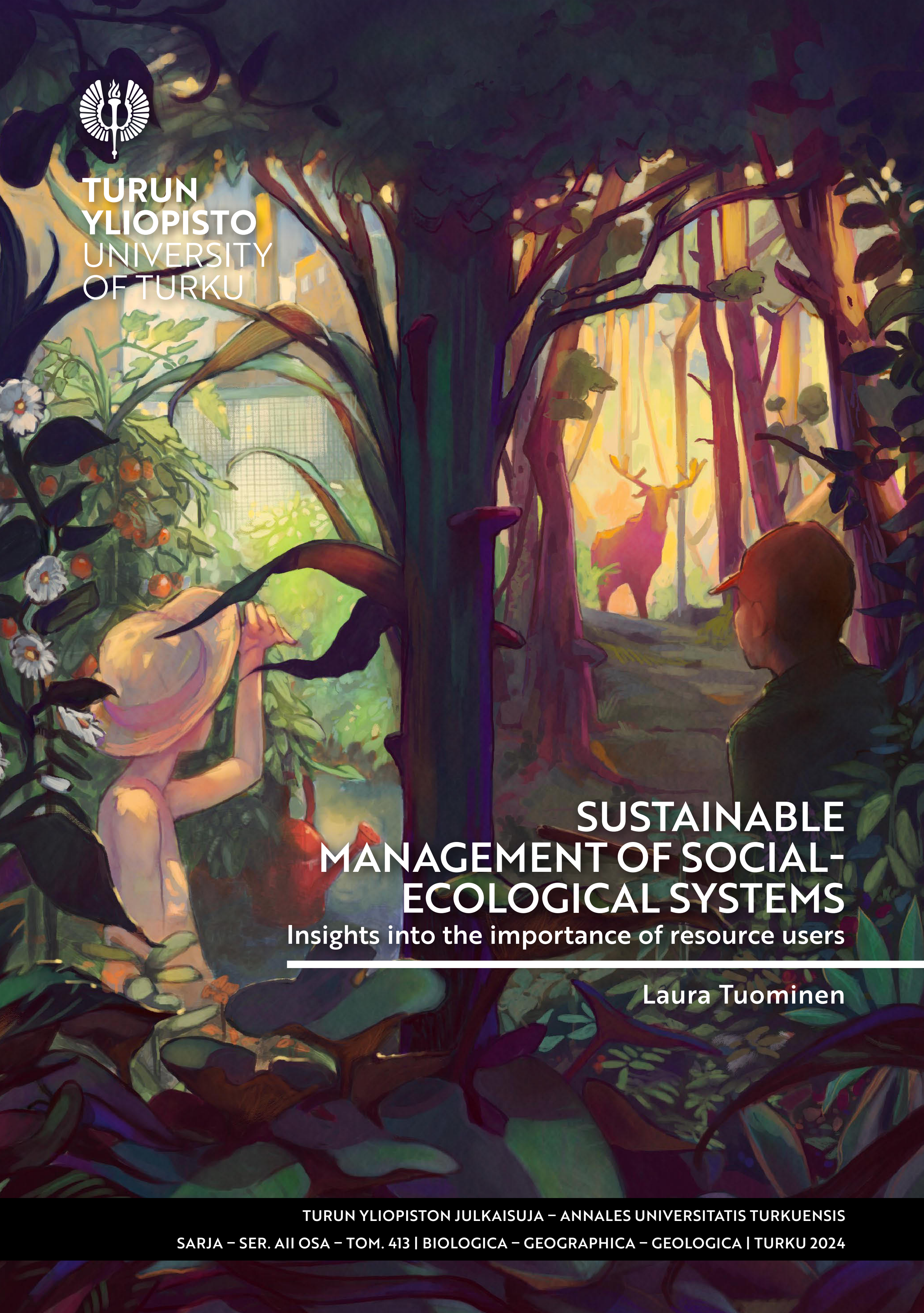

TURUN YLIOPISTO
UNIVERSITY OF TURKU

SUSTAINABLE MANAGEMENT OF SOCIAL-ECOLOGICAL SYSTEMS

Insights into the importance of resource users

Laura Tuominen

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”Täällä on paljon sellaista mitä ei voi ymmärtää”, Muumimamma sanoi itsekseen.
”Mutta miksi kaiken oikeastaan pitäisi olla juuri niin kuin on tottunut?”
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ABSTRACT

The continuous challenge of socially and ecologically sustainable management of natural resources demands us to tirelessly monitor the management systems and increase our understanding of them. The incorporation of both human needs and biophysical conditions for life is essential for long-term sustainability. Natural resource systems are complex Social-Ecological Systems (SES) that often require multi-level management. Active cooperation between and within the levels of management and involvement of the local level, i.e. resource users, in decision-making contributes to effective management and reduces the risk of overexploitation. This thesis investigates the management of two SESs: urban gardening and moose hunting by applying the SES framework. SES framework is a comprehensive analytical framework created to integrate both social and ecological aspects relevant to the sustainability of natural resource systems. The framework emphasizes the importance of the resource users and provides an extensive list of attributes for data collection. I investigated urban box gardening in the city of Turku and moose (*Alces alces*) hunting nationwide in Finland, to which the SES framework has rarely been applied before. Urban gardening enhances mental, physical, and social well-being and promotes individual resilience and local biodiversity but is still struggling to reach its full potential. Moose is an ecologically, socially, culturally, and economically important species but has suffered from large population fluctuations and stakeholder conflicts. The overarching aim of this thesis is to explore the questions of how and when is natural resource management sustainable. I focus particularly on the less studied but crucial level of management: the resource users.

Chapters **I** and **II** refer to an urban gardening program, where I combined field inventories to assess the objective ecological outcome (cultivation success) and questionnaires to assess the self-perceived ecological, social, and participants´ personal outcomes. First, I found that the outcomes are decoupled, meaning that the gardeners receive multiple benefits from the activity regardless of the gardening success, and vice-versa. In addition, I found that frequent and positive social interactions, as well as sunny and safe gardening locations significantly promote self-perceived outcomes. In the second study, I investigated in a before-after study if changes caused by the COVID-19 pandemic in social, economic, and political settings influence the outcomes of urban gardening and the benefits it produces. I found that the pandemic disturbance influences different parts of the system in different ways. Gardeners remain motivated to take care of their cultivations but report receiving less from it during the pandemic. The findings show that the negative effect of the pandemic extends to urban gardening activity. The results emphasize the importance of urban green spaces but also the need to create practices to secure the most important benefits from them in times of crisis.

In Chapter **III**, I assessed the long-term stability of moose harvest for over 4000 hunting groups. I found that, on average, the harvest declined by 1.1% per year but varies substantially between Finnish hunting groups. Certain characteristics of the hunting groups promote a more stable (declining less) harvest. Specifically, early establishment and longevity of the group and promotion of regular turnover of the leaders in the group improve stable benefits from the resource. In Chapter **IV** I investigate hunters and hunting group management in more detail via a questionnaire study. I found that well-working decision-making and joint action in the hunting groups are positively connected to compliance with hunting recommendations. Therefore, the social performance of the group management and the measures to maintain ecological sustainability are linked. In addition, a key aspect in reaching positive outcomes seems to be high social capital within the hunting group, between the hunting groups, and between levels of management.

In this thesis, I showed that the lowest level of management – the resource users – plays an important role in reaching sustainable outcomes in two very different SESs. Understanding the role of resource users is important as considerable support from the lowest level of the management, hunters and gardeners, is required for successful management. I find that the relationship between social and ecological sustainability is complex and context-dependent and a wider definition than economic is supported for social sustainability. I introduce several dynamics and factors that can assist in designing sustainable resource management. My thesis highlights that a deeper knowledge of the social dynamics at the local level can considerably facilitate regional and national-level management of SESs. Based on the findings of this thesis, I conclude that treating natural resource systems as integrated social-ecological systems can profoundly improve their management.

KEYWORDS: Natural resources, Multi-level Governance, Evolutionary theory, Co-management, Wildlife, Moose, Urban gardening, Cooperation, Resilience, Green infrastructure

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TIIVISTELMÄ

Sosiaalisesti ja ekologisesti kestävä luonnonvarojen hallinta on haaste, johon vastaaminen edellyttää syvällistä resurssijärjestelmien ymmärtämistä. Pitkän aikavälin kestävyyden kannalta sekä ihmisten tarpeiden että biofysikaalisten olosuhteiden huomioon ottaminen on olennaista. Luonnonvarat ovat monitahoisia sosio-ekologisia järjestelmiä (SES), joissa usein tarvitaan hallintaa monilla eri spatiaalisilla tasoilla. Aktiivinen yhteistyö hallinnan tasojen välillä ja sisällä sekä paikallisen tason eli luonnonvarojen käyttäjien osallistuminen päätöksentekoon edesauttaa toimivaa hallintaa ja pienentää liikakäytön riskiä. Tämä väitöskirja tutkii kahden SES:n – kaupunkiviljelyn ja hirvenmetsästyksen – hallintaa SES-viitekehystä soveltaen. SES-viitekehys on kattava analyyttinen viitekehys, joka on luotu yhdistämään sekä sosiaaliset että ekologiset osa-alueet luonnonvarajärjestelmien kestävän hallinnan tutkimiseksi. Viitekehys sisältää laajan valikoiman muuttujia järjestelmien analysointia ja aineiston keräämistä varten ja korostaa luonnonvarojen käyttäjien merkitystä kestävien tulosten kannalta. Tutkin väitöskirjassani laatikkoviljelyä Turun kaupungissa ja hirven (*Alces alces*) metsästystä valtakunnallisesti Suomessa. SES-viitekehystä on sovellettu näissä sosio-ekologisissa järjestelmissä vain harvoin aiemmin. Tiedetään, että kaupunkiviljely lisää henkistä, fyysistä ja sosiaalista hyvinvointia sekä edistää yksilöiden resilienssiä ja paikallista luonnon monimuotoisuutta. Kuitenkin sillä on usein vaikeuksia saavuttaa täyttä potentiaaliaan ja vakaata asemaa kaupunkisuunnittelussa. Hirvi puolestaan on ekologisesti, sosiaalisesti, kulttuurisesti ja taloudellisesti tärkeä laji, mutta sen hallinta on kärsinyt suurista kannan vaihteluista ja sidosryhmien konflikteista. Tämän väitöskirjan yleisenä tavoitteena on pohtia kysymyksiä: miten ja milloin luonnonvarojen hallinta on kestävää? Keskityn erityisesti vähemmän tutkittuun, mutta tärkeään hallinnan alimpaan tasoon: luonnonvarojen käyttäjiin.

Luvuissa **I** ja **II** tarkastellaan kaupunkiviljelyä, ja yhdistin kenttäinventaariot arvioidakseni objektiivisia ekologisia tuloksia ja kyselytutkimuksen arvioidakseni itsearvioituja ekologisia, sosiaalisia ja henkilökohtaisia tuloksia sekä niitä edistäviä tekijöitä. Osoitin, että objektiiviset ekologiset tulokset ja itsearvioidut tulokset eivät ole yhteydessä toisiinsa, mikä tarkoittaa, että viljelijät arvioivat saaneensa useita hyötyjä toiminnasta riippumatta viljelyn ekologisesta menestyksestä ja päinvastoin. Lisäksi ilmeni, että säännöllinen ja myönteinen sosiaalinen vuorovaikutus sekä aurinkoinen ja turvallinen viljelypaikka ovat tärkeitä tekijöitä itsearvioitujen tulosten

edistämisessä. Luvussa **II** tutkin, vaikuttavatko COVID-19 -pandemian aiheuttamat muutokset laajoissa yhteiskunnallisissa, taloudellisissa ja poliittisissa tekijöissä laatikkoviljelyn tuloksiin ja sen tuottamiin hyötyihin. Osoitin ennen-jälkeen -tutkimuksella, että pandemia vaikutti järjestelmän eri osiin eri tavoin. Viljelijät ovat edelleen motivoituneita huolehtimaan viljelmistä, mutta raportoivat saavansa laatikkoviljelystä vähemmän ekologisia, sosiaalisia ja henkilökohtaisia hyötyjä pandemian aikana. Tulokset osoittavat, että pandemian negatiivinen vaikutus ulottui myös kaupunkiviljelyyn. Tutkimukset korostavat kaupunkien viheralueiden merkitystä, mutta myös tarvetta luoda käytäntöjä, joilla niistä turvataan tärkeät hyödyt kriisiaikoina.

Luvussa **III** arvioin hirvenmetsästystutkimuksessa hirvisaaliin pitkäaikaista vakautta yli 4000 metsästysseuralle. Osoitin, että saalis laski keskimäärin 1,1 % vuodessa tutkimusajanjakson aikana (2007-2020), mutta trendi vaihteli huomattavasti metsästysseurojen välillä. Tietyt metsästysseurojen ominaisuudet edistävät vakaampaa (laski vähemmän) saalismäärää. Yhteenvetona voidaan todeta, että ryhmän varhainen perustaminen ja pitkäikäisyys sekä johtajien säännöllinen vaihtuvuus ryhmässä edistävät luonnonvarasta saatavien hyötyjen vakautta. Luvussa **IV** tutkin hirvenmetsästäjiä ja metsästysseurojen toimintaa laajalla kyselytutkimuksella. Havaitsin, että metsästysseurojen toimiva päätöksenteko ja yhteistoiminta sekä metsästäjien tyytyväisyys niihin ovat yhteydessä metsästyssuositusten noudattamiseen. Näin ollen vaikuttaa siltä, että metsästysseurojen toiminnan sosiaalinen kestävyys vaikuttaa toimenpiteisiin, joilla ylläpidetään ekologista kestävyyttä ja päinvastoin. Lisäksi tutkimuksen perusteella keskeinen tekijä myönteisten tulosten saavuttamisessa on korkea sosiaalinen pääoma eli luottamus ja kommunikaatio metsästysryhmän sisällä, metsästysryhmien välillä sekä hallintatasojen välillä.

Tässä väitöskirjassa osoitan, että hallinnan alimmalla tasolla – luonnonvaran käyttäjillä – on tärkeä rooli kestävien tulosten saavuttamisessa kahdessa hyvin erilaisessa sosio-ekologisessa järjestelmässä. Tieto luonnonvaran käyttäjistä on tärkeää, koska kestävään toimintaan ja hallinnan onnistumiseen tarvitaan usein huomattavaa tukea hallinnan paikalliselta tasolta. Havaitsen, että sosiaalisen ja ekologisen kestävyyden välinen yhteys on monimutkainen ja asiayhteydestä riippuvainen. Osoitan, että kestävyyden arvioinnissa olisi tärkeää ottaa huomioon useita sosiaalisia sekä ekologisia mittareita ja esitän laajempaa kuin taloudellista määritelmää sosiaaliselle kestävyydelle. Lisäksi esitän useita tekijöitä, jotka voivat auttaa kestävän luonnonvarahallinnan suunnittelussa. Tulosteni perusteella korostan, että paikallisen tason sosiaalisen dynamiikan syvällisempi tuntemus helpottaa merkittävästi SES:ien alueellista ja kansallista hallintoa. Tämän väitöskirjan havaintojen perusteella luonnonvarajärjestelmien käsitteleminen integroituina sosio-ekologisina järjestelminä parantaa merkittävästi niiden hallintaa sekä tutkimusta.

ASIASANAT: Natural resources, Multi-level Governance, Evolutionary theory, Co-management, Wildlife, Moose, Urban gardening, Cooperation, Resilience, Green infrastructure

Table of Contents

List of Original Publications

This dissertation is based on the following original publications, which are referred to in the text by their Roman numerals:

I Tuominen L.S., Helle S., Helanterä H., Karell P., Rapeli L., Richmond D., Vuorisalo T., Brommer J.E. Structural equation modeling reveals decoupling of ecological and self-perceived outcomes in a garden box social-ecological system. *Scientific Reports,* 2022; 12, 6425

II Tuominen LS, Helanterä H, Karell P, Rapeli L, Vuorisalo T, Brommer JE. Evidence of COVID-19 pandemic influence on well-being produced by urban gardening: A before-after study. *npj Urban Sustainability* revised manuscript

III Tuominen LS, Wikström M, Helanterä H, Karell P, Pusenius J, Rapeli L, Ruha L, Vuorisalo T, Brommer JE. Factors promoting hunting groups` sustainable harvest of moose in a co-management system. *Scientific Reports,* 2023; 13, 21076.

IV Tuominen LS, Wikström M, Helanterä H, Karell P, Rapeli L, Vuorisalo T, Brommer JE. Is it possible to have fun while following the rules? Social and Ecological Sustainability in moose management. Submitted manuscript

1 Introduction

1.1 Management of natural resource systems

Sustainable management of natural resources is challenging due to their complex nature [1, 2]. Natural resources form multidimensional Social-Ecological Systems (SES) and their management often results in so-called wicked problems which, in addition to complexity, include social conflicts about their goals and solutions [3, 4]. Management refers to the organization of decision-making processes and implementation of practices to influence people`s actions and natural resources, toward the achievement of certain objectives [3]. Management of SESs often functions at multiple levels, from countries and regions to resource users [5]. To address wicked problems and increase efficiency and commitment to decisions, co-management is implemented in many natural resource systems [6, 7]. In co-management, two or more actors between and/or within levels collaborate and share management functions, rights, and responsibilities [8]. Co-management is often applied to common-pool resources which are resources that are neither private or government-owned [9, 10]. They cannot be completely excludable from others and if someone extracts from the resource it is away from other users [11]. Common-pool resources are particularly vulnerable to the risks of selfish actions and overuse, i.e., "the tragedy of the commons", therefore demonstrating the need for co-management [9, 12, 13].

It is increasingly acknowledged that sustainable resource use in the long term cannot be reached without considering both human needs (social sustainability) and biophysical conditions for life (ecological sustainability) [1, 10, 11]. The idea is embedded in the Social-Ecological Systems (SES) framework, which is recognized as one of the most comprehensive frameworks to examine the sustainability of natural resource systems [4, 12, 13]. It is an analytical tool that assists in finding systems` relevant attributes. The framework recognizes that SESs are built of several sub-systems: Governance systems, Resource systems, Resource units, and Actors, all intertwined through the fifth sub-system Interactions (Figure 1). Under each sub-system, the SES framework presents a wide variety of variables potentially relevant to achieve sustainable Social and Ecological Outcomes. Social and Ecological Outcomes are relevant performance measures such as equity, livelihood outcomes, sustainability, overharvesting or resilience. The sub-system Governance systems refers to the processes how decisions are made and mechanisms by which activities are directed such as the laws, rules, and policies that guide decisions [3]. Resource systems and resource units refer to aspects of the ecological context and the resource itself which alter the possibilities for sustainability, such as the size and productivity of the system and the mobility and economic value of the units. Lastly, the Actors sub-system refers to the attributes of the resource users relevant for the management, such as their number, socioeconomic attributes, and social capital. In addition, the SES framework states that natural resource systems, the sub-systems, and therefore the outcomes are influenced by the wider Social, economic, and political settings and Related ecosystems. The SES framework has its foundations on extensive empirical work and it has been successfully applied to analyze resource systems throughout the world [10, 12-14].

The SES framework emphasizes that the resource users (Actors) play an integral part in the management of many natural resources [2, 15, 16]. To reach long-term sustainability resource management needs to be carefully planned and implemented, as to increase cooperation between the resource users [14, 15]. Cooperation between resource users increases the probabilities to avoid poor management and the tragedy of the commons [17]. Thus, I further explored - within the SES framework – known evolutionary-based mechanisms that increase the probability of cooperation (Figure 1). According to evolutionary theory, cooperation evolves either because of direct or indirect fitness benefits to individuals [18]. Mutually beneficial exchange, or reciprocity, becomes possible when the same individuals meet each other more often [19]. Therefore, certain preconditions such as relatedness, frequent interactions between individuals, and stability of a group, are expected to increase the probability of cooperation [20, 21]. The SES framework does incorporate reciprocity through several variables in the Actors sub-system such as shared norms, trust, and social capital [22]. Nevertheless, a separate investigation of the particular mechanisms derived from evolutionary theory can certainly improve the understanding between SES literature, social sciences, and evolutionary biology.

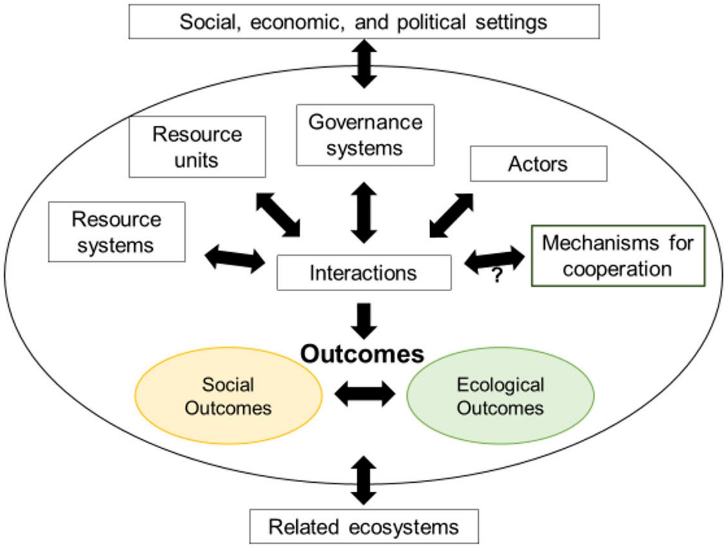

Figure 1. A modified schematic diagram of the SES framework based on Ostrom [4]. Sub-systems Resource systems, Resource units, Governance systems, and Actors are intertwined through the fifth sub-system Interactions and form Outcomes. Wider Social, economic, and political settings and Related ecosystems influence and are influenced by the system. Social and Ecological outcomes may or may not be not be associated with each other. In this thesis, the impact of a collection of variables under an added sub-system Mechanisms for cooperation is investigated in relation to other sub-systems.

1.2 The resource systems

Natural resource management is known to have suffered from so-called panaceas where the context of the resource system is not regarded enough [2, 23]. For example, a harvesting policy working perfectly in one place or time will probably not work well when the ecological or social conditions change. Continuous learning and adaptation of policies are required for sustainable solutions in complex systems [24]. Therefore, research on the specific ecological and social context of different natural resource systems is crucial in order to measure and accomplish an appropriate fit of the management systems [7, 16, 25, 26]. The relevance of the different variables listed in the SES framework for reaching sustainable outcomes varies between resource systems and contexts and not all of them should or even can be included and measured always. Regardless of the wide applicability of the SES framework, it has not been extensively tested in the management research of urban or wildlife systems [27-30]. The case studies in this thesis consider urban box gardening and moose hunting in Finland. Next, I will introduce and define the case studies studied in this thesis in more detail and discuss their framing.

1.2.1 Urban gardening

Urban green space has become ever more important when the majority of the world`s population lives in cities [31]. Urban green spaces such as parks, trees, and urban gardens create multiple ecosystem services: they promote mental and physical health, create biodiversity, strengthen social networks, and offer space for collective action [32-37]. Their socially and ecologically sustainable management can widely benefit people and society. Even though European cities are dedicated to maintaining or even increasing the amount of urban green infrastructure, urban green spaces are threatened by ongoing densification processes [38, 39].

Urban box gardening is small-scale urban gardening where garden boxes ($1m^2$) are placed on public land. Since garden boxes can be located almost everywhere, citizens can actively influence the amount and quality of urban green space in the city [40, 41]. Garden boxes have a high potential to make green spaces more diverse and socially beneficial at a rather low cost [42, 43]. The urban box gardening system in the city of Turku in Finland, studied here for the first time for our knowledge, is created by a program where the municipality offers free boxes to the enrolled participants. There are quite large gardening groups where co-management and resource sharing are more probable as well as gardeners who have their own separate boxes where sharing or co-management is not practiced. It is a good example of an SES where the property rights system is divided into at least two categories (Table 1) [4, 12]. I therefore mainly refer to public urban gardening and urban green space literature but include a discussion about the urban green commons. Urban green commons are public green spaces such as community or allotment gardens that are located in urban areas, collectively organized, and co-managed [44-46]. Like other commons, urban green commons are vulnerable to defective management, low institutional support, conflicts over land use, and unequal share of benefits [4, 47, 48]. My sample population consists of urban box gardeners in Turku who are people interested and committed to gardening, and not representative of the urban population in general. However, the sampled population offers an opportunity to explore gardeners` perceptions and the activity in changing conditions. Box gardening has not been studied broadly compared to other forms of urban gardening regardless of its recent popularity [49-51]. Due to the small resource amount that it produces, the system dynamics likely differ from other urban gardens. The economic potential is limited and the gardeners are likely more motivated by non-tangible outcomes than yield or self-sufficiency. Therefore, the relation between the social and ecological outcomes and aspects that promote their sustainability are unknown.

The SES framework predicts that the outcomes of natural resource systems are influenced by changes in the wider social, economic, and political settings [4]. The COVID-19 pandemic changed these settings significantly and offered a possibility to investigate the influence of a disturbance on urban gardening and its outcomes

[52-54]. Disruption of normal life associated with COVID-19 restrictions, uncertainty, fear of the disease, and social isolation influenced negatively people`s physical and mental health, and challenged the individual and community resilience [55-57]. Individual resilience means the ability of individuals to adapt and recover from adversity where internal resources as well as social support play an important role [58, 59]. Community resilience is defined as the adaptive capacity of its social system, improved by for example social networks, social capital, and collective learning [60]. Because cities are highly interconnected and compact, urban populations are vulnerable to disturbances. Therefore, maintaining individual and community resilience is vital for them [58, 61-63]. Disturbance can also cause beneficial transformation where a system evolves in a way that improves resilience [61]. Urban green spaces have been found to promote resilience in cities through their multiple ecosystem services [37, 45, 64]. It has been shown that during the pandemic, people visited green areas more frequently and placed higher importance on the urban green space [65-68]. People also reported that urban gardening helped them to cope with stress and negative emotions, therefore maintaining resilience [69-74]. However, it is not well known how exactly the outcomes created by urban gardening changed when compared to before the pandemic and after the initial lockdowns [68]. Even though, and particularly because, urban box gardening embodies the potential to improve individual and community resilience, more knowledge is needed about how this SES is influenced by a large-scale disturbance. It is one way to prepare better for future disturbances and even decrease their negative effects on people and communities.

1.2.2 Moose hunting

Wildlife offers high social, cultural, and economic outcomes for humans, increasing the risk of overuse and loss of ecological outcomes [75, 76]. Because wildlife is mobile, it causes challenges in the management and particularly in monitoring and/or definition of resource boundaries [29, 30]. Therefore, management needs to be carefully planned and implemented. There is evidence that in order to reach long-term sustainability, wildlife management should take into better account local social and ecological context [30].

A sustainable and stable moose (*Alces alces*) population is desired for several reasons. Moose are a fundamental part of a boreal forest ecosystem and a valuable catch in hunting but can cause lethal traffic accidents and severe damage in managed forests [75, 77]. Therefore, there are a variety of stakeholders with differing and even conflicting interests and values [78]. The objective however, is to provide both harvest to resource users and manage the resource sustainably. Historically in Finland, the moose population has been fluctuating considerably [79, 80]. Currently, it is strictly managed by a multi-level management system through hunting licenses: 15 regional wildlife councils first set goals for moose density and population every three years and then 59 moose management areas plan the yearly harvest for their area based on the goals. Moose management areas inform local hunters about the recommendations for suitable harvest numbers separately for bulls, cows, calves, and the age of bulls based on the antler size. The third level of the Finnish moose management system consists of 282 game management associations that organize the hunting logistics for hunting groups and hunters. Hunting groups and hunters form the lowest level of management: the resource users who apply and use the moose licenses [81]. Regardless of the involvement of stakeholders and between-level collaboration, moose management in Finland is largely characterized as top-down controlled through the strict license policy by the authorities [6].

As such, wildlife in Finland is not owned by anyone and therefore it is considered a common-pool resource [29, 82]. A minimum of 1000 ha is needed to apply for moose hunting licenses, often leading to hunting groups combining the hunting grounds from several landowners. In our study, we analyze two types of hunting groups: registered hunting societies and non-registered hunting groups. Registered hunting societies are democratic and the resource is shared and co-managed (Table 1). Non-registered hunting groups are not required to be democratic and the resource can resemble a privately-owned system when one person owns enough land. Moose management has seldom been studied at resource-user level [29, 83] but more knowledge is needed since the management system is considerably dependent on the hunters` hunting effort [84]. In addition, hunters` compliance with the harvest recommendations is necessary to maintain a sustainable moose population in the long term. Regardless of the strict license-based system, the density, sex, and age distribution can be altered locally to some extent [85]. Hunting groups can apply for moose hunting licenses as they see appropriate, they are free to use their moose hunting licenses restrictively so they don`t have to use all the licenses obtained and are not forced to follow the specific recommendations. Hunting groups might not be equally capable or willing to sustain a stable moose population or follow the recommendations set [76]. A deeper understanding of how social and ecological outcomes are connected and which aspects promote them in moose hunting at the level of resource users can assist in planning a more sustainable management system.

Table 1. The case studies analyzed as SESs in this thesis entail a gradient of property-rights systems. They are not fully common-pool resources or privately-owned resources. The influence of the difference is investigated in the studies and literature referring to the commons is included when interpreting the results.

CASE STUDY	BOX GARDENING	MOOSE HUNTING
COMMON-POOL	Urban green commons: Larger groups where co-management more probable	Wildlife commons: Registered societies where democratic decision-making is required
PRIVATE	Gardeners gardening alone their boxes (group number = one)	Non-registered hunting groups where non-democratic decision-making more probable

1.3 Social and ecological outcomes

The SES framework and research within highlight the importance and understanding of the connection between social and ecological dynamics and outcomes in reaching sustainability in the long term [86]. However, the direction and strength of their relationship are strongly dependent on their definition, measurement, and context [87, 88]. Regardless of the importance, social and ecological outcomes are not often studied concurrently [89]. In this thesis, I aim to incorporate information on ecological and social processes in both SESs. Urban garden boxes and moose hunting both have important ecological outcomes related to the cultivations and moose population respectively. However, both activities also encompass high social and non-tangible outcomes. Typically, social outcomes are defined as socio-economic and measured as the livelihood benefits for the resource users [12]. Still, a wider definition can be justifiable for several reasons. First, at least in the case of urban and wildlife SESs, human interests and motivations are much broader than just economic. Second, if the economic importance is low, it can lead to other motivations. Lastly, when considering overall sustainability, good ecological outcomes are often a matter of social well-being and interaction. Therefore, social outcomes should be defined accordingly to the specificity of the research objectives and include multiple benefits when possible [25].

At the resource user level in urban box gardening, positive ecological outcomes are defined as successful cultivations and local biodiversity. The resource is small but if well-connected to other diverse urban green spaces, it plays a part in the network of urban biodiversity [34, 43]. In this thesis, the objective ecological outcomes and gardeners` own estimation of the ecological outcomes are measured. The livelihood importance of small-scale urban gardening is low and other outcomes are likely more relevant [36, 90]. Physical and mental well-being and social benefits are therefore included in the social outcomes for urban gardeners. Overall, a positive connection between the ecological outcome and multiple benefits measuring social outcome is expected to improve the long-term sustainability of the system.

In moose hunting, a sustainable ecological outcome is defined as a viable moose population in the long term. In Finland, it is maintained through careful monitoring and license policy as well as specific hunting recommendations targeting population demography [91]. It is necessary for the multilevel management system and sustainable ecological outcomes that the hunters and hunting groups determine the recommendations appropriate and respect them. Noteworthy, a stable moose harvest offers a reliable source of moose meat and recreational benefits for the hunting group and its members [76]. Therefore, for the groups of resource users the socially sustainable harvest is a stable harvest rate over the years. Even though hunting success and stable catch are a significant part of the hunters` motivations and an insurance of the activity`s social sustainability, the group and other hunters play a role in social outcomes [84, 92] and hunters` overall satisfaction [93-95]. Since the management system is dependent on the hunters` hunting effort, their satisfaction with the activity is important [91]. Therefore, hunters` assessment and satisfaction with the decision-making and collective action in their group also measure a positive social outcome [96-98]. If the social outcome is positively connected to the ecological outcome, different levels of the management system will likely work well together improving the overall sustainability of the system [99].

The SES framework and evolutionary theory offer an extensive list of conditions potentially promoting socially and ecologically sustainable outcomes in natural resource management [4, 100]. Therefore, the data collection in this thesis is based on them and a wide collection of variables is measured in both resource systems. The resource users – gardeners and hunters – and their attributes present the main component to investigate in this thesis [4, 101]. Resource users are in both systems the ones implementing the management. Their personal differences, attitudes, and demographic variables are likely to influence the outcomes and satisfaction with the activity [15, 102-104]. Potentially relevant variables in the governance system on a resource user level are for example the rules within the groups of resource users and their organization and the dynamics with other groups [92, 96]. The factors stemming from the evolutionary theory are important in cooperative action, and increased cooperation within the group likely produces positive outcomes [17, 19, 20]. Lastly, the resource, cultivations and moose, itself influences the probability of sustainable outcomes. In the two resource systems studied here, the garden boxes allowed us to more objectively measure variables related to the physical locality and resource. The variables included in each study are further described in the Data collection section.

1.4 The aims of the thesis

The overarching aim of this thesis is to fill in knowledge gaps on how and when is natural resource management sustainable. I treated the resource systems as Social-Ecological Systems (SES) and measured both the social and ecological aspects as much as the study settings allowed. One challenge in the field is to include both ecological and social performance measures of sustainability, even though their connection is important in reaching long-term sustainability. Research, where those measures are considered simultaneously, is necessary to understand their relationship in more detail. A deep understanding of the local social and ecological context is required to create and implement a well-fitting management system. However, prior to this thesis, more knowledge was needed about the resource user level of the natural resource systems included here. I applied the SES framework to two different types of natural resource systems in Finland: urban box gardening and moose hunting. This allowed the possibility to examine the applicability of the framework in novel contexts. This thesis also aimed to investigate if the evolutionary explanations of cooperation offer insight into natural resource management and the SES framework and its application. First, I investigated if a wide variety of self-perceived outcomes are related to the objectively measured ecological outcomes in an urban gardening SES using as a case study urban box gardening in the city of Turku in Finland (**Chapter I**). In addition, I studied which aspects based on the SES framework and evolutionary theory promote self-perceived and ecological outcomes (**Chapter I**). I further explored the question by investigating in a before-after study if the outcomes of urban gardening, and therefore the resilience it creates, are influenced by changes in the wide societal settings as predicted by the SES framework (**Chapter II**). Next, I investigated similar questions in another natural resource system: moose hunting. I assessed the long-term stability of moose harvest and explored which social factors promote it (**Chapter III**). A geometric mean change in moose harvest is computed over 14 years (2007-2020) for over 4000 moose hunting groups. It has, to our knowledge, not been studied whether local-level management processes are associated with long-term harvest trends of wildlife [29, 105]. Finally, I investigated whether the measures to maintain ecologically sustainable management of moose are connected to the social performance measures of a hunting group management and which factors promote them (**Chapter IV**). In this thesis, I combine ecological and social data in order to increase our understanding of natural resource system management at the resource user level. In addition, this thesis provides practical implications on how to improve the sustainability and successful management of urban gardening and moose hunting.

2 Materials and Methods

2.1 Data collection

2.1.1 Urban garden boxes

Chapters **I** and **II** of the thesis investigated urban gardening, box gardening, in a medium-sized city of Turku in Southern Finland. The city established an urban box gardening program in 2016 where free garden boxes (1 m^2) and soil are provided for citizens who enroll in the program. Citizens receive one or more boxes and the only rule in the program is that the boxes need to be located on a public land. Otherwise, the citizens can determine the specific location and their cultivations, and organize their gardening groups. The program is popular and every year new gardeners enroll in it. For the study conducted in Chapter **I**, the data was collected in 2019, and there were 698 garden boxes in 245 different locations. In the second study (Chapter **II**), the years 2019, 2020, and 2021 were compared. In 2020 there were 674 garden boxes in 243 locations and in 2021 there were 762 garden boxes in 297 locations. The boxes are located fairly evenly around the city (Figure 2). In both Chapters, the ecological and self-perceived outcomes were measured by field inventories and questionnaires, respectively. In addition, variables potentially influencing the outcomes were measured by these two methods of data collection.

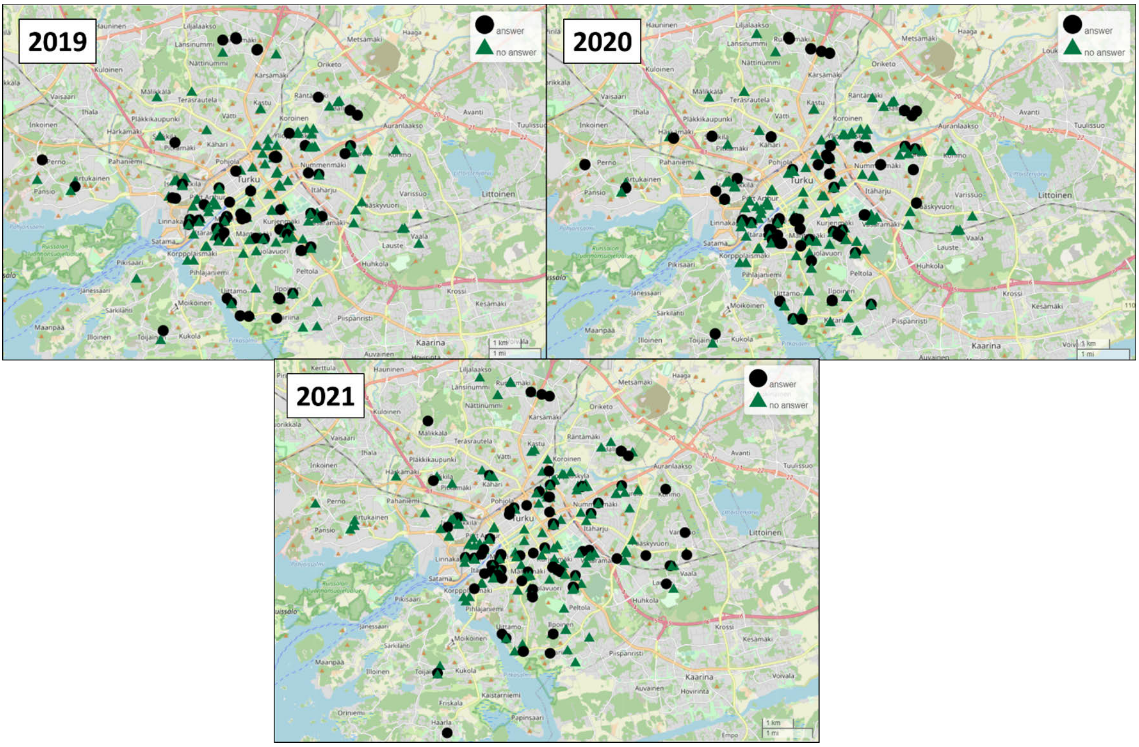

Figure 2. The garden boxes were located widely around the Turku city area in all the study years 2019, 2020 and 2021. The black balls illustrate the gardening groups that responded to the after-season survey, and the green triangles illustrate the gardening groups that did not respond. The responses are spread evenly around the city and therefore, do not show any strong visible geographic bias. It is good to note that for Chapter **I** the data used from 2019 included also the before-season survey respondents and therefore there would be more green triangles not presented here in the sample.

The garden boxes are located in a public place and therefore it is possible to objectively measure the ecological outcome by field inventories. Every year the garden boxes were inspected three times per growing season five weeks apart (June, July, and September). The three visits are sufficient to capture the short growing season of Finland. The following six measurements were used to determine the ecological outcome in both Chapters **I** and **II**. During each visit cultivated species were identified and counted, the number of cultivated individuals belonging to each species was estimated, the quality of each species and their area cover was evaluated, and the area covered by weeds in the box was estimated. In addition, the economic value of cultivations for each gardening group was estimated. The average values of the three field inventories and the average values per box for each group are used in the analyses. The average values are used in the analyses to consider differences in the gardening effort and success over the whole summer.

The social outcome was measured by electronic questionnaires sent to the gardeners. Since the outcome contains a wide variety of potential benefits received from gardening, unlike typically in the SES studies, and it is self-assessed by the gardeners, it is named “the self-perceived outcome” for clarity. The gardeners were asked to fill out two electronic questionnaires, one before the growing season and one after the season. The after-season questionnaire contained questions considering 14 different benefits potentially received from the activity [33, 36]. These were: stand in the community, quality time with friends or family, community feeling, education of children, nature connection, know-how, mental relaxation, physical recreation, creation of biodiversity, self-sufficiency, beautification of the area, and fresh vegetables. The gardeners assessed for each benefit if they did not receive it, received it a little or received it a lot from box gardening during the summer. The list of the benefits was based on the self-identified expectations before the summer and on previous research on the subject [33, 36]. Each gardening group had a name that they provided in the questionnaire, reported to the city, and which was written on a sign in their boxes. This enabled us to connect the information collected from the field to the otherwise anonymous questionnaire data. The response rate for the data used in Chapter **I** was 53.1% which resulted in a sample size of 121 gardeners after connected to the field data [106]. For Chapter **II**, only the responses from the after-season questionnaire were used in the analyses which resulted in an average response rate of 28.4% from the three years. Each year we were unable to connect a few survey respondents to the field data (incorrect name provided), and therefore the sample size is slightly lower than the number of after-season survey respondents.

In Chapter **I** the second aim was to apply the SES framework and evolutionary theory to investigate which aspects promote the ecological and self-perceived outcomes in urban gardening [4, 13, 20]. The extensive second-tier variable list of the SES framework was explored in order to pick the potentially relevant variables in relation to urban gardening [12]. 12 variables and three variables based on the evolutionary theory were chosen to predict outcomes. The SES variables measured in the field were the average exposure of the box to the sun (shade), seclusion of box location (privacy), visible damage made to cultivations or boxes (damage), and visible additional constructions made to or around the boxes (effort). The questionnaires collected variables measuring the presence of an agreed gardening plan in the group (rules), division of work in the group (involvement), group size, number of other box gardeners nearby (others number), starting year, experienced damage to the cultivations (damage), worries of something happening to the cultivations (worries), and social capital created during the summer. The variables based on the evolutionary theory and collected by the questionnaires were the frequency of group meetings during the summer, relatedness within the group, and changes in the group composition (stability). In Chapter **II** the aim was to investigate how the ecological and self-perceived outcomes differ between the year 2019 before COVID-19 and during the pandemic in 2020 and 2021. Therefore, in addition to the previously listed information, in 2020 and 2021 questions considering the COVID-19 pandemic were included in the questionnaire. Briefly, respondents were asked whether the COVID-19 pandemic has caused changes in gardening habits, attitudes toward gardening, or the economic situation of the gardeners.

2.1.2 Moose hunting

In the case studies of moose hunting, data was collected at a national scale in Finland for both Chapters **III** and **IV**. The aim was to collect a representative sample to describe moose hunters and hunting groups in Finland. In Chapter **III** we measured the hunting groups` long-term trend in moose harvest from 14 years (2007-2020) and whether the qualities of hunting groups influence the trend. For Chapter **III** the data was obtained from public data sources from the Natural Resources Institute Finland, the Finnish Wildlife Agency, and the Finnish Patent and Register Office. The geometric mean annual change in moose harvest measured the ecological outcome. All hunting groups in Finland are required each hunting season to report how many moose adults and calves they harvest. An “adult equivalent” was used in the analyses, where harvesting one calf was estimated as ½ adult. We computed the geometric mean annual change in moose harvest during 2007-2020 for a hunting group *g* with a non-zero “adult equivalent” moose harvest *H* starting in year *f* and ending in year *l* as

$$\lambda_g = \left({H_{g,l}}/{H_{g,f}} \right)^{\frac{1}{1+l-f}} \tag{1}$$

, where the denominator in the exponent denotes the number of years between the first and last non-zero harvest. This formulation ignores information on harvest between the first and last year but is mathematically equivalent to computing the metric using all annual harvests (Chapter **III** Electronic Supplement). In addition, years without harvest are ignored in this approach, but they are relatively rare. A stable long-term harvest is achieved when λ_g is one, whereas a value of λ_g below unity implies harvest was, on average, declining. The long-term change in harvest λ_g was computed for hunting groups harvesting moose in more than 10 years.

In Chapter **III** several variables describing the hunting groups based on the SES framework and evolutionary theory were collected to measure their influence on the long-term harvest trend. First, as mentioned before there are two ways to organize a moose hunting group in Finland to apply for hunting licenses, and we classified hunting groups used in the analyses in them. Shortly, a registered hunting society is required to function democratically through two yearly meetings and a steering board chosen by its members. A non-registered hunting group has no formal organization and is not required by law to follow any democratic decision-making processes. Second, in Finland, hunting groups have the possibility to jointly apply for moose hunting licenses. Shared moose hunting licenses require a level of collaboration in the division of animals between the groups. For each hunting group, we determined if they had shared licenses since 2016. Third, the Game Management Association (282), Moose Management Area (59), and Wildlife Agency Office (15) the hunting groups belong to was determined for each of them. The qualities of registered hunting societies were possible to investigate more specifically. The Finnish Patent and Register Office provides public data of the year a society is registered (age of the society) and the society reports to them their rules and/or the names of the society members that have signature rights (typically the leading members of the steering board). We requested from the Finnish Patent and Register Office all records of signature rights, including the names of the persons which are reported starting in the 1980s. As a measure of the turnover of the steering board, we scored how many times the names of leading board members changed since 1985. As a measure of board members potentially being relatives, we further scored whether two or more board members who did not share their first and second names, shared a surname or not.

For Chapter **IV** an electronic questionnaire was sent in 2021 to Finnish moose hunters to collect variables describing the hunters, hunting groups, and their management more precisely. Altogether 4745 hunters answered the questionnaire (4736 accepted for analyses) representing 2768 hunting groups. Data presents about 3.9% of the 123 000 cervid hunters in Finland and over 50% of the hunting groups. The representability of the data was investigated based on background data acquired from the Finnish Wildlife Agency considering the area, and hunters` gender and age. Even though there was no strong bias in the response, data weights are included correcting for wildlife agency regions (area) and age groups, calculated using the R package survey [107]. Ecological and social outcomes of a hunting group management were measured by statements evaluated by the respondents. Statements were categorized into three groups: decision-making and joint-action (social outcomes) and natural resource management (ecological outcome). Decision-making was defined with statements evaluating hunters` satisfaction with it, and its functionality, equality, inclusiveness, and transparency. Joint action was defined with statements evaluating team spirit, compliance with rules, presence of conflicts, communication, participation in shared work, and hunters` satisfaction with how the catch is shared, hunting opportunities, and how hunts are organized. Natural resource management was defined with statements evaluating whether the local moose population is in a sustainable state and if the group follows the different hunting recommendations.

The questionnaire in Chapter **IV** collected several variables potentially predicting social and ecological outcomes. The data collection was mainly based on the SES framework and evolutionary theory and the variables were categorized into three sub-systems Actors, Governance, and Cooperation. The variables included to describe the hunters in the Actors sub-system are age, gender, education, hunting experience, distance from residence to hunting grounds, role in the hunting group, social and livelihood importance given to hunting, land-ownership, knowledge level about the resource, and trust in population estimates made by the Natural Resources Institute Finland. The variables included to describe the group in the Governance sub-system are collaboration with other hunting groups, license sharing with other hunting groups, conflicts between other actors in the area, the way the hunting group is organized (registered or non-registered), hunting group size, and the share of land-owners in the group. The variables included to describe the hunters and the group in the Cooperation sub-system are frequency of meetings with other members during and outside the hunting season, relatedness with other members, commitment of members, acceptance of new members in the group, and frequency of guests visiting the group.

2.2 Statistical analyses

2.2.1 Urban garden boxes

In Chapter **I** the urban box gardening SES was modeled by applying Structural Equation Modeling (SEM) [108]. First, we performed a Confirmatory Factor Analysis (CFA) to construct a measurement model for two latent variables: ecological and self-perceived outcomes measured by reflective indicators [109]. The ecological outcome was measured by six previously listed indicators recorded during field inventories. The self-perceived outcome was measured by three indicators consisting of benefits evaluated by the gardeners in the questionnaire. Each indicator is a composite consisting of four benefits categorized as social, individual, or ecological benefit. The two latent variables were modeled simultaneously to investigate their association. The global fit of the CFA model was evaluated by several fit indices: p-value, RMSEA, CFI, and SRMR [110]. Second, the full SE model was built by regressing the 15 previously listed potential predictor variables on the two latent variables. The data contained missing data due to the combination of field and questionnaire variables. To maintain an adequate sample size to perform the models, a multiple imputation (MI) was performed for the missing data of independent variables [111, 112]. To assure the reliability of the results in the presence of over 60% missing data in a few variables, 100 imputed datasets were generated [113, 114]. MI considers the variability between the generated datasets and therefore accounts for the uncertainty of imputed data. Analyses were conducted using Mplus version 8.5 [115].

First, in Chapter **II** the questionnaire responses for the questions related to the COVID-19 pandemic were presented as exploratory tables. In addition, a binomial test was performed to investigate if the reported changes in attitudes or economic situation due to COVID-19 are significantly more positive or negative. Second, the ecological and self-perceived outcomes were modeled by a Principal Component Analysis (PCA). The PCA was performed separately for the six measures recorded in the field inventories (ecological outcome) and the 14 benefits evaluated by the gardeners in the questionnaires (self-perceived outcome). Even though the SES framework emphasizes their connection, the analyses were performed separately because of their disconnection in the previous work and weak correlations found here (Pearson`s correlation coefficient varies between -0.2-0.2). Third, the differences between the years 2019, 2020, and 2021 in the ecological and self-perceived outcomes were explored by a general linear mixed model analysis. The response variables in the models were the meaningful two ecological and three self-perceived principal component variables created by the PCA. The PC scores were computed for each gardener. The explanatory variables were the focus variable, i.e. the year the data was collected, controlled by the gardening group size, family members in the group, frequency of group meetings, number of other gardeners, starting year, number of boxes, privacy, and shade. A gardener ID was included as a random effect to control for the gardeners who were present over several data collection years. Analyses were run in R by package FactoMineR (PCA) and package lme4 (general linear mixed model) [116].

2.2.2 Moose hunting

In Chapter **III** the predictors explaining differences in the mean change in harvest between the hunting groups were analyzed using two linear mixed models. In the first model for all hunting groups, the fixed effects were whether the hunting group was a registered hunting society or a non-registered hunting group and whether the group had shared a hunting license or not. The second model only considered registered hunting societies and the fixed effects were whether the group had shared a hunting license or not, the year the society was established, the number of changes in the leading board members, and whether board members shared a surname or not. In both models, the Wildlife Agency Region, Moose Management Area, and Game Management Association were included as random effects. The random effects corrected for the non-independence of hunting groups across different spatial units. All linear mixed models were solved using Restricted Maximum Likelihood (REML) implemented in AsReml in R [117].

In Chapter **IV** a Confirmatory Factor Analysis (CFA) was first applied to construct a measurement model for the three outcomes of interest: hunting groups` Decision-making, Joint action, and Natural resource management [109]. The three latent variables are measured by reflective indicators which were statements from the questionnaire. Reflective indicators were found to be left-skewed, as expected because most of the respondents stated high values for the statements. The transformation for the variables to follow normal distribution did not improve the results and the original variables are used in the analyses with an MLR estimator accounting for non-normality [118]. The global fit of the model was evaluated by several fit indices: RMSEA, CFI, and SRMR [110]. Second, a Structural Equation Model (SEM) was built to investigate which predictor variables are statistically associated with the latent variables [108]. In this study, three composite factors Actors, Governance, and Cooperation were built consisting of previously listed composite indicators [119]. Missing data for independent variables in the SE model was imputed by Multiple Imputation (MI) [111]. MI substitutes missing values by the FIML method and accounts for uncertainty by considering variability between multiple datasets. Ten imputed datasets were evaluated to be appropriate when none of the variables contained over 10% of missing data [120]. The models are estimated by taking into account the (minor) spatial non-independence by including Wildlife Agency regions as a cluster variable [121]. In addition, data weights correcting for wildlife agency regions (area) and age groups were included in the models [122]. Analyses were conducted using a complex analysis method by Mplus version 8.6.

3 Results and Discussion

3.1 Factors promoting ecological and self-perceived outcomes in a garden box social-ecological system

In Chapter **I**, a CFA was first performed to construct a measurement model for the ecological and self-perceived outcomes of urban box gardening as latent variables (Figure 3: right side). The Swain corrected global fit of the CFA model to the data was acceptable (chi-square value = 35.07, df = 26, p-value = 0.110, RMSEA = 0.056, RMSEA 90% C.I. = 0.000 / 0.099, CFI = 0.946) and all the indicators had significant loadings onto their latent variables, as expected [110]. A more positive ecological outcome was associated with an increase in the species number, economic value, quality, number, and area of cultivations, and a decrease in the area of weeds. A more positive self-perceived outcome was associated with an increase in the social, individual, and ecological benefits. The results highlight that a model where multiple indicators measure the outcomes as latent variables gives a more comparable and realistic view of natural resource systems than one single measure [123]. In addition, the method includes a measurement error for the latent variables which acknowledges that they cannot be measured exhaustively [108]. The definition of sustainability is dynamic and context-dependent, and SES studies would benefit from including several measurements for the outcomes [124].

Contrary to the expectations, we find that the ecological and self-perceived outcomes are not significantly correlated (correlation = 0.132, p-value = 0.385) [36, 125]. These findings suggest that gardeners who evaluate to receive high social, individual, and ecological benefits do not necessarily succeed in producing positive ecological outcomes, and vice-versa. There are a few possible explanations for the finding. First, the gardeners have a limited number of small garden boxes so the importance of the resource itself – the cultivations and their success – might be low. The gardeners` main motivations lie somewhere else [101]. Gardeners can be satisfied with the activity due to its social and individual well-being benefits even when they don`t succeed very well with the cultivations [36]. Second, as the ecological outcome is objectively evaluated by field inventories, our finding implies that the gardeners might self-evaluate high ecological outcomes regardless of the real outcomes. Therefore, increasing the gardeners` ecological awareness and knowledge could strengthen the connection [125]. The result suggests that information about local biodiversity and how to increase it should be properly available for people participating in urban gardening projects [102]. Based on the findings, the self-evaluation of the ecological outcomes, even though often applied in the field, should be supported with more objective evaluations.

The full SEM discloses several variables based on the SES framework and evolutionary theory which are associated with ecological outcomes and particularly with self-perceived outcomes (Figure 3). The SEM explained 36.3% of the variance of the ecological outcome and 84.8% of the variance of the self-perceived outcome. The ecological and self-perceived outcomes are evidently impacted by different variables resulting in a disconnection. However, this study might not capture the whole variance of the outcomes because successful gardeners likely tend to respond to the questionnaire more often. Future studies should focus on the variables explaining the variability of the ecological outcomes and, if possible, reasons for failure [34, 102, 125]. First, the model reveals a challenge in the gardening program: over the years both the ecological and self-perceived outcomes diminish for the gardeners. We assumed that a gained gardening experience would have a positive influence on the outcomes, but it seems that when the enthusiasm of the first year decreases the outcomes decrease too [100, 126]. The program would benefit from a better understanding of the mechanisms behind this effect through long-term monitoring. The rest of the variables were significantly associated solely with self-perceived outcomes. Worries about vandalism, theft, or animal damages on cultivations stated at the beginning of the summer have a negative influence. Interestingly, it seems that regardless of something actually happening to the cultivations, the worries about it have an impact. The finding highlights the importance of the gardening location and its perceived safety [127]. In addition, we find two significant variables emphasizing the social importance of the activity: social capital created during the summer and frequent meetings with group members both have a positive influence. The result suggests that positive social experiences, such as positive comments and helping or meeting others, are an important part of the activity and gardeners` satisfaction [101, 128]. Face-to-face meetings are known to play an important role in successful natural resource management and our study further supports that [21, 101, 129, 130]. Furthermore, the reciprocity created by group meetings seems to be more relevant than other mechanisms stemming from the evolutionary theory [17]. When gardeners meet each other often it can lead to higher trust and efficiency, better division of labor, and social control leading to an increase in cooperation and positive outcomes [17, 22]. In the case of urban SESs, our study highlights the importance of the gardeners – the resource users – in reaching positive outcomes.

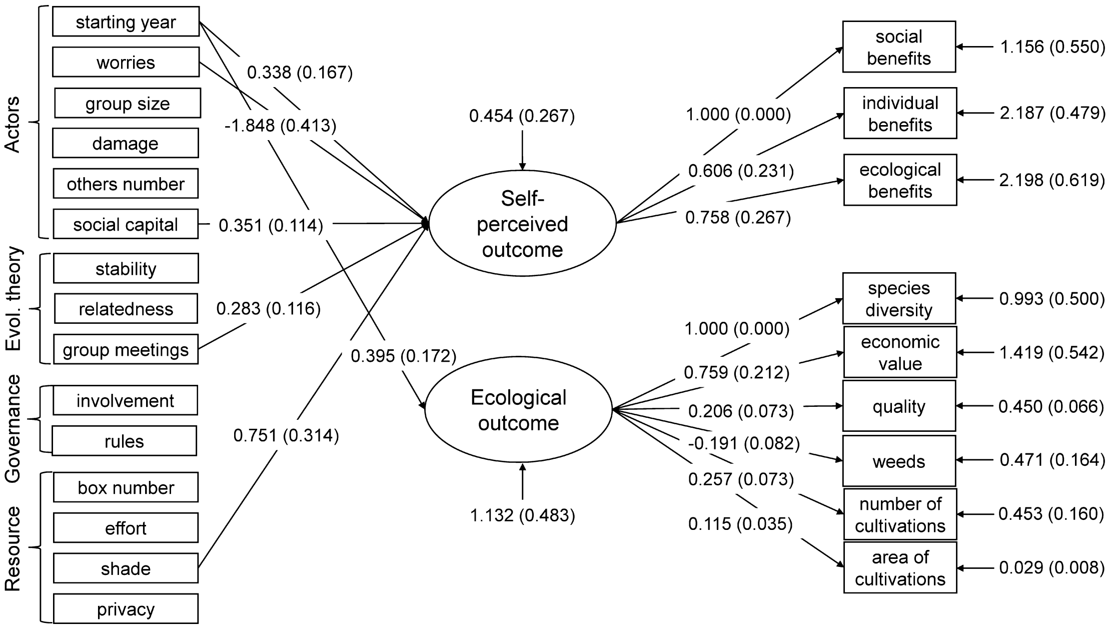

Figure 3. The SEM results for the variables belonging to the sub-systems Actors, Governance, Resource, and Evolutionary theory, predicting the two latent variables Self-perceived and Ecological outcomes described by their reflective indicators. The regression coefficients presented by arrows pointing to the latent variables show the significant (p-value < 0.05) associations between the predictors and the outcomes (note that the non-significant predictors were not omitted from the model). The estimates presented are unstandardized estimates and their standard errors are presented in brackets. Error terms signifying the variance not explained by the model are included for latent variables and reflective indicators.

3.2 Evidence of COVID-19 pandemic influence on well-being produced by urban gardening: A before-after study

In Chapter **II** we compare how the outcomes created by an urban SES – box gardening – change from before, to during and toward the end of the COVID-19 pandemic. We find that in 2020 about 20% and in 2021 about 30% of the questionnaire respondents reported some attitude changes toward gardening due to the pandemic. Since the gardeners are participating in a voluntary program, they most probably already give high value to box gardening regardless of the pandemic which is why the change is not evident for the majority of the gardeners [71, 131]. The reported attitude changes are significantly more positive than negative in both years, meaning that gardeners consider gardening to be more important or have started gardening due to the pandemic. The finding is supported by several previous studies and indicates that box gardening is important for individual resilience amidst the pandemic [65, 68, 71, 72, 132, 133]. The possibility for safe social interaction and accessible small-scale green space close to people benefit individual and community resilience [40, 72, 131].

We find two meaningful principal components for the ecological outcome variables which are named here the “Overall ecological outcome” and “Simpler strategy for quality”. The overall ecological outcome did not differ between the years but, during the pandemic, the cultivations achieved higher quality though fewer species and individuals than in 2019 (2020: df = 143.01, t-value = 4.646, p-value < 0.001, 2021: df = 163.44, t-value = 2.754, p-value = 0.007) (Figure 4a). We find three meaningful principal components for the self-perceived outcome variables which are named here the “Overall self-perceived outcome”, “High social, low practical outcomes”, and “High family, low individual outcomes”. We find evidence that the overall outcomes which the gardeners self-perceived to receive from the activity decreased when compared to before COVID-19 (Figure 4b). The difference was significant between 2019 and 2021 (df = 130.2, t-value = -2.468, p-value = 0.015), and there was a decreasing yet non-significant trend between 2019 and 2020. In addition, we find that in 2021 gardeners receive more social and less practical outcomes than before the pandemic (df = 168.29, t-value = 2.179, p-value = 0.031).

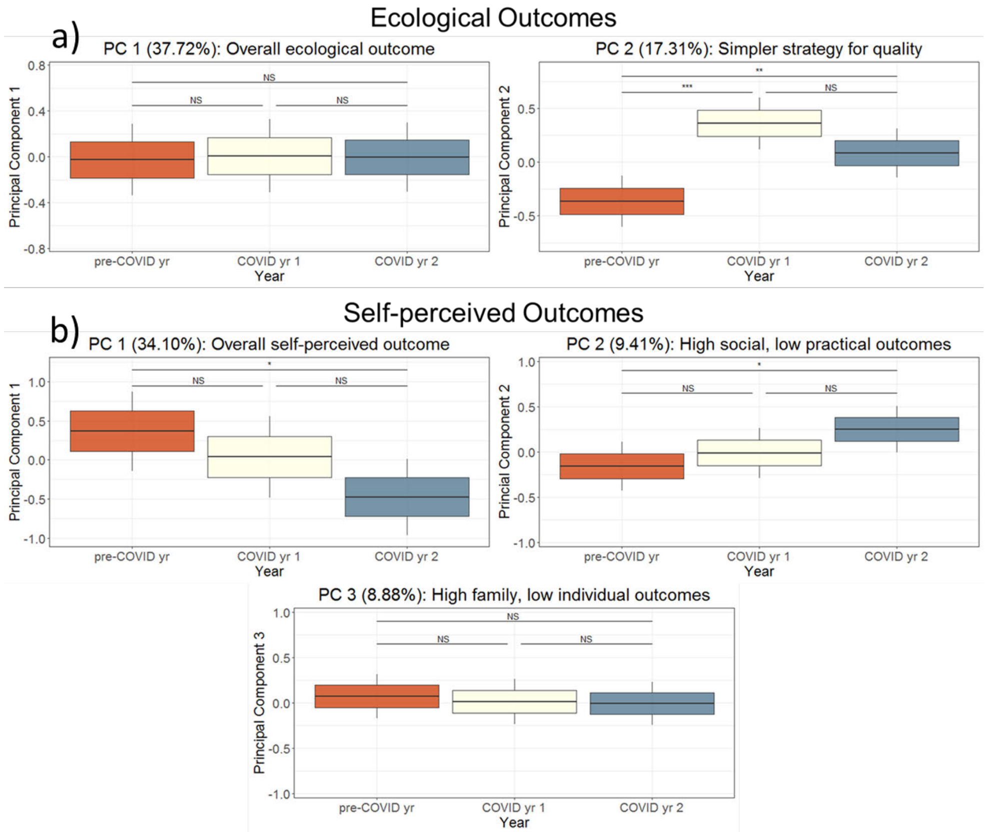

Figure 4. The differences in the **a)** "Overall ecological outcome" and "Simpler strategy for quality", and **b)** the "Overall self-perceived outcome", "High social, low practical outcomes", and "High family, low individual outcomes" between the pre-COVID year (2019), COVID year 1 (2020), and COVID year 2 (2021). The values are the mean, their standard error, and 95% confidence intervals extracted from the model outputs. Therefore, they include all the other variables included in the models controlling for the results. There is a significant difference between **a)** the pre-COVID year and COVID years 1 and 2 in "Simpler strategy for quality", and **b)** between the pre-COVID year and COVID year 2 in "Overall self-perceived outcome" and "High social, low practical outcomes". Non-significance marked NS, p-value < 0.05 marked *, p-value < 0.01 marked **, and p-value < 0.001 marked ***.

The results of Chapter **II** show that even the outcomes of a small SES with rather low economic importance are influenced by wider societal changes - as predicted by the SES framework [2, 4]. The results suggest that gardeners remain motivated to take care of the cultivations and assign higher general importance to the activity, but rather paradoxically, report receiving fewer outcomes from it. The divergent findings for the overall ecological and self-perceived outcomes support their disconnection found in Chapter **I**. We observe some kind of strategy change: gardeners establish simpler cultivations with fewer species and individuals which then enable them to reach higher quality. Changes in gardening habits due to the pandemic have also been reported in other studies, and there are several possible reasons [71]. It is possible that because of the stressful situation, gardeners wanted to keep the activity less complicated [72]. Also, gardeners might have had more time which led to more informed decisions and higher quality [67, 134]. The negative influence of the COVID-19 pandemic on the benefits gardeners self-perceive to receive from the activity was against our expectations based on the increase in importance and free time [71, 135]. However, there are several possible reasons for the finding. First, the boxes are placed in a public place which can increase concerns about getting infected with COVID-19 and thus decreasing the perceived benefits [68, 136]. Second, even though gardening promotes well-being and positive emotions during the pandemic as found in several other studies, they can still decrease when compared to before the pandemic [72, 74]. Therefore, the result indicates that the negative influence of the pandemic and the policy measures also extends to urban gardening [55]. Third, as many gardeners gave higher importance to gardening, it might have led to higher overall expectations consequently lowering the perceived benefits. We find that during the pandemic, gardeners evaluate to receive more social and less practical benefits. The finding suggests that the already high social importance of the activity strengthened due to the disturbance that involved for example social restrictions [63, 137, 138]. Larger gardening groups in Turku present characteristics of urban green commons. It could be beneficial to investigate if the urban green commons form of the activity provides more individual and community resilience than individual gardening [45].

We find several signs of long-term adaptation or even transformative change in the urban gardening SES due to the COVID-19 pandemic [44, 61]. The positive change in attitudes grew, applications for new boxes multiplied, change in self-reported outcomes strengthened, and in gardening strategy remained. The gardeners and the gardening community showed the ability to change which could lead to a larger transformation increasing resilience toward future disturbances [58, 61]. However, the transformative change and whether it is beneficial for urban gardening should be verified after the disturbance. The work supports that urban gardening promotes resilience during disturbances but its outcomes are diversely impacted and with possible long-term consequences.

3.3 Factors promoting hunting groups` sustainable harvest of moose in a co-management system

In Chapter **III** we assessed the long-term trend in moose harvest for Finnish hunting groups who harvested moose in more than 10 years during 2007-2020. Altogether 4279 hunting groups were included in the analyses of which 3537 (83%) were registered hunting societies and 742 (17%) were non-registered hunting groups. On average, moose harvest declined by approximately 1.1% annually (mean = 0.988, 95% quantiles = 0.893:1.088). The objective of the moose management in Finland during the study period has been to reduce the moose density which has led to the decrease in harvest over the years [25]. However, a stable harvest where similar amounts of moose can be harvested yearly is optimal for the hunting groups. Typically hunting groups harvested the maximal number of moose they had licenses for. However, this was not always the case and, on average, hunting groups harvested 81% of the moose they had licenses for during 2016-2020. Hunting groups can affect the moose population demography. A potential conflict may arise in a co-management system if objectives at different levels of the system differ considerably. For the long-term sustainability of the system as a whole, the objectives should be aligned at the various levels.

We find considerable variation in moose harvest between hunting groups across the years. On average, a hunting group harvested 8.0 moose adult equivalents annually, totaling 31 939 adult moose equivalents per year, and a majority (88%) of the total number of moose harvested in Finland during the study period, assuring these groups are representative of Finnish hunting groups. Higher management units explain almost half of the variance in the harvest (41%), as expected due to the differences in the ecological conditions determining the moose population and other regional differences in the management [78]. There were no significant differences in the harvest trend between non-registered hunting groups and registered hunting societies (χ_1^2 = 0.06, P = 0.80) or between groups that shared or never shared a moose hunting license (χ_1^2 = 0.15, P = 0.69). However, we find that within registered hunting societies, moose harvest was more stable (geometric mean approaching one) in older societies and in hunting societies where leading board members changed more often (Table 2). There are several possible explanations for the findings. In older societies, experience and knowledge about the resource and the social and ecological context can lead to more sustainable outcomes [2, 100, 139]. Historically, moose population has fluctuated dramatically in Finland which is undoubtedly challenging for hunting groups [80]. Therefore, hunting societies that are not managed well are likely to be eliminated over the years. It is also possible that there are localized areas which support a more stable moose population where hunting societies then persist and continue harvesting regardless of overall population fluctuations. We present two non-exclusive possibilities for the positive influence that frequent leadership turnover seems to have on the hunting groups. First, frequent changes in leaders imply high social capital in the group and well-functioning democratic arrangements which in turn reduces the possibility of power hoarding [140-142]. Changes in leaders ensure that power and responsibilities are shared rather than accumulated to certain individuals [142-144]. Second, the groups must have members interested in becoming leaders and taking responsibility implying a well-functioning group, high social capital, and member commitment [143, 145]. Our findings in Chapter **III** suggest that rather than the longevity of the leadership increasing trust and cooperation, as expected, a dynamic social structure in the groups is associated with a more sustainable ecological outcome [19, 146]. Our results emphasize that regardless of a well-functioning management system, a deeper understanding of the resource user level can enhance sustainable and stable outcomes in the long term [142].

Table 2. Mixed model of the geometric mean proportional change in moose harvest of 3434 registered hunting societies during 2007–2020. Fixed and random effect estimates are provided with their standard error (SE), and test statistics. Fixed effects were tested with a Wald chi-square test and random effect variance components using the Z test. The fixed effect "Not shared a license" is the contrast to hunting groups that shared a moose hunting license during 2016–2020. For random effects, also the proportion of total variance explained for each random effect (prop) is provided. The fixed effect "Year founded" is standardized to have the mean year (1970) as zero. The fixed effect "Number of boards" notes the number of times the society was led by different boards (chair, vice-chair, secretary) as reported to the Finnish Patent and Register Board since 1985, and is relative to its median 4. The fixed effect "Board members shared surnames" denoted whether surnames were shared among leading board members each time they changed. Significant fixed effects and (for random effects) significant proportions of variance explained are printed in bold.

FIXED	**ESTIMATE**	**SE**	**WALD χ^2**	**P**
INTERCEPT	0.994	0.00520		
NOT SHARED A LICENSE	-0.0007	0.0022	0.20	0.65
YEAR FOUNDED	**-8.19e-05**	**4.69e-05**	**11.4**	**<0.001**
NUMBER OF BOARDS	**5.65e-04**	**2.56e-04**	**6.7**	**0.010**
BOARD MEMBERS SHARED SURNAMES	3.38e-4	1.57e-3	0.046	0.83
RANDOM	**Estimate ($x10^{-4}$)**	**SE ($x10^{-4}$)**	**Z**	**prop**
WILDLIFE AGENCY REGION	2.99	1.47	2.03	**0.12**
MOOSE MANAGEMENT AREA	1.79	0.90	1.99	**0.07**
GAME MANAGEMENT ASSOCIATION	5.82	0.75	7.71	**0.24**
RESIDUALS	13.72	0.35		**0.56**

3.4 Is it possible to have fun while following the rules? Social and ecological sustainability in moose management

In Chapter **IV**, the social and ecological outcomes of hunting group management and factors promoting them were assessed by a CFA and SEM. The outcomes – hunting groups` decision-making, joint action, and natural resource management latent variables – were significantly measured by all their indicators. Higher values reported for the statements in the questionnaire measured presumably more sustainable outcomes (Figure 5: right side). The very high correlation in the CFA model between decision-making and joint action (0.935) indicates that the latent variables measure basically the same phenomenon, in this case, the social outcomes of moose hunting. However, they are considered conceptually separate in this study. Natural resource management is moderately positively associated with both social outcomes (decision-making: 0.459, joint action: 0.524). This suggests that the social and ecological outcomes of Finnish moose hunting SES are connected at the resource user level [25]. When hunters positively evaluate their group`s decision-making and other joint actions, the hunters and their groups also tend to follow the hunting recommendations and perceive the local population to be sustainable, and vice-versa. Evidently, moose hunting is a multifaceted activity and hunters seek a variety of social benefits in addition to a stable harvest [93, 95]. The result suggests that improvement of the social cohesion in hunting groups could be one way to improve hunters` compliance with higher-level wildlife management. Therefore, satisfactory social outcomes originated by the hunting activity are required to ensure a sustainable moose population in the long term through the hunting recommendations [147].

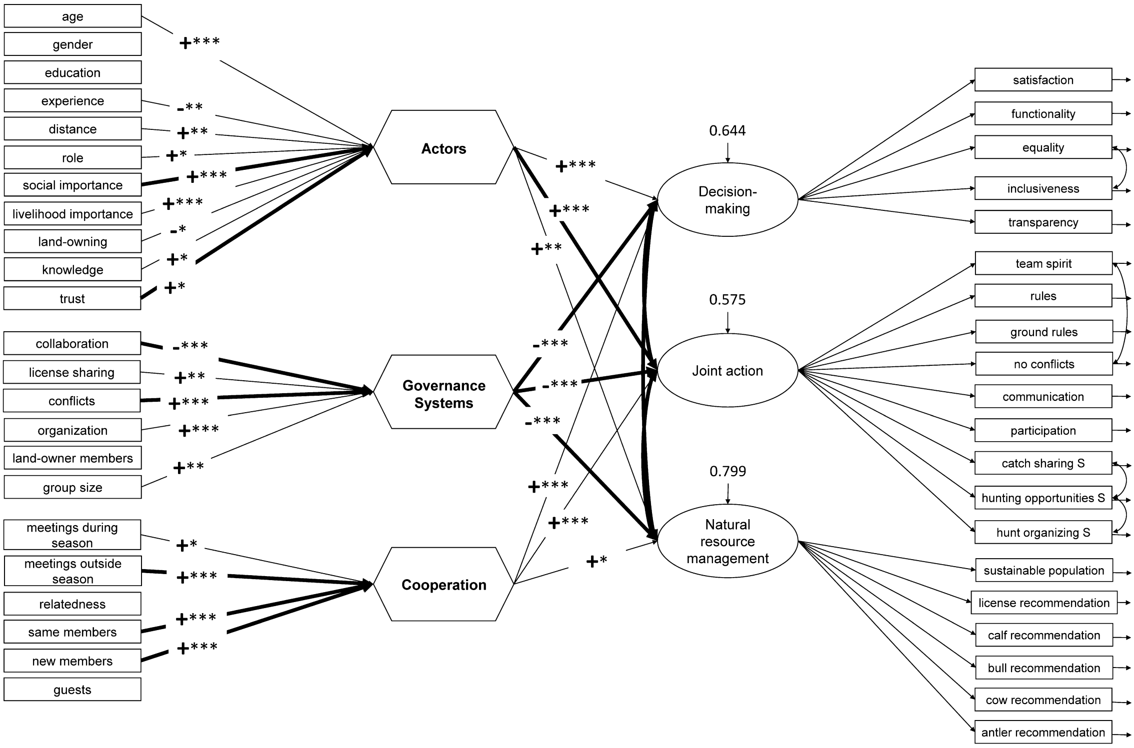

Figure 5. Structural Equation Model (SEM) results for the significant values in the model. CFA model values are presented in Figure 2 of chapter **IV**, and therefore they are not included here. For factor loadings on the composite variables and on the latent variables, we present if they had a positive or negative influence and with asterisk how significant the connection is (p-value < 0.001 = ***, p-value < 0.01 = **, p-value < 0.05 = *). The standardizes error terms (variance not explained by the SEM) are marked for each latent variable. Arrows for factor loadings with values over 0.3 are bolded in the figure as they signify a high factor loading.

According to the SEM, we find that particularly the Governance composite, i.e. the differences in the hunting groups and their relations with other groups seem to align social and ecological outcomes of the hunting group (Figure 5). However, all the composite factors influence significantly the outcome latent variables, even though some have lower factor loadings. More specifically, certain variables were found to be relevant in constructing the composite factors. We find that for Governance, the more the groups collaborate with other groups, and the fewer conflicts they have with other actors in the area, the higher the outcomes. The importance of collaboration and either the absence of conflicts or well-functioning conflict-resolution mechanisms are strongly supported by previous research [92, 129, 142]. They both create shared knowledge, trust, and social capital enabling better hunting strategies and group management [4, 8]. Positive social control can also increase, which then leads to higher compliance with the hunting recommendations [17, 92]. Unresolved conflicts or power asymmetries need to be considered extremely carefully in co-management settings [140, 148]. Possibly, monitoring mechanisms for the hunting groups` collaboration, conflicts, and conflict resolution could provide useful information for the managers to improve these aspects in the future. For Actors composite, the higher social importance hunters give to the activity and the more they trust the population estimates made by Natural Resources Institute Finland, the higher the outcomes. The former supports that strong social networks and high social capital are positive for successful natural resource management [96, 142, 149]. High social importance can thus increase commitment to the activity which facilitates the organization of group management [4, 16]. The latter highlights the importance of trust between the levels of management for long-term sustainability. The population estimates are an integral part of the system because the decisions regarding moose licenses are made based on them [99, 150]. Clearly, when hunters trust the scientific knowledge upon which decisions are made, they follow hunting recommendations more often [91, 142]. Interestingly, that also positively influences the social outcomes which might imply a general satisfaction and trust extending from the group to the higher management levels. For Cooperation, the more frequently the same members stay in the group, the more frequently new members are accepted into the group, and the more the hunters meet each other outside the hunting season, the higher the outcomes and particularly the social ones. Stability created by long-standing members probably increase reciprocity and trust between the hunters, leading to positive outcomes [139, 146]. Also, the knowledge created with time stays in the group [100]. Noteworthy, it seems that groups with a combination of committed members and frequently accepted new members are associated with positive outcomes. New members imply a dynamic group where new energy and ideas are perceived positively which then creates positive outcomes. Lastly, hunters meeting each other often even outside the hunting season indicates strong social ties between them. Strong social ties increase trust and promote shared norms, rules, and strategies as supported by research in other SESs [2, 17, 96, 129]. Overall, most of the significant variables promoting sustainable outcomes in a moose-hunting SES are related to high social capital and suggest that it should be maintained and increased at all levels of management.

Two variables were investigated in both Chapters **III** and **IV** but were not found significant in either in promoting sustainable outcomes. The variables were whether the hunting group was registered or non-registered and whether the hunting group collaborated through license-sharing or not. The findings are in contrast with our assumptions based on research in other SESs [129, 140, 151]. However, there are some possible explanations. First, about 20% of the hunters belonging to a registered hunting society reported in the questionnaire that their society does not function as democratically as it should regarding the two annual meetings and decision-making practices [152]. Second, the finding that registered hunting societies with higher turnover in leaders reach more stable moose harvests also suggests variability within the societies. Third, it can be that the non-registered hunting groups function democratically even though they are not required to do so. In the future, it would be beneficial to explore how the required democratic decision-making of the registered hunting societies is realized and whether it is possible that the societies are less democratic than intended. The second variable found not to be significant in the studies in Chapters **III** and **IV** was the collaboration between hunting groups through license-sharing. The finding is surprising since license-sharing is a mechanism created to improve information sharing, coordination of strategies, and more sustainable hunting [17, 22, 78, 142]. In Chapter **IV** we however find that collaboration and fewer conflicts between the groups are significant for the management. The finding indicates that in addition to license-sharing, another type of collaboration happens and might be more influential at the local level. However, to understand the result better, it would be important to explore how the groups collaborate in other ways than through license-sharing.

4 Conclusions

4.1 Key findings

4.1.1 Urban gardening

The results of Chapter **I** show that the objectively evaluated ecological outcomes and self-perceived social, ecological, and individual outcomes are decoupled in urban box gardening: the primary motivations for box gardening lie somewhere else than in successful cultivations (Figure 6) [9]. I suggest that when the sustainability of SESs is evaluated, both objective and self-evaluated measurements should be used to create a realistic understanding of the outcomes [124]. Clearly, careful planning and implementation of the programs are required for urban green spaces to reach their high potential of multiple well-being benefits, local biodiversity, and urban resilience [32-34, 45, 153]. Possibly, increasing awareness and knowledge about how to improve local biodiversity and achieve higher ecological outcomes could strengthen the connection between the outcomes of our study system [34, 125]. The observed challenge of decreasing outcomes over the years shows that it could be beneficial for the program to carry out long-term studies and monitor the activity in order to understand how the gardeners` motivations and satisfaction change over time and how they could be maintained. Based on the findings, two aspects can be highlighted to increase the self-perceived outcomes. First, to promote the social aspects of urban gardening [22, 130]: when gardeners meet each other often, help each other, get to know new people, and receive positive feedback, they are more satisfied and evaluate to reach higher benefits from the activity. It is possible that developing the program towards urban commons could improve the outcomes even more. Second, the location of the boxes is relevant. Gardeners with boxes in sunnier locations evaluate to receive more from the activity. In addition, the perceived safety of the box location increases the benefits. A safe location probably increases gardeners` trust that they can invest more in their cultivations.

In Chapter **II**, the findings suggest that urban gardening promotes individual resilience most probably by helping people to cope with the challenges COVID-19 caused to mental, social, and physical well-being [67, 69, 72, 73, 154, 155]. Compared to other urban gardening, garden boxes and similar small-scale urban gardening programs can be a rather easy and cost-efficient solution to increase resilience in cities. I find that during the pandemic, gardeners remain motivated to produce overall ecological outcomes but they change to simpler strategies (Figure 6). However, the negative influence of the COVID-19 pandemic extends to the self-perceived benefits received from gardening. Therefore, the positive influence of urban gardening decreases during disturbances. My findings suggest that establishing an urban gardening program is not enough but further effort, such as participatory planning and long-term monitoring can assist in recognizing different needs and challenges in times of disturbances [38, 45, 65, 70]. In addition, during disturbances the motivational effect of social benefits is emphasized, and the program can benefit from a development toward more social settings such as urban green commons [48, 138]. In a rare before-after study setting, I offer new evidence that the influence of the pandemic continues after over a year from the lifting of the restrictions, which suggests a transformational change [61, 156]. Such transformation could lead to a larger societal change increasing long-term individual and community resilience [58]. I conclude that the sustainability of urban gardening and the resilience it produces are influenced by changes in the wide societal settings, as expected [2, 4]. However, the influence is not straightforward and affects different parts of the system differently. Therefore, a profound understanding of the system dynamics at the resource user level is needed to design them well and increase their adaptability in times of crisis. Concluding, my studies on this topic support that urban green spaces and urban gardening programs should have a permanent and secure place in cities for their multiple positive outcomes and resilience [68, 154].

4.1.2 Moose hunting

In Chapter **III** I show that there is substantial variation in long-term moose harvest maintaining the social sustainability of the activity among the over 4000 Finnish hunting groups in the study (Figure 6). I find that regardless of the importance of national and regional management, as well as regional ecological conditions, the level of the resource users plays a role in successful co-management [23, 78]. Resource users implement the decisions and influence the probability for sustainable management of the system as a whole. The study reveals that moose hunting is a good example of the varying definition of sustainability when the objectives seem to not be the same at the different levels of management. I find that the early establishment of the hunting groups and their longevity improve the possibility of reaching a more stable moose harvest over the years. The finding indicates that the knowledge the group collects over the years about the resource system and group management is valuable for sustainable harvest [4]. The second significant characteristic, a frequent turnover of leaders in the group, suggests that an active and democratic hunting society with committed members correlates with more socially sustainable resource management [144, 157]. However, I suggest that the processes of democratic decicion-making in the hunting societies should be investigated in more detail. Even though the Finnish moose management system is quite top-down managed, the study reveals that a deeper understanding of the resource users, the hunting groups, can increase the sustainability of the management system [4, 129].

The findings in Chapter **IV** suggest that the ecological and social outcomes are connected in moose hunting at the resource user level (Figure 6). The hunting groups` decision-making, other joint action, and satisfaction with them are connected to the compliance with and support for hunting recommendations given. The results shows a positive dynamic between the levels of the management system by disclosing that satisfaction with the group and with the management system overall are connected. Therefore, the support and information provided for hunting groups to improve their functions can strengthen the entire management system. The study offers a novel insight into the SES framework by two significant factors, new members and same members, inspired by the evolutionary theory of cooperation [17, 20, 146]. When committed members stay in the group but also new members are regularly accepted into the group, sustainable outcomes are promoted. The findings in this study emphasize that the social capital created in the system is more important for sustainable management rather than hunters` identity [91, 103, 104]. Therefore, processes that increase social capital and facilitate communication between the individuals within a hunting group, between the groups, and between the levels of management, such as trust, face-to-face meetings, and collaboration, should be promoted to improve sustainable outcomes [83, 142].

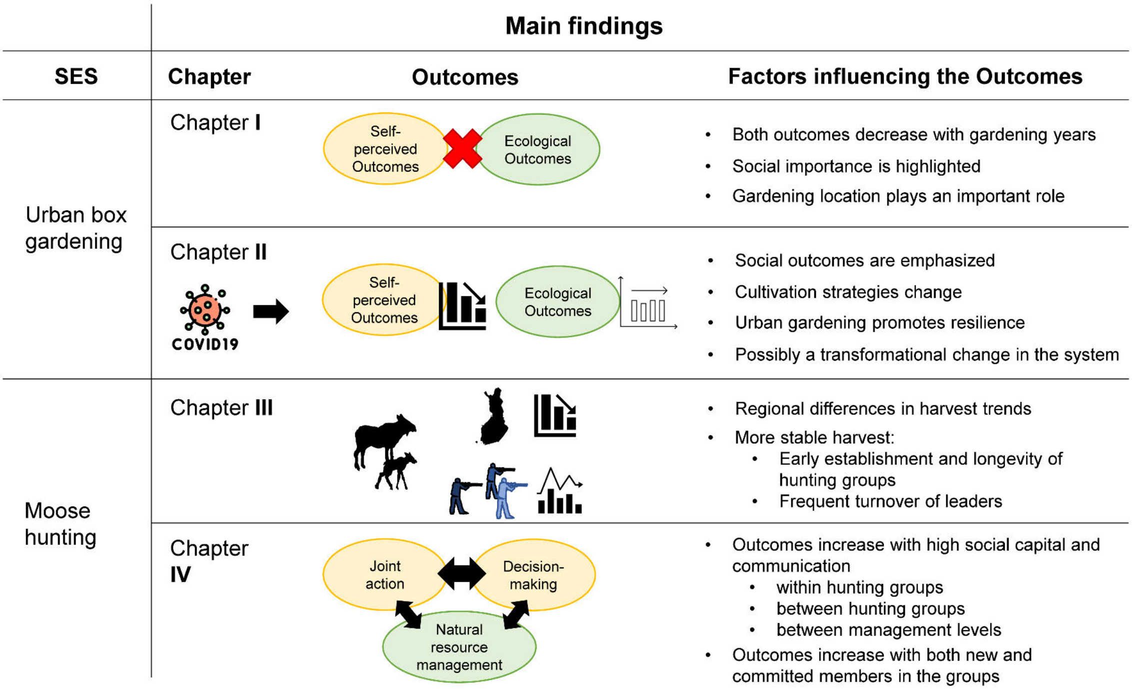

Figure 6. A visual summary of the key findings in each Chapter of the thesis. On the left, the Social and/or Ecological Outcomes of the SES and their connection to each other or change in time are presented. On the right, the key findings considering the factors influencing the outcomes are listed.

4.1.3 Management of the Social-Ecological Systems

Overall, I conclude that treating natural resource systems as integrated social-ecological systems is beneficial for research as well as their management [13]. The SES framework is applicable in studies of urban gardening and wildlife management allowing insightful analysis and offering deeper understanding. One challenge in the SES research as well as in this thesis has been the combination of both social and ecological data [86]. However, the laborious method is worth the effort when possible since it can uncover important associations between the different parts of the system. Wicked problems (social conflicts) clearly require adaptability of the management in changing conditions, such as disturbances and in different contexts [3, 4]. The studies in two different resource systems show that the interconnection of social and ecological parts of the systems differs between natural resources. However, in these two very different SESs similar social interplays, such as frequent meetings seem to drive the higher outcomes. The findings highlight that the relevant social outcomes in natural resource systems extend beyond the scope of just economic and livelihood benefits [124]. The Structural Equation Modeling method used in Chapters **I** and **IV** accounts for the multifaceted nature of sustainability as well as the difficulty of ever measuring it comprehensively, therefore improving the possibilities for comparison between different case studies and SESs [28, 123]. My results highlight that the study of natural resource management should pay more attention to social dynamics, including interpersonal trust and the ability to collaborate, as it tries to establish how to optimally manage scarce, non-renewable resources. A deeper understanding of the resource user level, which has been the focus of this thesis, can improve the adaptability and functioning of management systems.

4.2 Implications for future management practices

The core idea of my thesis has been to improve the understanding of the social and ecological sustainability of natural resource management at a resource user level. However, an aspiration to create practically applicable knowledge is deeply embedded in my work. Therefore, I chose to offer a list of practical recommendations for the management of urban gardening programs and moose hunting based on the findings of this thesis. However, I suggest that the recommendations should not be forced but rather provided for the resource users or the managers, and their effect monitored in different contexts and over time.

4.2.1 Urban gardening

The recommendations based on the findings of Chapters **I** and **II** for the sustainable management of urban gardening programs.

- A formulation of mechanisms to create knowledge and provide information for participants about how to improve local biodiversity and reach high ecological outcomes could strengthen the connection between ecological and self-perceived outcomes (**I** & **II**)
- Urban gardening initiatives and programs should monitor changes in the satisfaction and motivations of the participants to ensure their long-term success (**I**)
- The social importance of urban gardening is high. Increasing positive social interactions such as face-to-face meetings and reciprocity and community spirit between the participants and developing the program toward urban green commons could increase their satisfaction (**I** & **II**)
- The location is relevant. In the case of urban gardens, sunny locations and the perceived safety of the location increase the outcomes (**I**)

- Access to urban green spaces and urban gardening should be ensured during disturbances and crises if possible. When restrictions for social interaction and recreation as policy methods are implied, the social importance of the activity seems to strengthen (**II**)
- Maintaining the most important benefits provided by urban gardening for participants during disturbances might require additional effort. The relative importance of the types of sought benefits appears to change during societal disturbance. Therefore, bottom-up and participatory mechanisms could assist in maintaining the positive benefits (**II**)
- Urban gardening programs might be settings for beneficial transformational change improving individual and community resilience (**II**)

4.2.2 Moose hunting

The recommendations based on the findings of Chapters **III** and **IV** for the sustainable management of moose hunting.

- Multi-level management is required for many SESs, but the sustainable objectives at different levels of the co-management management system should be in line in the long term (**III**)
- When the natural resource users are organized in groups, the management system and stable and sustainable outcomes seem to benefit from the early establishment and the long-term persistence of the groups (**III**)
- A dynamic group where new members are regularly accepted while members are also committed to the group and where democratic rules ensure the regular turnover of the leaders of the group should be promoted (**III** & **IV**)
- In order to improve compliance with and support for the recommendations ensuring sustainable ecological outcomes, the moose management system should focus on the group dynamics and decision-making in the groups of resource users and users` satisfaction with them (**IV**)
- A strong emphasis on creating mechanisms to increase social capital between the individuals within an organized group, between the groups of individuals, and between the levels of management promotes the social and ecological outcomes of the management. Such mechanisms are, for example, organizing social gatherings in the group, monitoring collaboration and conflicts between the groups, creating conflict-resolution mechanisms between the groups, involving resource users in higher-level decision-making, or increasing transparency of the decisions (**IV**)

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Laura Sofia Tuominen

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