i> (Nehring, 1898) from Turkey, revealed by RAPD analysis	AD, PGD	SM	M	C
Yücedağ C. and Gailing O.	2013	Genetic variation and differentiation in <i>Juniperus excelsa</i> M. Bieb. populations in Turkey	PGD	P	F	C
Kapli P., et.al.	2013	Molecular phylogeny and historical biogeography of the Anatolian lizard <i>Apathya</i> (Squamata, Lacertidae)	PGD	H	G	C
Furman A., et.al.	2013	Phylogeography of the large <i>Myotis</i> bats (Chiroptera: Vespertilionidae) in Europe, Asia Minor, and Transcaucasia	PGD	SM	M	R
Ülgentürk S., et.al.	2013	Predators of <i>Marchalina hellenica</i> (Hemiptera: Marchalinidae) on pine Fs in Turkey	TD	I	F	R
Türk S.	2013	Mesudiye (Ordu) ve çevresindeki bazı vejetasyon tiplerinin biyoçeşitliliğinin araştırılması	TD	P	M	R
Çağatay E.	2013	Türkiye'nin yabani zeytin (<i>Olea europaea</i> subsp. <i>europaea</i> var. <i>sylvestris</i>) populasyonlarındaki genetik çeşitliliğin ITS-1 belirteçleri yardımıyla belirlenmesi ve yaygın	AD	P	F	C

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
		olarak kullanılan kültür zeytini (<i>O. europaea</i> subsp. <i>europaea</i> var. <i>europaea</i>) çeşitlerinin bu belirteçlerle karakterizasyonu				
Küçükkaykıcı C. E.	2013	Türkmen dağları (Eskişehir- Kütahya) yer böcekleri (Coleoptera: Carabidae)'nin fenolojileri ve vertikal tür çeşitliliğinin araştırılması	TD	I	M	L
YILDIZ D.	2013	Kahramanmaraş-Dereköy yöresindeki bir dağ çağlası (<i>Amygdalus arabica</i> Oliv.) popülasyonunda fenolojik gözlemler	P	P	F	L
Kesikoğlu H. M.	2013	Sultan Sazlığı Milli Parkı ve Ramsar alanı kıyı değişiminin uydu görüntü analizleriyle incelenmesi	EEF	E	W	L
Mert A.	2013	Ormanın yapısal çeşitliliğinin uydu verileri kullanılarak kestirimi	HS	E	F	L
Karakaş R.,	2012	Does Black-winged kite <i>Elanus caeruleus</i> (Desfontaines, 1789) have an expansion in its range in Turkey?	SD	B	G	R
Onmuş O., et.al.	2012	Environmental factors affecting nest-site selection and breeding success of the white stork (<i>Ciconia ciconia</i>) in Western Turkey	PSA/SCs, PA	B	M	R
Albayrak T., et.al.	2012	Phylogeography and population structure of Krüper's Nuthatch <i>Sitta krueperi</i> from Turkey based on microsatellites and mitochondrial DNA	AD, PGD	B	F	C
Atay E et.al.	2012	Saproxylous beetles on old hollow oaks (<i>Quercus</i> spp.) in a small isolated area in southern Turkey: (Insecta: Coleoptera)	TD	I	F	L
Özdemir N., et.al.	2012	Variation in body size and age structure among three Turkish populations of the treefrog <i>Hyla arborea</i>	PSA/SCs	H	F	L
Demirci B., et.al.	2012	Altitudinal genetic and morphometric variation among populations of <i>Culex theileri</i> Theobald (Diptera: Culicidae) from northeastern Turkey	AD	I	M	R
Moreira B., et.al.	2012	Local versus regional intraspecific variability in regeneration traits	DT	P	F	R
Yavuz K.E et.al.	2012	Nesting habits and breeding success of the white stork, <i>Ciconia ciconia</i> , in the Kızılırmak delta, Turkey: (Aves: Ciconiidae)	DT	B	M	L
Kabasakal B. And Albayrak T.,	2012	Offspring sex ratios and breeding success of a population of the great tit, <i>Parus major</i> : (Aves: Passeriformes)	DT	B	M	L
Yamaç E. And Bilgin C.C.,	2012	Post-fledging movements of cinereous vultures <i>Aegypius monachus</i> in Turkey revealed by GPS telemetry	MB	B	F	R

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
Kebapçı U., et.al.	2012	The land snail fauna of Mut district (Mersin province, Turkey)	TD	I	M	L
Biricik M., and Karakas R.,	2012	Birds of Hasankeyf (South-Eastern Anatolia, Turkey) under the threat of a big dam project	TD	B	M	L
Sevgili E., and Simsek F.M.,	2012	Distribution pattern and molecular identification of Anopheles maculipennis complex in eight river basins of Anatolia, Turkey	PGD, SD	I	W	C
Özdil F., et.al.	2012	Genetic variation in turkish honeybees Apis mellifera anatoliaca, A. m. caucasica, A. m. meda (Hymenoptera: Apidae) inferred from RFLP analysis of three mtDNA regions (16S rDNA-COI-ND5)	PGD	I	M	C
Başkale E. And Kaya U.,	2012	Decline of the levantine frog, pelophylax bedriagae camerano, 1882, in the western aegean region of turkey changes in population size and implications for conservation: (Amphibia: Ranidae)	PA	H	W	R
Helvacı Z., et.al.	2012	Morphometric and genetic structure of the edible dormouse (Glis glis): A consequence of F fragmentation in Turkey	PGD	SM	F	C
Özkan L., et.al.	2012	Breeding biology of spur-winged lapwing (Vanellus spinosus l.) at boğazkent, Antalya/ Turkey 2009-2011	PA, DT	B	W	L
Çiçek K., et.al.	2012	Preliminary data on the age structure of Phrynocephalus horvathi in Mount Ararat (Northeastern Anatolia, Turkey)	DT	H	G	L
Oran S and Öztürk Scedil,.	2012	Epiphytic lichen diversity on Quercus cerris and Q. frainetto in the Marmara region (Turkey)	TD	P	F	R
Akbaba B. and Ayaş Z.	2012	Camera trap study on inventory and daily activity patterns of LMs in a mixed F in north-western Turkey	TD	LSM	F	L
Görmüş S.	2012	Korunan alanlarda peyzaj karakter analizi: Kastamonu-Bartın Küre dağları Milli Parkı örneği	EEF	E	F	L
Yılmaz C.	2012	Türkiye kumsallarındaki Caretta caretta populasyonlarının genetik yapısı	PGD	H	C	C
Elverici M.	2012	The spider fauna of an olive grove and associated shrublands in Muğla, Milas, Kızılkışlacık with notes on their diversity and composition	TD	I	A	L
Vardareli N.	2012	Datça hurması (Phoenix theophrasti) populasyonlarındaki genetik çeşitliliğin SSR belirteçleriyle	AD, PGD	P	C	R

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
		saptanması ve türün diğer palmye türleri ile ilişkisinin ortaya konulması				
Demirtaş S.	2012	Türkiye Erinaceus (Erinaceomorpha: Mammalia) cinsinin moleküler filocoğrafyası	PGD	SM	M	C
Görgülü E.	2012	İç Anadolu Bölgesinde yetişen Isatis glauca'nın genetik çeşitliliğinin moleküler işaretleyicilerle karakterizasyonu	PGD	P	G	R
Yalçın S.	2012	Modeling the current and future ranges of Turkish pine (Pinus brutia) and oriental beech (Fagus orientalis) in Turkey in the face of climate change	SD	P	F	R
Kabalak M. And Sert O.	2011	Faunistic composition, ecological properties and zoogeographical composition of the family Elateridae (Coleoptera) of the Central Anatolian Region of Turkey	SI	I	F	R
Akay A.E. et.al.	2011	Monitoring the local distribution of striped hyenas (Hyaena hyaena L.) in the Eastern Mediterranean Region of Turkey (Hatay) by using GIS and remote sensing technologies	SD	LM	M	L
Biricik M. And Karakaş R.,	2011	On the occurrence of white-headed duck Oxyura leucocephala (SCOPOLI, 1769) in South-eastern Anatolia, Turkey	SD	B	W	L
Çiçek K., et.al.	2011	Population dynamics of rana macrocnemis boulenger, 1885 at uludağ, western turkey: (Anura: Ranidae)	PSA/SCs	H	G	L
Onmuş O. And Siki M.,	2011	Shorebirds in the Gediz Delta (İzmir, Turkey): Breeding and wintering abundances, distributions, and seasonal occurrences	SD, PA	B	W	L
Onmuş O et.al.	2011	Status and development of the population of the globally threatened dalmatian pelican, Pelecanus crispus, in turkey: (Aves: Pelecanidae)	SD	B	W	C
Saygılı F. Et.al.	2011	The spatial and temporal distributions of waterbirds in Lakes Akşehir-Eber and Lake Köyceğiz in western Anatolia, Turkey - A comparative analysis	SD	B	W	L
Nergiz H. Et.al.	2011	Nest site selection and reproductive success of white-headed duck (Oxyura leucocephala Scopoli, 1769) in the Van Lake Basin (Turkey)	DT	B	W	L
Anlaş S. et.al.	2011	Notes on the seasonal dynamics of some coprophagous Scarabaeoidea (Coleoptera) species in Manisa province, western Anatolia	P	I	M	L

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
Arslangündoğ du Z. and Yilmaz E.,	2011	The effects of tree stand layers on resident bird species in Belgrade F, Istanbul, Turkey	TD	B	F	L
Tecimen H.B. and Kavgaci A.,	2011	Evaluation of net nitrogen mineralization rates at Pinus brutia ten. Fs and maquis shrublands in Southern Turkey	NR	E	F	R
Dönmez C., et.al.	2011	Modelling the current and future spatial distribution of NPP in a Mediterranean watershed	NPP	E	F	R
Özyavuz M., Ş	2011	A change vector analysis technique to monitor land-use/land-cover in the yıldiz mountains, Turkey	HS	E	M	R
Subaşı U. And Güvensen A.,	2011	Breeding systems and reproductive success on Salvia smyrnaea	DT	P	G	L
Mutun S.,	2011	Intraspecific genetic diversity of the oak gall wasp Andricus lucidus (Hymenoptera: Cynipidae) populations in Anatolia	PGD, AD	I	F	C
Kornilios P., et.al.	2011	The role of Anatolian refugia in HFI diversity: An mtDNA analysis of Typhlops vermicularis Merrem, 1820 (Squamata, Typhlopidae)	PGD	H	G	R
Albayrak T., et.al.	2011	A model of habitat suitability for Krueper's Nuthatch Sitta krueperi	SD	B	F	C
Karakaş R.,	2011	Contribution on the status and distribution of shrike species in South-eastern Anatolia, Turkey	SD	B	G	R
Furman A., et.al.	2011	Morphometric variation and genetic diversity of the lesser and greater mouse-eared bats (Chiroptera: Vespertilionidae) in Thrace and Anatolia	PGD	SM	M	C
Kurt Y. Et.al.	2011	Genetic comparison of pinus brutia ten. populations from different elevations by RAPD markers	AD	P	F	R
Perktaş U.	2011	Ecogeographical variation of body size in Chaffinches Fringilla coelebs	BM	B	F	R
Başkale E., et.al.	2011	Reproductive ecology and body size-fecundity relationships of the green toad, pseudopoda viridis (laurenti, 1768), in the kocaçay stream, İzmir, turkey: (Amphibia: Anura)	BM	H	W	L
Türkmen N. And Düzenli A.	2011	Early post-fire changes in Pinus brutia Fs (Amanos Mountains, Turkey)	DR	E	F	L
Ozkan K. And Mert A.	2011	Ecological land classification and mapping of Yazili Canyon Nature Park in the Mediterranean region, Turkey	HS	E	F	L
Kavgaci A. et.al.	2011	Diversity of floodplain Fs in the Igneada region (NW Thrace - Turkey)	HS	E	F	L

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
Ünal S., et.al.	2011	Interpretations of vegetation changes of some villages rangelands in Çankiri province of Turkey	TD	P	G	L
Taşdemir A., et.al.	2011	Contribution to the knowledge on the distribution of Chironomidae and Chaoboridae (Diptera: Insecta) species of lakes on Taurus Mountain Range (Turkey)	TD	I	W	L
Yavuz Erciyas K.	2011	Karadeniz üzerinden nokturnal göç eden Passeriformes (Aves) türlerinin sonbahardaki göç stratejileri	MB	B	W	L
Çağlayan Demirbaş S.	2011	Karayollarından kaynaklanan peyzaj parçalanmasının korunan alanlar ve önemli doğa alanları üzerine etkilerinin irdelenmesi	EEF	E	M	C
Angın S.	2011	Trakya ve Karadeniz bölgesinde yayılış gösteren Mus (Linnaeus, 1758) (Mammalia: Rodentia) cinsinin RAPD-PCR analizi	PGD	SM	M	R
Alpagut-Keskin N., et.al.	2010	Genetic differentiation among peripheral populations of bombina bombina from Thrace and Anatolia: An allozyme analysis	PGD, AD	H	G	R
İlemin Y. And Gürkan B.,	2010	Status and activity patterns of the caracal, Caracal caracal (schreber, 1776), in datça and bozburun peninsulas, southwestern turkey: (Mammalia: Felidae)	SD	LM	F	L
Avgın S.S. and Emre I.,	2010	Studies on the ground beetles (Coleoptera: Carabidae) of the saghk plain - Gavur Lake Marsh area, kahramanmaraş, Turkey	TD	I	W	L
Durmuş A. And Adizel O.,	2010	Breeding ecology of night heron (Nycticorax nycticorax Linne,1758) in the lake Van Basin, Turkey	DT	B	W	L
Furman A., et.al.	2010	Cryptic diversity of the bent-wing bat, Miniopterus schreibersii (Chiroptera: Vespertilionidae), in Asia Minor	PGD	SM	M	R
Sözen E. And Ozaydin B.,	2010	A study of genetic variation in endemic plant Centaurea wiedemanniana by using RAPD markers	AD	P	G	L
Öztürk S. and Güvenç S.,	2010	The distribution of epiphytic lichens on Uludag fir (Abies nordmanniana (Steven) Spach subsp. bornmuelleriana (Mattf.) Coode & Cullen) Fs along an altitudinal gradient (Mt. Uludag, Bursa, Turkey)	SI	P	F	L
Kavgacı A., et.al.	2010	Long-term post-fire succession of Pinus brutia F in the east Mediterranean	DR	E	F	R
Fırıncioğlu H.K., et.al.	2010	Assessment of grazing effect on two sub-shrubs (astragalus schottianus and	DR	P	G	L

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
		thymus sipyleus) dominated mountain bozoğlan GLs in the semi-arid central-southern anatolian region of turkey				
Korkmaz E.M., et.al.	2010	Genetic structure of Chorthippus parallelus (Orthoptera: Acrididae: Gomphocerinae) populations in Anatolia: A stable rear edge population	PGD	I	G	C
Albayrak T. and Erdoğan A.,	2010	A gis-based approach to assess the population size of krüperâ€™s nuthatch, sitta krueperi at a newly found breeding area in inner anatolia: (Aves: Passeriformes)	PA	B	F	L
Sesli M. And Yeğenoğlu E.D.	2010	Determination of the genetic relationships between wild olive (Olea europaea oleaster) varieties grown in the aegean region	PGD	P	F	R
Özkan K. And Gülsoy S.	2010	Ecological land classification and mapping based on vegetation-environment hierarchical analysis - A case study of Buldan F district (Turkey)	HS	E	F	L
Kavgacı A., et.al.	2010	Cedar F communities in Western Antalya (Taurus Mountains, Turkey)	HS	E	F	R
Varol O. And Tel A.Z.	2010	Ecological features of the Pinus pinea Fs in the north-west region of Turkey (Yalova)	HS	E	F	L
Sabahaddin Ü., et.al.	2010	Ecological interpretations of rangeland condition of some villages in Kirikkale province of Turkey	TD	P	G	L
Özkan N., et.al.	2010	Ecological analysis of chironomid larvae (Diptera, Chironomidae) in Ergene River Basin (Turkish Thrace)	TD	I	W	L
Çağlar E.	2010	Mikrosatellit temelli markörlerle Centaurea nivea' daki genetik çeşitliliğin belirlenmesi	AD	P	G	R
Güçlü Ö.	2010	Nil yumuşak kabuklu kaplumbağası, Trionyx triunguis (Testudines: Trionychidae), populasyonlarının genetik yapısı	PGD	H	C	C
Mungan R.	2010	Buğdaycıl'ın (Luscinia svecica) Dicle Kuş Halkalama İstasyonu'ndaki (Diyarbakır) göç dinamiği	MB	B	G	R
Yıldız Z. M.	2010	Bolkar dağlarında (Niğde-Ulukışla) yaşayan Rana holtzi Werner, 1898 (Anura:Ranidae)'in populasyon dinamiği	DT, PA	H	W	L
Balçık B. F.	2010	Mapping and monitoring WL environment by analysis different satellite images and field spectroscopy	EEF	E	W	L
Bilgin R., et.al.	2009	Phylogeography of the greater horseshoe bat, Rhinolophus ferrumequinum (Chiroptera:	PGD, AD	SM	F	C

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
		Rhinolophidae), in southeastern Europe and Anatolia, with a specific focus on whether the Sea of Marmara is a barrier to gene flow				
Dogru A.O., et.al.	2009	A change detection analysis in the Izmir bird paradise: Integration of remote sensing and geographic information system	EEF	E	W	L
Gücü A.C., et.al.	2009	Occurrence of the critically endangered mediterranean monk seal, monachus monachus, at olympos-beydağları national park, turkey (mammalia: phocidae)	SD, PA	LM	C	L
Fritz U. Et.al.	2009	Mitochondrial diversity of European pond turtles (Emys orbicularis) in Anatolia and the Ponto-Caspian Region: MT old refuges, hotspot of extant diversification and critically endangered endemics	AD	H	W	R
Doğan H.M., et.al.	2009	Evaluation of the NDVI in plant community composition mapping: A case study of Tersakan Valley, Amasya County, Turkey	ECFT	E	F	L
Terzioğlu S., et.al.	2009	Monitoring F structure at landscape level: A case study of Scots pine F in NE Turkey	HS	E	F	R
Günlü A., et.al.	2009	Spatiotemporal changes of landscape pattern in response to deFation in Northeastern Turkey: A case study in Rize	HS	E	F	L
Sert H. Et.al.	2009	Mitochondrial HVI sequence variation in Anatolian hares (Lepus europaeus Pallas, 1778)	AD	SM	M	R
Üzüm N. And Olgun K.,	2009	Age and growth of the Southern Crested Newt, Triturus karelinii (Strauch 1870), in a lowland population from northwest Turkey	PSA/SCs	H	W	L
Gücel S. and Seçmen O.,	2009	Conservation biology of Asperula daphneola (Rubiaceae) in Western Turkey	DT	P	G	R
Aslan E.G. and Ayvaz Y.,	2009	Diversity of Alticinae (Coleoptera, Chrysomelidae) in Kasnak Oak F Nature Reserve, Isparta, Turkey	TD	I	F	L
Onmuş O., et.al.	2009	Distribution of breeding birds in the gediz delta, western turkey: (Aves)	SD, PA	B	W	L
Kovanci O.B., et.al.	2009	Lycaenid butterflies (Lepidoptera: Lycaenidae) of northwestern Turkey with notes on their ecology and current status	PA, TD	I	M	R
Tozkar C.O., et.al.	2009	The phylogenetic relationship between populations of marginally and sympatrically located Pinus halepensis	AD, PGD	P	F	R

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
		Mill. and Pinus brutia Ten. in Turkey, based on the ITS-2 region				
Tavşanoğlu Ç., and Coşgun U.	2009	Effect of goat browsing on growth form of maquis species in Köprülü Kanyon National Park (Antalya, Turkey)	HS	E	F	L
Böcük H., et.al.	2009	Plant diversity and conservation of the North-east Phrygia region under the impact of land degradation and desertification (Central Anatolia, Turkey)	DR	P	M	R
Ocak A., et.al.	2009	An investigation of diversity, distribution and monitoring on Poaceae (Gramineae) species growing naturally in Bilecik province at the intersection of three Phytogeographical regions (Northwest Anatolia - Turkey)	TD	P	G	R
Ezer T., et.al.	2009	The succession, habitat affinity, and life-forms of epiphytic bryophytes in the Turkish oak (Quercus cerris) Fs on Mount Musa	TD	P	F	R
Bakır Y.	2009	Achillea multifida (DC.) (Asteraceae)'nın koruma biyolojisi ve koruma genetiği	AD	P	F	R
Kırca S.	2009	Belgrad Ormanı (İstanbul) çevresinde peyzaj devamlılık değerlerinin belirlenmesi üzerine araştırmalar	EEF	E	F	L
Özdirek L.	2009	Estimation of demography and seasonal habitat use patterns of Anatolian mouflon (Ovis gmelinii Anatolica) population in Konya Bozdağ protection area using distance sampling	DT	LM	G	L
Özdemir A., et.al.	2008	Embryonic mortality in loggerhead turtle (Caretta caretta) nests: A comparative study on Fethiye and Göksu Delta beaches	DT	H	C	L
Gürel F., et.al.	2008	Life-cycle and foraging patterns of native Bombus terrestris (L.) (Hymenoptera, Apidae) in the Mediterranean region	P	I	M	R
Türkozan O. And Yilmaz C.,	2008	Loggerhead turtles, Caretta Caretta, at Dalyan beach, Turkey: Nesting activity (2004-2005) and 19-year abundance trend (1987-2005)	PA, DT	H	C	L
Uzun A. Et.al.	2008	Year-to-year variation in clutch size and breeding success of the little egret, Egretta garzetta linnaeus, 1766, in turkey	DT	B	W	L
İnaç S., et.al.	2008	The bird species of Kumasir lake (Kahramanmaraş-Turkey) and a view	TD	B	W	L

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
		of environmental ethics on sustainable WL management				
Kaynaş B.Y. and Gürkan B.,	2008	Species richness and abundance of insects during post-fire succession of a <i>Pinus brutia</i> F in Mediterranean region	DR	E	F	L
Çakır G., et.al.	2008	F cover change and fragmentation using Landsat data in Maçka State F Enterprise in Turkey	EEF	E	F	L
Kadioğulları A.I. and Başkent E.Z.,	2008	Spatial and temporal dynamics of land use pattern in Eastern Turkey: A case study in Gümüşhane	HS	E	F	R
Kaya Z., et.al.	2008	Genetic differentiation of <i>Abies equitrojani</i> (Asch. & Sint. ex Boiss) Mattf. populations from Kazdağı, Turkey and the genetic relationship between Turkish firs belonging to the <i>Abies nordmanniana</i> Spach complex	PGD	P	F	R
Kurt Y., et.al.	2008	Isozyme variation in four natural populations of <i>Cedrus libani</i> A.Rich. in Turkey	AD	P	F	L
Korkmaz H., et.al.	2008	Contribution to the knowledge of the syntaxonomy and ecology of <i>macchie</i> and F vegetation in Paphlagonia, north anatolia, Turkey	TD	P	M	R
Yiğit N. Et.al.	2008	Allozyme variation in <i>Rattus rattus</i> (rodentia: muridae) in turkey, with particular emphasis on the taxonomy	AD	SM	M	C
Mermer A., et.al.	2008	Abundance of syntopic newts, <i>Triturus karelinii</i> (Strauch, 1870) and <i>Triturus vittatus</i> (Gray, 1835) in Uludağ National Park (Bursa, Turkey)	PA	H	W	L
Akkartal F. A.	2008	Land cover change assessment in the belek Fland with multirate satellite imagery using change vector analysis technique	ECFT	E	F	L
Hüseyinova R.	2008	Samsun-Tekkeköy-Hacıosman ormanı ve Samsun-Bafra-Balık göllerinde yayılış gösteren bazı bitki türlerinin grime stratejilerine göre sınıflandırılması ve bitki fonksiyonel tiplerinin belirlenmesi	ECFT	E	W	L
Meydan Taşkınsu S.	2008	Yukarı Seyhan Havzası'nda uzaktan algılama yöntemleri ile arazi örtüsünün sınıflandırılması ve bazı orman meşcerelerinde verimliliğin modellenmesi	NPP	E	F	R
Hepcan Coşkun Ç.	2008	Doğa korumada sürdürülebilir bir yaklaşım, ekolojik ağların belirlenmesi ve planlanması: Çeşme-Urla yarımadası örneği	EEF	E	M	L
Selçuk E. S.	2008	Türkiye'nin kuzeyinde yayılış gösteren Yediuyur, Glis glis (Linnaeus, 1766) (Mammalia:	PGD	SM	F	C

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
		Rodentia) populasyonlarının RAPD-PCR ile analizi				
Gündürü U.	2008	Batı Karadeniz ve Trakya'da yayılış gösteren <i>Mus L.</i> , 1758 (Mammalia: Rodentia) cinsinin allozim varyasyonları	PGD	SM	G	R
Çelik A. D.	2008	Taşköprü-tekçam sarıçam (<i>Pinus sylvestris L.</i>) klonal tohum bahçesindeki çiçeklenme fenolojisi	P	P	F	L
Kravkaz S. İ.	2008	Kastamonu yöresindeki <i>Crocus spp.</i> 'nin fenolojik özellikleri	P	P	F	R
Kaya S.	2008	Poecilimon birandi (Orthoptera, Phaneropterinae) alçak ve yüksek rakım populasyonları: Ekolojik ve temporal farklılaşmanın fenotipik ve genetik verilerle incelenmesi	PGD	I	G	R
Ayaz D., et.al.	2007	Population estimate and body size of European pond turtles (<i>Emys orbicularis</i>) from Pazarağaç (Afyonkarahisar/Turkey)	PA, BM	H	W	L
Fontaine M., et.al.	2007	Elevation and exposition rather than soil types determine communities and site suitability in Mediterranean mountain Fs of southern Anatolia, Turkey	TD	P	F	R
Aslan A. And Erdoğan A.,	2007	On the distribution of the white-spectacled bulbul, <i>pyncnonotus xanthopygos</i> (hemprich & ehrenberg, 1833), in turkey	SD, PA	B	M	R
Ilgaz Ç., et.al.	2007	Population decline of loggerhead turtles: Two potential scenarios for Fethiye Beach, Turkey	PA	H	C	L
Balkız Ö., et.al.	2007	Range of the Greater Flamingo, <i>Phoenicopterus roseus</i> , metapopulation in the Mediterranean: New insights from Turkey	PA	B	W	R
Arıkan H., et.al.	2007	Some comments on the breeding biology of <i>Pelodytes caucasicus</i> Boulenger, 1896 (Anura: Pelodytidae) from Uzungöl, northeast Anatolia	P	H	W	L
İsfendiyaroğlu S., et.al.	2007	The Caucasian black grouse <i>Tetrao mlokosiewiczii</i> in Turkey: Recent survey results and conservation recommendations	SD	B	G	R
Fırıncioğlu H.K. and Seefeldt S.S., Ş	2007	The effects of long-term grazing exclosures on range plants in the Central Anatolian Region of turkey	DR	P	G	R
Saygılı F. and Yiğit N.,	2007	Notes on the nesting and breeding of <i>Delichon urbica</i> (Linnaeus, 1758) (Aves: Passeriformes) near Köprüköy (Kizilirmak, Turkey)	P, DT	B	M	L

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
Sivrikaya F., et.al.	2007	Evaluating land use/land cover changes and fragmentation in the Camili F planning unit of northeastern Turkey from 1972 to 2005	HS	E	F	L
Tağil Ş	2007	Quantifying the change detection of the Uluabat WL, Turkey, by use of Landsat images	HS	E	W	R
Başkent E.Z.and Kadioğullari A.I.,	2007	Spatial and temporal dynamics of land use pattern in Turkey: A case study in İnegöl	HS	E	F	L
Keleş S., et.al.	2007	Temporal changes in F landscape patterns in artvin F planning unit, Turkey	HS	E	F	L
Gottschalk T.K., et.al.	2007	Assessing the potential distribution of the Caucasian black grouse Tetrao mlokosiewiczzi in Turkey through spatial modelling	SD	B	G	R
Çolak R., et.al.	2007	Morphometric and biochemical variation and the distribution of the genus Apodemus (mammalia: Rodentia) in turkey	AD, PGD	SM	M	C
Miaud C et.al.	2007	Age, size and growth of the endemic Anatolian mountain frog Rana holtzi from Turkey	BM	H	W	L
Kavgacı A.	2007	Demirköy-İğneada longos ormanları ve çevresinin bitki toplulukları ve kuruluş özellikleri	TD	P	F	L
Didrickson Keşaplı Ö.	2007	Autumn migration dynamics, body mass, fat load and stopover behaviour of Willow Warbler(Phylloscopus trochilus 1758)at Manyas Kuşçenneti National Park (Northwestern Turkey)	MB	B	W	L
Özdilek A.	2007	Genetic differentiation of Liquidambar orientalis mill. varieties with respect to matK region of chloroplast genome	PGD	P	F	R
Savcı E. A.	2007	Ankara-Gölbaşı çevresinde Centaurea tchihatcheffii Fisch. & Mey. (Asteraceae)'in biyo-ekolojisi	PA	P	G	R
Gür H. And Barlas N.,	2006	Sex ratio of a population of Anatolian ground squirrels <i>Spermophilus xanthoprimum</i> in Central Anatolia, Turkey	PSA/SCs	SM	G	L
Özkan B.,	2006	An observation on the reproductive biology of <i>Glis glis</i> (Linnaeus, 1766) (Rodentia)	P	SM	F	R
Kosztolányi A., et.al.	2006	Ecological constraints on breeding system evolution: The influence of habitat on brood desertion in Kentish plover	DT	B	C	L

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
Elmaz Ç. and Kalay M.,	2006	The breeding success of <i>Chelonia mydas</i> (L. 1758) and <i>Caretta caretta</i> (L. 1758) on Kazanlı beach	DT	H	C	L
Avgın S.S.,	2006	Distribution and diversity of ground beetles in Başkonuş mountain National Park of Turkey	TD	I	F	L
Aşan Baydemir N. And Albayrak I.	2006	A study on the breeding biology of some bat species in Turkey (Mammalia: Chiroptera)	DT	SM	M	L
Tağil Ş.	2006	Change of habitat fragmentation and quality in the balıkesir plain and its surroundings with landscape pattern metrics (1975-2000)	EEF	E	M	R
Gözcüoğlu B., et.al.	2005	A study on <i>Mus domesticus</i> Rutty, 1772 and <i>Mus macedonicus</i> Petrov and Ruzı	AD	SM	U	R
Gür H., Gür M.K.,	2005	Annual cycle of activity, reproduction, and BM of anatolian ground squirrels (<i>Spermophilus xanthoprımus</i>) in Turkey	BM, P	SM	G	L
Yurttaş H., et.al.	2005	Variability in natural populations of <i>Anopheles sacharovi</i> (diptera: Culicidae) from southeast Anatolia, revealed by morphometric and allozymic analyses	AD	I	W	L
Tavşanoğlu Ç. and Gürkan B.,	2005	Post-fire dynamics of <i>Cistus</i> spp. in a <i>Pinus brutia</i> F	DR	E	F	L
Perktaş U. And Ayaş Z.,	2005	Birds of Nallıhan Bird Paradise (Central Anatolia, Turkey)	TD	B	W	L
Sert H., et.al.	2005	Genetic diversity within Anatolian brown hares (<i>Lepus europaeus</i> Pallas, 1778) and differentiation among Anatolian and European populations	PGD, AD	SM	M	C
Kankılıç T., et.al.	2005	Allozyme variation in <i>Spalax leucodon</i> Nordmann, 1840 (Rodentia: Spalacidae) in the area between Ankara and Beyşehir	AD	SM	G	R
Kaya U.et.al.	2005	Population status of the Taurus frog, <i>Rana holtzi</i> Werner (1898), in its terra typica: Is there a decline?	PA	H	W	L
Türkmen N.and Düzenli A.	2005	Changes in floristic composition of <i>Quercus coccifera</i> macchia after fire in the Çukurova region (Turkey)	DR	E	F	R
Kaynaş B.Y. and Gürkan B.	2005	Changes in Buprestidae (Coleoptera) community with successional age after fire in a <i>Pinus brutia</i> F	DR	E	F	L
Özbahar İ.	2005	Breeding biology, population size and spatial distribution of a common nightingale (<i>Luscinia megarhynchos</i> Brehm, 1831) population at Yalınca (Ankara)	DT	B	G	L

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
Auer M. and Taşkavak E.,	2004	Population structures of syntopic <i>Emys orbicularis</i> and <i>Mauremys rivulata</i> in western Turkey	PSA/SCs , DT	H	W	L
Sert H. and Erdoğan A.,	2004	The avifauna of Termessos National Park (Antalya-Turkey)	TD	B	F	L
Uygur Set.al.	2004	Population densities of yellow starthistle (<i>Centaurea solstitialis</i>) in Turkey	PA	P	G	R
Berberoglu S., et.al.	2004	Mapping and monitoring of coastal WLs of Çukurova Delta in the Eastern Mediterranean region	EEF	E	W	R
Can Keşaplı Ö.	2004	A study of passerine migration at METU (Ankara, Central Turkey) based on the mist-netting method	MB	B	G	L
Güçlüsoy H. And Savaş Y.,	2003	Status of the mediterranean monk seal, <i>monachus monachus</i> , in the foça pilot monk seal conservation area, turkey	PA, PSA/SCs	LM	C	L
Turna I.,	2003	Variation of some morphological and electrophoretic characters of 11 populations of Scots pine in Turkey	AD	P	F	C
Aslan A., and Kızıroğlu I.,	2003	A study on the ornithofauna of Sakaryabaşı/Eminekin Pond and its vicinity	SD	B	W	L
Yılmaz T.	2003	Mogan gölü ve çevresi örneğinde ıslak alanlardaki değişimin saptanması	EEF	E	W	L
Furman A. And Özgül A.,	2002	Distribution of cave-dwelling bats and conservation status of underground habitats in the Istanbul area	SD	SM	M	R
Tezcan S. and Rejzek M.	2002	Longhorn beetles (coleoptera: cerambycidae) recorded in cherry orchards in western turkey	TD	I	A	R
Kandemir G.	2002	Genetics a physiology of cold and drought resistance in Turkish red pine populations from Southern Turkey	PT	P	F	R
Kutlu Öç	2002	Seyhan nehri ve Tuz gölü yaban hayatı koruma alanında alan kullanımlarının kuş habitatları kaybı yönünden incelenmesi	EEF	B	W	R
Balkız Ö.	2002	The Phylogeny of wild goats (<i>Capra aegagrus</i> E.) in Turkey as determined by mtDNA d-coop sequencing	PGD	LM	G	C
İlbi L. A.	2002	Nazilli kenti planlı alanlarında odunsu taksonlar üzerine fenolojik gözlemler	P	P	U	L
Ayva B.	2002	Edremit yöresi (Balıkesir) örümceklerinin (Araneae) sistematik ve faunistik açıdan incelenmesi	TD	I	M	L
Özüt D.	2001	Conservation genetics of Anatolian mouflon (<i>ovis gmelinii anatolica</i>)	AD	LM	G	L
Turan E. A.	2001	Ankara kenti yeşil alanlarındaki önemli ağaç ve çalıların mevsimsel özellikleri üzerine bir araştırma	P	P	U	L
Özbucak Bayrak T.	2001	Samsun İli çevresindeki <i>P.orientalis</i> L. topluluklarında bulunan bazı odunsu	P	P	F	L

Authors	Year	Title	EBV	Sp Group	Hab	Geo-Scale
		taksonlarda yaprak gelişimi ve makro elementlerin mevsimsel değişimi				
Özel Ersöz S.	2001	The Pattern of genetic variation of pinus brutia ten populations from southern Turkey determined by nuclear SSR markers	PGD	P	F	R
Alten B., et.al.	2000	Species composition and seasonal dynamics of mosquitoes in the Belek region of Turkey	P, TD	I	M	L
Çiçek Filiz F.	2000	Genetic variation in adaptive seedling traits of natural populations of abies equitrojani aschers. et sint. from Kazdağı	PGD	P	F	R
Lise Y.	2000	The Impact of anthropogenic factors on the composition of genetic variation on pinus brutia ten. populations determined by DNA markers	AD	P	F	R
Kılıç D. D.	2000	Amasya Kırklar Dağı'nda bulunan bazı endemik bitkilerin fenolojileri üzerine bir araştırma	P	P	F	L
Gürsan M.H.	1999	Breeding biology and feeding ecology of the eastern imperial eagle, Aquila heliaca in north-central Anatolia	DT	B	F	L
Zeydanlı U.	1998	Effects of land use practices on steppe plant biodiversity implications for in situ conservation	SD, TD	P	G	L
Oğurlu I.	1997	The estimation of a red deer population density based on pellet counts	PA	LM	F	L
Taş E.	1997	Bir quercus cerris l. var. cerris ormanında bulunan bazı odunsu ve otsu bitkilerin fenolojileri üzerine bir araştırma	P	P	F	L
Yiğit N., et.al.	1996	Investigations on biology of Meriones crassus Sundevall, 1842 (Mammalia: Rodentia) in Turkey	DT	SM	G	R
Kara N.	1996	Kızılçamın (Pinus brutia ten.) doğal populasyonlarında izoenzim çeşitliliğinin araştırılması	AD	P	F	R
Parr S. et.al.	1995	A baseline survey of lesser kestrels Falco naumanni in central Turkey	PA	B	G	R
Çiçek F.F.	1994	Biology of crocus olivieri subsp. Olivieri	P, PT	P	G	L
Turan L.S.	1990	The breeding biology of magpie (Pica pica L.) in Beytepe, Ankara	DT	B	M	L
Küçük M.	1989	Maçka-Meryemana ve Altındere vadisi milli parkının önemli ağaç türleri üzerinde fenolojik gözlemler ve sonuçları	P	P	F	R
Kızıroğlu I.	1982	Investigation on the breeding biology of four Parus-species near Ankara	DT	B	F	L

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PERSONAL INFORMATION

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EDUCATION

Degree	Institution	Year of Graduation
MS	Ankara University Landscape Architecture	2011
BS	Ankara University Landscape Architecture	2007
High School	Atatürk Anatolian High School, Ankara	2002

WORK EXPERIENCE

Year	Place	Enrollment
2013-Present	Nature Conservation Center	GIS and Modelling Expert
2010-2013	Çankaya Municipality	Landscape Architect
2008-2010	Underwater Research Society	GIS Expert
2007-2008	ESRI Turkey	Trainer

FOREIGN LANGUAGES

Advanced English

PUBLICATIONS

1. Demirbař Çaęlayan, S., Balkız, Ö., Arslantař, F., Sanalan, K.C., Lise, Y., Zeydanlı, U. “Şehir Planlama Aracı Olarak Ekosistem Hizmetleri: Çankaya İlçesi Örneęi, Ankara”, Doęa Koruma Merkezi, 236 sayfa (2020).
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HOBBIES

Trekking, Boxing, Drawing, Gardening, Movies |

