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Arable land per capita in the world – its changes and consequences on agriculture production

Bachelor's Thesis

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Sustainable Use of Natural Resources

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Declaration

I hereby declare that I have authored this bachelor's thesis carrying the name „Arable land per capita in the world – its changes and consequences to agricultural production" independently under the guidance of my supervisor. Furthermore, I confirm that I have used only professional literature and other information sources that have been indicated in the thesis and listed in the bibliography at the end of the thesis. As the author of the bachelor's thesis, I further state that I have not infringed the copyrights of third parties in connection with its creation.

In Prague on date of submission ____________________________

Dedication

This thesis is dedicated to my beloved father, the late Peter Thomas Kraft.

Acknowledgements

I would like to acknowledge Theresa Ann Reinhardt Piskáčková, Ph.D. for her invaluable mentorship and guidance.

Orná půda na obyvatele ve světě – její změny a důsledky na zemědělskou produkci

Shrnutí:

Využití orné půdy se v minulém století drasticky změnilo v důsledku měnících se globálních zemědělských trhů, opouštění půdy, urbanizace a nárůstu populace. Tato práce podává přehled literatury zabývající se změnami ve využívání půdy a jejich hnacími silami - urbanizací, nakládáním s odpady a politikami v Evropské unii. Pojednávám o těchto sektorech společně, abych zdůraznila, že se nejedná o ojedinělé problémy, které je třeba vyřešit, ale o vzájemně se významně ovlivňující jevy, jež by proto měly být při vytváření souhrnné politiky považovány za jeden. První část je přehledem využití půdy od její historie až po současnost a poskytuje údaje o měnících se krajinných oblastech v důsledku hnacích sil, které zahrnují demografii, technologický pokrok, institucionální vlivy, charakteristiky zemědělství a ekonomiku. Zabývám se urbanizací a zalesňováním jako hlavními hybateli moderních změn ve využívání půdy. Druhá podkapitola je přehledem schémat nakládání s odpady v celoevropském měřítku, zabývá se mírou třídění ve vybraných regionech a jaké metody třídění, sběru a nakládání s odpady se v konkrétních regionech osvědčily nejlépe. Podkapitola tři pojednává o agendě oběhového hospodářství, teorii plánovaného chování a zároveň je obecným přehledem evropské politiky nakládání s odpady. Zahrnuje případové studie o tom, jaké metody fungovaly nejlépe a které ze směrnic podnítily změnu. Podkapitola čtyři znovu spojuje nakládání s odpady a další důsledky urbanizace se změnami ve využívání půdy. Pojednává o Společné zemědělské politice, agroenvironmentálních schématech a o tom, kde byly úspěšně a neúspěšně implementovány. Zabývám se trendy jak současnými, tak budoucími. Statistiky Prahy jsou v celé práci udávány pro srovnání toho, jak si město vede vedle cílů EU a dalších městských oblastí na kontinentu. Je zmíněn pokrok v plnění cílů OSN v oblasti udržitelného rozvoje. Zmiňuji se i o pražské iniciativě oběhového hospodářství.

Klíčová slova: využívání půdy, změny ve využívání půdy, zemědělská půda, orná půda, hnací síly změn ve využívání půdy, urbanizace, nakládání s odpady, recyklace, udržitelnost, oběhové hospodářství, politika, agroenvironmentální režim

Arable land per capita in the world – its changes and consequences on agricultural production

Summary:

Arable land use has changed drastically in the last century due to changing global agricultural markets, land abandonment, urbanization, and population increases. This thesis is a review of the literature surrounding land use change and its drivers, urbanization, waste handling, and policies in the European Union. It looks at these sectors together to highlight that these are not singular issues to be resolved, but affect one another significantly, and therefore should be considered as one when creating policy for both. The first part is a review of land use from its history to modern-day and provides figures on changing landscapes due to drivers which include demographics, technological advances, institutional influences, farm characteristics, and economics. It expands on urbanization and afforestation as major drivers of modern land use change. Sub-chapter two is a review of waste management schemes throughout Europe, separation rates of selected regions, and which methods of waste separation, collection, and the treatment worked best for specified regions. Sub-chapter three discusses the circular economy agenda, the theory of planned behavior, and is a general overview of European policy as it pertains to waste handling. It includes case studies on what methods worked best and which directives incited change. Sub-chapter four reassociates the waste management and other urbanization consequences to land use change. It discusses the Common Agricultural Policy, agri-environmental schemes, and where they were successfully and unsuccessfully implemented. Current and future trends are addressed. Prague statistics are supplemented throughout the thesis to give comparisons of how the city is performing next to the goals of the EU and other urban areas on the continent. Progress on the United Nations' Sustainable Development Goals is mentioned. Prague's Circular Economy initiative is addressed.

Keywords: land use, land use change, agricultural land, arable land, drivers of land use change, urbanization, waste handling, recycling, sustainability, circular economy, policy, agri-environmental scheme

Content

1 Introduction

The United Nations recognizes there is an issue with land use change. Rural land is abandoned, agricultural land is lost to afforestation, and people are migrating from rural areas to urban ones. Its relation to population increase, urbanization, sanitation, good waste-handling practices, and food availability is becoming more prevalent. The 2030 Agenda for Sustainable Development and its Sustainable Development Goals map out an ambitious agenda for the coming years in which all are protected from hunger, poverty, and pollution by shifting practice and policy to sustainable paths. Within this agenda are goals that focus on promoting sustainable land use and improvement of urban planning.

Sustainability as a concept is very complex and varied - in recent years it has become its own scientific discipline (Mauri 2020). Terms attributed to sustainability include: zero-waste, bio, organic, all-natural, non-GMO, renewable, eco-friendly, compostable, recyclable, biodegradable, reusable, sustainably-made, cruelty-free, eco-tourism, carbon-offset, and vegan (Mauri 2020). Using 'sustainable' as an adjective has become fashionable and the meaning has become muddled - researchers in sustainability science know this moniker can change; for example, waste-to-energy plants were once considered "sustainable" as they utilized waste as a resource, but now emit too high emissions to be truly sustainable or "eco-friendly". Environmental sustainability is a rather open concept in which any practice that preserves finite natural resources, reuses waste, prevents waste, decreases carbon emissions, embraces a circular economy, and utilizes renewable energy is "environmentally sustainable" (European Commission 2020).

Biodiversity loss, food shortages, climate change, decreased resources, erosion, air, water and land pollution, even the ability to fight infectious disease will worsen if humans do not take the time to reflect, give feedback, and adjust (Foley et al. 2005, Jepsen et al. 2015) the current systems. Understanding drivers of land use change within political, technological, economic, and natural contexts will provide insight into which policies work best to meet sustainability goals (Jepsen et al. 2015). Proper management of waste is a necessary step to support the living environment. The wide-scale adoption of a circular economy wherein zero waste is produced is a hopeful plan with actions that can modify failing linear economic structures. The goals of the EU and the world are those which bring humanity to more sustainable futures. The consequences of waste mismanagement, land abandonment, urbanization and failing policy cannot be ignored, especially in the midst of the climate crisis.

2 Aims of the thesis

What are the effects of policy and consequences of urbanization and waste management on arable land distribution trends?

The aim is to present a literature review using case studies of various countries and statistics from Prague, Czech Republic for comparison to address the issues of arable land change per capita, waste handling procedures, policy implementation, and projected future trends in Europe.

3 Literature review

3.1 Agriculture land distribution and trends

3.1.1 Land classification and world land use trends

Land use surveying and mapping began in Babylon and has continued to today to better understand changes in cadastral and agricultural lands from natural landscapes (Wallis 1981). Studying land use change as it pertains to urbanization and agricultural land abandonment is a relatively new phenomenon, only seen on a wide scale in the last few decades because of newly available tools to measure and analyze it (Meyer and Früh-Müller 2020). Land classification can be done in several different ways with different categories according to the application of the survey; although the change of vegetation cover is typically due to human intervention, intentionally or unintentionally. When discussing land use and particularly agricultural expansion it is most typical to use a form of land classification system that is focused on the man made uses of the land and combining most natural areas under a single category. A typical classification of land is as follows: land underlying buildings and other structures (built-up areas), land under cultivation (this includes forested and agricultural land), recreational land, and other land (OECD 2015).

Within, each category may be further divided according to application of the survey, for instance for governments, land speculators, or restoration. Within agricultural land there are usually three major categories that could be included: arable land, permanent crops, and pastures (Lyuri 2008). These categories represent different levels or frequencies of land disturbance and intensity of management. Arable land is land which is under an annual crop rotation change or may be left fallow, or unplanted, temporarily. Permanent crops include orchards and vineyards. Pastures may be mowed but are seldom if ever tilled. Currently agricultural land comprises approximately 5 billion hectares globally; encompassing 38% of the Earth's total land cover (FAO 2020).

Global agricultural land has been increasing for the last 300 years (Fig. 1). Approximately 12 million km2 of forests have been clear cut, and grasslands and pastures have declined by approximately 5.6 million km2 (Ramankutty and Foley 1999) since that time. This is most rapid in the last 150 years, due to technological innovations from the industrial era (Jepsen et al. 2015, Ramankutty and Foley 1999). In Fig. 1, the change is visually apparent in the lower panels compared to the top by the expansion of orange and red, pasture and cropland, respectively. The regions in which both arable and agricultural land have increased since the

1960s are Africa, Asia, and South America; South America undergoing the largest increase, with a 30% increase in agricultural land and 85% of that increase is arable land. (Lyuri 2008). Presently, 36.9% of the world's landscape is agricultural land (WorldBank 2018).

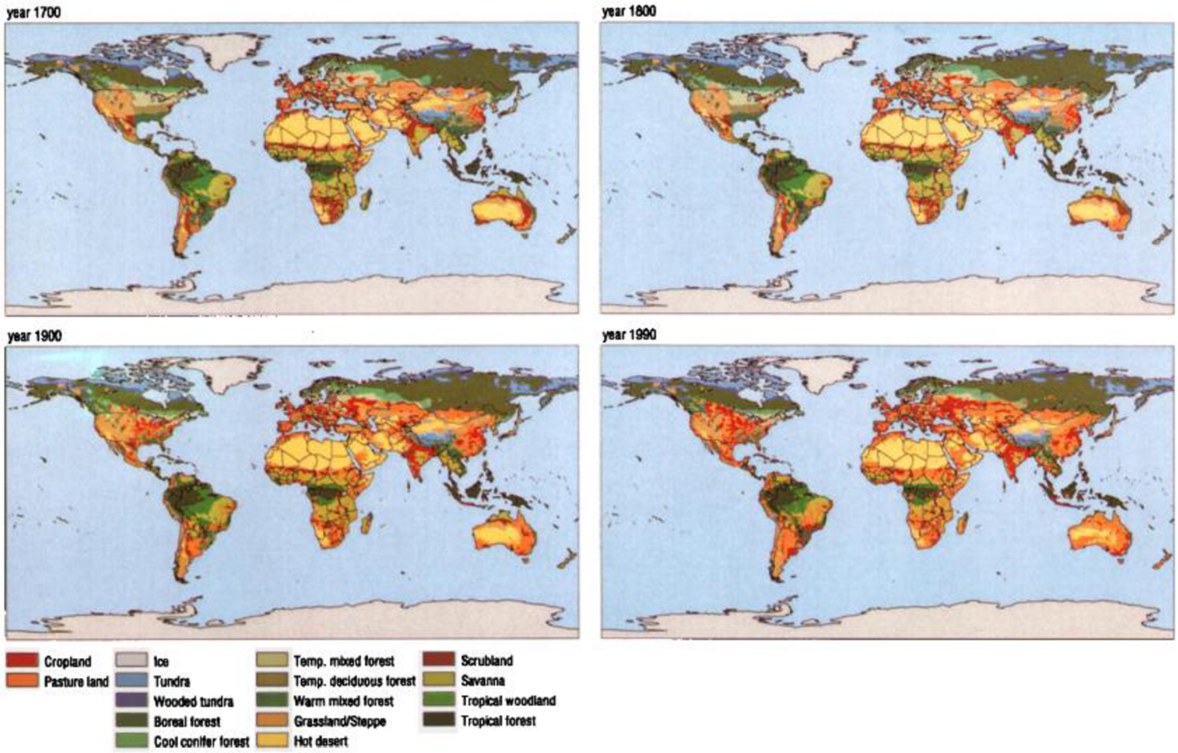

Fig 1 Historical land classifications from years 1700, 1800, 1900, and 1990. (Goldewijk 2001)

Despite increasing global agricultural area, worldwide cropland per capita has decreased from approximately 0.45 hectares per person in 1961 to about 0.21 hectares per person in 2016 (FAO 2020). The world population was approximately 3 billion in 1950, is currently 7.7 billion, and is projected to increase to approximately 11 billion by 2100 (UN 2019). Technological advances, which increase crop production, have been partial to increased human lifespans and the total human population (Frejka 2001). Partly due to these technological advances, resulting in grain and agricultural product surpluses, there have been decreases in agricultural land in Europe, Oceania, North and Central America (Lyuri 2008). Agricultural land in Europe has reduced by 14% in agricultural land and 15% in arable land (figures from 2008) (Lyuri 2008). These trends are also evident at the national level in the Czech Republic (Table 1).

Table 1 Arable Land Change in ha/person on the world, EU and Czech level 1993-2018 (Source: WorldBank 2018)

Region	Year		Net Change
	1993	2018	
	Hectares/person		
World	0.25	0.18	-0.065
European Union	0.27	0.22	-0.049
Czech Republic	0.32	0.23	-0.089

When agricultural land is abandoned, there are two main types of land that replace it. The first is built-up areas such as human settlements, industry, and architecture (Lyuri 2008). The second is fallow areas (Lyuri 2008). The fallow lands naturally get reclaimed by forested land if left abandoned long enough (Lyuri 2008). Both pathways can be problematic for the species that have evolved to depend on agricultural landscapes and the benefits that these species provide to the larger landscape (Lyuri 2008, Bethwell et al. 2022). Ecosystem services provided by agricultural landscapes include provisions such as food and animal fodder; and non-provisioning services including cultural heritage, habitat, and biodiversity (Bethwell et al. 2022). Changing human consumption patterns, increased population, and urbanization will negatively impact provisioning and non-provisioning ecosystem services (Erb et al. 2009). The provisions from agro-ecosystems that do not provide capital are often overlooked by farmers and policymakers; food production and urbanization are given priority, as they result in higher monetary gain (Bethwell et al. 2022). Though the economic value of the forested area is hard to quantify, the ability of large forests have to offset carbon is invaluable (Taye et al. 2021, Hamilton 2022); and though changes can be made to the agricultural sector to offset its carbon footprint, it will not net-zero (Schnieder et al. 2007). Conversely, increased urban populations are generally beneficial to both people and industries, economically, but often have negative environmental impacts (UN 2019).

3.1.2 Modern drivers in Europe

Changes in land use and land quality is never singular; many drivers influence the process in synchrony. (Ustaoglu 2017). Generally, the main drivers across all studies are urbanization, technology, socio-economic factors, policy, more pressure for nature conservation, and biophysical factors (Ustaoglu 2017). Causes of land change can be categorized into five major drivers: demographic, economic, technological, institutional, and socio-cultural; with location factors and farm and farmer characteristics considered as well (Jepsen et al. 2015, van Vliet et al. 2015). Typically, farm and farmer characteristics found to be a major influence on both intensification and dis-intensification according to van Vliet et al. (2015) implying that policy and regional factors have little influence. Demographics and socio-cultural drivers had the least influence on agricultural land use change while technological and institutional drivers had the highest influence on intensification (van Vliet et al. 2015). The most common drivers of land use change and management shifts were land reforms, mineral fertilizer, and farming equipment (Jepsen et al. 2015). The greatest drivers of agricultural land intensification, and thus land changes, are technological and institutional drivers (van Vliet et al. 2015). Access to mechanized farm equipment, and general land and cultivator improvements, government subsidies, land ownership, and policy are all significant variables in agricultural land intensification (van Vliet et al. 2015).

In the case of dis-intensification of agricultural land, farmer characteristics and institutional drivers overwhelmingly had greater influence; economic drivers and location factors were second-highest influential factors (van Vliet et al. 2015). For farm and farmer characteristics, things like land management, farmer age, and land abandonment are greater drivers (van Vliet et al. 2015). Reduction of agricultural land, a change in land management and agricultural land schemes, as well as their subsidies hold greater influence (van Vliet et al. 2015). For economic drivers, employment and urbanization are representative while for location factors, accessibility and soil quality are the most deterministic factors when examining agricultural land dis-intensification (van Vliet et al. 2015). Converse to van Vliet et al. (2015), Ustaoglu et al. (2017) found that demographic drivers of dis-intensification are highly statistically significant in agricultural land use change to urbanization, specifically demographic drivers relating to population changes.

Drivers of landscape change studies carried out in Europe were heavily influenced by the perception of the researcher, whereas a systematic method would be more favourable for consistent outcomes (Plieninger et al. 2016). The ways in which land use researchers study land use change are not uniform, and so data may contrast, even from surveys carried out in the same region (Hersperger et al. 2010). The research could be conducted in a more structured manner. An "organizational heuristic" may be used in which models connect land use change to certain drivers, and within each model are found "core components", being driving forces, actors, and land use change (Hersperger et al. 2010). To define each: driving forces is an amalgam of many different drivers which shape land change - these include economic, technological, cultural, political, and natural drivers (Hersperger et al. 2010). Actors are defined as individuals, agencies, and institutions involved with the organization, use, and change in land dynamics (Hersperger et al. 2010). Finally, land change is a change in usage or coverage of land; this includes urbanization, afforestation, and land abandonment (Hersperger et al. 2010).

In the greater metropolitan area of Nuremberg, 2.7% of agricultural land has been lost to built up areas, and 3.1% to afforestation over the last 15 years (Meyer and Früh-Müller 2020). The agricultural land use changed by comparison to population density was approximately 750 people per km2, and the development rate of the population stayed constant at a maximum of 2.3% annually (Fig. 2). Cost of land per hectare, the slope of the terrain, and soil properties were the most significant factors in agricultural land use change within the region of study (Meyer and Früh-Müller 2020). More expensive land rents were less likely to be converted to forested areas (Meyer and Früh-Müller 2020). Smaller farms had higher rates of agricultural land change (Meyer and Früh-Müller 2020). Generally, the study found that major changes in land use occurred on agricultural land, with conversions to grassland, forested areas, and built-up areas as most prevalent (Meyer and Früh-Müller 2020). As a comparison: Figure 3 depicts two maps of Prague with similar changes to Nuremberg from the years 2012 and 2018. The Functional Urban Area of Prague, between the years 2012 and 2018, had a reduction in agricultural land and increase of built up areas (Fig. 3). Artificial artifacts claimed the largest amount of agricultural land within this time period.

Meyer and Früh-Müller (2020) predict that in the future, this pattern will continue due to a globalized agricultural market, as well as changes in government policies and subsidies. Built-up areas tended to increase within the existing metropolitan area. Afforestation seemed to cluster within areas that were already densely forested. The authors note that the change of agricultural land is likely attributed to weak policy standards within the region, with calls for the “greening” of areas taking precedence over the protection of agricultural land (Meyer and Früh-Müller 2020).

Agricultural land use change in Nuremberg was highly attributed to an increase in population density and unemployment rates (Meyer and Früh-Müller 2020). Low soil quality and high slopes in terrain were major drivers in agricultural land use change; these drivers also accounted for significant amounts of agricultural land abandonment (Meyer and Früh-Müller 2020). Less intensive, smaller farms were at higher risk of afforestation, because small, family-owned farms had less negotiating power than larger, monopolized farms (Meyer and Früh-Müller 2020).

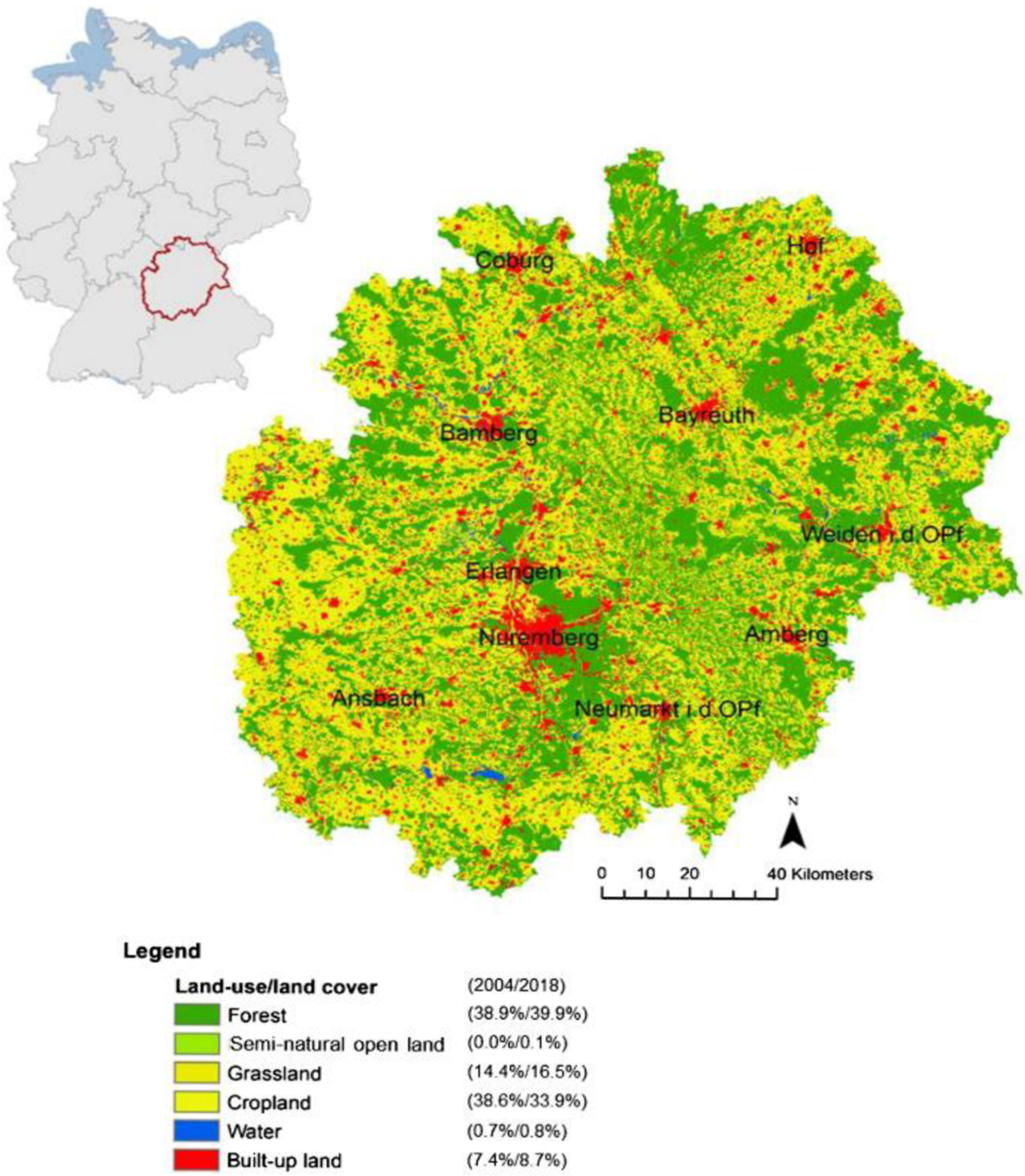

Fig 2 Urban sprawl in the Nuremberg metropolitan area (Meyer et al. 2020).

Fig 3 Land cover categories in Central Bohemia, Czech Republic in 2012 and 2018. According to the bar graph; agricultural areas are in yellow, natural and semi-natural areas are in green, artificial artifacts are in red, water is in blue, and wetlands are in grey. (Urban Atlas 2018)

3.1.3 Urbanization's effect on land use change

In Ustaoglu et al. (2017), they describe urbanization as the main driver of agricultural land loss. Land used for agriculture is typically flat, accessible and generally considered to be less vulnerable than forests or natural areas (Meyer and Früh-Müller 2020, Ustaoglu et al. 2017). Expanding urbanization in Prague has mostly converted agricultural land to built-up areas due to increased population (Urban Atlas 2018). Afforestation has also played a role in the changing of cropland, at least in the Czech Republic and many parts of the EU (Meyer and

Früh-Müller 2020). City-dwellers' preference for and right to recreation in nature has influenced surrounding urban area land use to favor reforestation of otherwise arable land (UN 2019).

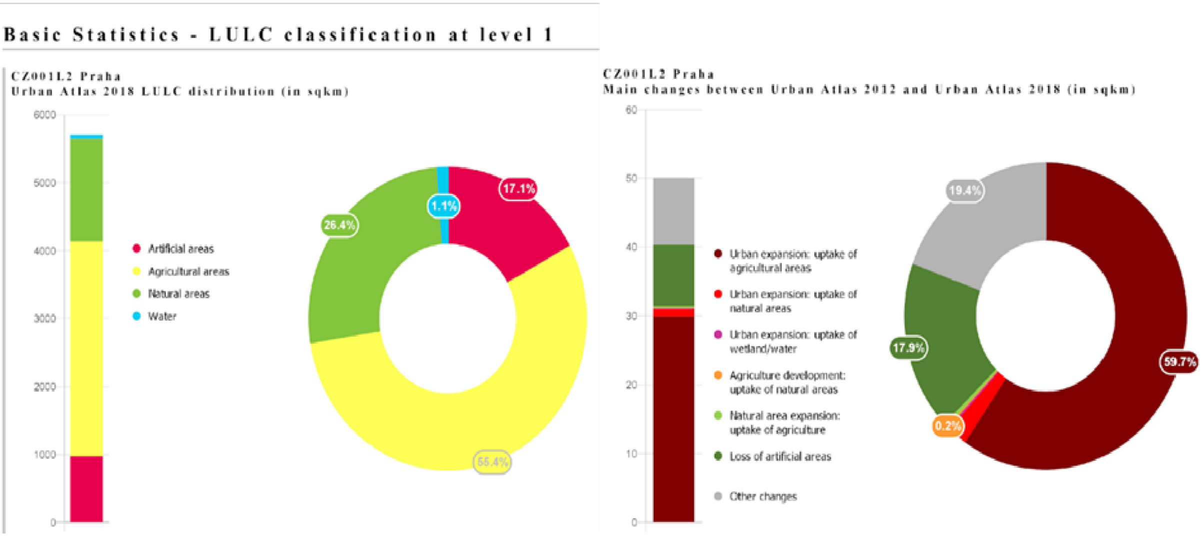

Fig 4 Land classification and net change in km2 in Prague, the Czech Republic from 2012 to 2018. (Urban Atlas 2018) Fig. 4 is selected from Urban Atlas's 2018 land use/land change report on Prague for years 2012 and 2018. The graph on the left represents the total land use for the year 2018. The graph on the right represents main changes in land use in Prague according to Urban Atlas's data from the years 2012 and 2018.

Table 2 Land change in Prague from years 2009-to 2019. (Source: Czech Office for Surveying, Mapping and Cadastre, 2020)

Category	Year		Net Change
	2009	2019	
	Hectares (ha)		
Agricultural Land Total (ha)	20426	19617	-809
Arable Land	14933	14084	-849
Gardens	4	4	0
Orchards	634	591	-43
Permanent Grasslands	871	964	93
Vineyards	10	12	2
Non-agricultural Land Total	29183	30004	821
Forest Land	5	5	0
Bodies of Water	1	1	0
Built-up Areas	5	5	0
Other Areas	18051	18595	544
Total Area	49610	49621	11

Over the last ten years in the Czech Republic, land categorized for agriculture reduced by 809 ha (Table 2). Within agricultural land, are several subcategories. Arable land decreased the most by 849 ha. Orchards lost 43 ha, while there was no net change for gardens, and Vineyards saw an increase of 2 hectares. Non-Agricultural Land Total increased over 821 ha. "Other Areas" had the largest increase by 544 ha. This is followed by Forest Land, with an increase of 0.3 ha, Permanent Grasslands with an increase of 93 ha, Built-Up Areas with an increase of 0.1 while Bodies of Water did not change. The Total Area increased by 11 ha.

Urban expansion is more likely on prime agricultural land (Ustaoglu 2017). Climate also plays a significant role in land use change, with higher temperatures and more precipitation events influencing land use change (Ustaoglu 2017). The elevation and slope of land had less urban expansion, with urbanization occurring on flatter terrain (Ustaoglu 2017). It also appears that recreational and residential developments nearby urban sprawl contribute to the uptake of agricultural land (Ustaoglu 2017). Increased economic opportunities in urban centers contribute to land abandonment and decreased rural populations (Ustaoglu 2017, UN 2019).

European policy which permits early retirement influences decision making of farmers who choose to retire earlier - they are less likely to invest in their land and more likely to abandon it sooner (Ustaoglu 2017). In family-owned farms with no inheritor, the land owner is more likely to rent or sell their farms. New purchasers with less connection to the land have a higher likelihood of selling it to urban contractors (Ustaoglu 2017).

Urbanization has been generally positive for people economically, lifting many out of poverty and offering a wide-scale availability of professional opportunities (UN 2019). It also introduces people to new cultures, gives greater access to the community, access to better healthcare and education, access to more resources, and diversity in general (UN 2019). Developing countries will see the largest urban population booms in the coming decades. A well-informed policy at both supra-national and region-specific levels aimed at making the lives of rural and urban citizens better is necessary to fortify their subsequent economies and environments (UN 2019). If urban expansion is improperly planned and production/consumption regularities remain stable, it will cause an increase in pollution and environmental degradation (UN 2019). Thus, policy adjustments to address the changes in population distribution should be implemented to protect farmers and rural dwellers economically (UN 2019, European Parliament 2013, Reed et al. 2014). Farmers and rural dwellers are at particular risk economically, so keeping population levels at maintenance could be solved with subsidies or other economic benefits to decrease land abandonment, environmental degradation, and loss of productivity (UN 2019, European Commission 2013, Reed et al. 2014).

Reducing the amount of land that is converted to built-up areas can be addressed by a policy reform in which subsidies are improved. Meyer and Früh-Müller (2020) note that these large-scale changes in agricultural land across all conversions imply deficiencies in the Common Agricultural Policy of the EU. They propose comprehensive reform to spatial planning wherein agricultural land is given greater focus (especially compared to urbanization). There is a need for budgetary analysis and its long-term impacts on agricultural production.

3.2 Municipal waste management in consequence to land use changes

3.2.1 Urbanization and waste generation

One of the major consequences of urbanization is the increasing amount of waste (UN 2019, Circle Economy 2019). This is a two-fold problem as urbanization over the last hundred years has created a concentration of the population into urban areas and industrialization creating more waste per person (UN 2019). The expansion of urban migration naturally increases urban waste generation (Purity et al. 2016). The limited space in urban areas makes waste treatment difficult (Purity et al. 2016).

In the mid-1900s the increased waste from industrial booms reached noticeable levels of concern. Previous strategies of waste disposal and management, such as open dumps and burning, were no longer enough to deal with the increasing generation of waste and, especially, the amount of non-decomposable waste which started to have visible damage to surrounding environment (Braunegg et al. 2004, Carvahlo et al. 2014). Plastic waste has become a major problem in industrialized countries (Braunegg et al. 2004). New methods for sorting, energy recovery, and reuse were created to address the problem (Braunegg et al. 2004). Exposure to waste remains an issue for the urban poor, especially in developing countries (UN 2019). To manage urbanization efficiently, policy makers must have a robust understanding of trends in population change, how urbanization degrades the environment, and how to safely handle waste (UN 2019, Circle Economy 2019).

In 2017 most EU countries generated more than 500 kilograms of waste per capita (Fig. 5). Denmark produced the highest amount of municipal solid waste and Romania produced the least. Czech Republic is among the lowest producers. Countries with higher GDP tended to be more wasteful. However, waste generation should not be conflated with waste treatment. A country which is a high producer of waste may be more effective at treating it than a country that is a low producer of waste.

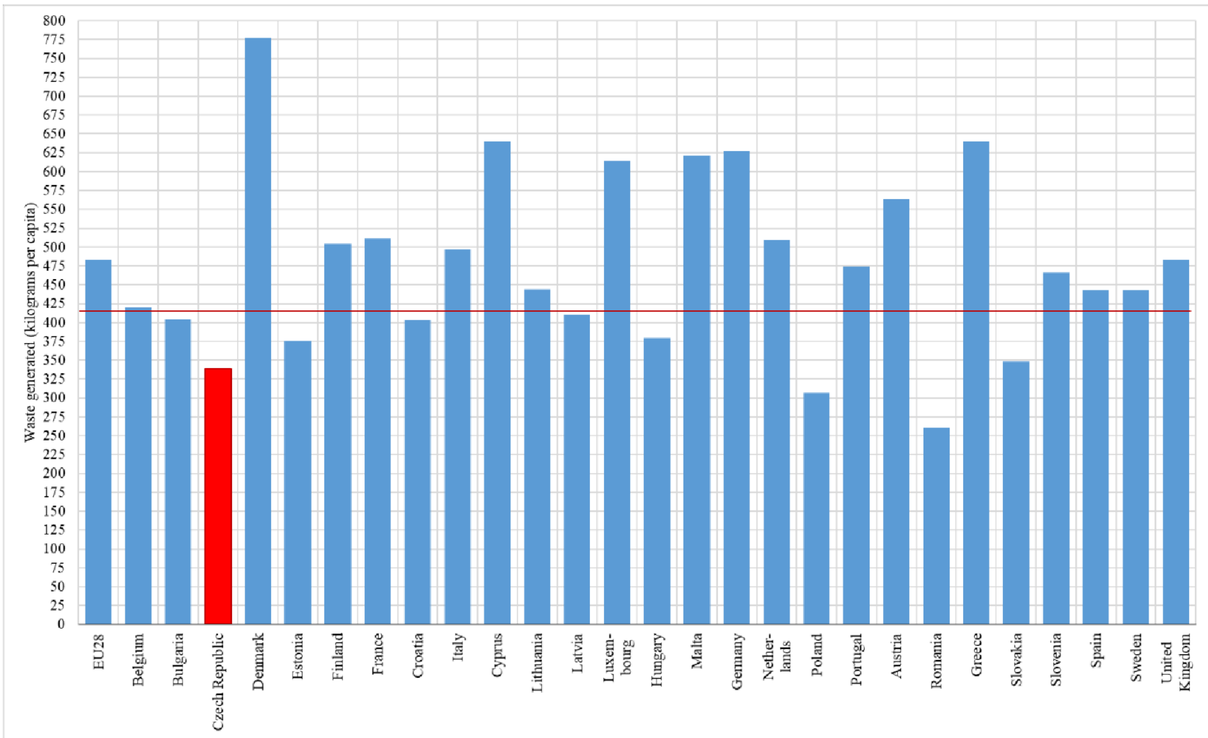

Fig 5 Municipal solid waste generation in EU28 for the year 2017. The average rate of recycling is shown as a red line crossing through the bar graph. The Czech Republic is highlighted in red (Source: Eurostat 2017).

3.2.2 Waste impact on land utilization

Given the limited space of urban areas, waste becomes increasingly difficult to handle, dispose of and treat. Waste treatment plants develop on land in the greater metropolitan areas that could be used, or once was used, for agricultural purposes, or clear-cut forests for waste treatment plants (Meyer and Früh-Müller 2020, Ustaoglu et al. 2017). Land suitability assessments are currently used when selecting sites for landfills in urban areas, determined by experts who consider multiple factors including ecological and economic values (Marull et al. 2007). These decisions are more critical and complex with global population increases and urbanization, and concerns for public health and the environment (Demesouka et al. 2019). Pressure from the public to keep waste treatment facilities away from residential areas limits the available space for these developments, meaning landfills will be more frequently used (Demesouka et al. 2019).

Increased industrialization in small areas creates air pollution as well as areas that are uncharacteristically warm due to densely packed urban industry, or "heat islands" (UN 2019). Waste may also be shipped to rural areas, open dumps, and ocean dumps, leaving land and water sources vulnerable to pollution (UN 2019). The shrinking rural population means there are fewer people to properly manage waste sent to these regions, or they lack the technology needed for proper disposal of waste (UN 2019, Circle Economy 2019). This damages ecosystem services and public health.

Facing these consequences may lead to policy implementation and action. A modern example is Portugal; one of the first European countries to focus on environmental protection (Costa et al. 2010). Prior to 1997, Portugal had a problem with open landfills that contaminated soil and groundwater. It led to a national legislation: 'Strategic Plan for Urban Waste Management Services' (Carvahlo et al. 2014). In result, 300 open dumps were closed and the construction of municipal solid waste and recycling facilities took place (Carvahlo et al. 2014). By 2011, Portugal improved its plastic packaging recycling, recycling 64% of packaging by weight (Carvahlo et al. 2014). This exceeded the 55% goal given by the EU's Packaging and Packaging Waste Directive.

3.2.3 Waste management in Europe

With new understandings of the impact waste mismanagement has on human health and the land, policies were put in place to reflect this understanding and correct the practice. The Waste Framework Directive, developed by the European Parliament and Council in 2008, focuses on the prevention of pollution, increased waste recycling, better public health, and environmental protections. The directive defines a waste hierarchy of policy priorities: 1) prevention, 2) recovery methods, and 3) disposal methods (European Parliament 2008, Directive 2008/98/EC). Implementation of this directive has diverted approximately 7.6% of waste from landfills between the years 2010 and 2018. Waste sent to landfills from urban areas in the EU as a proportion of the waste generated decreased from 23% to 20% in the same time period (EEA 2021). (Data from the European Environment Agency is collected from Eurostat, which collects and validates their data in collaboration with member states).

For some waste streams, such as mixed households and similar waste, relatively good progress has been made towards diverting waste from landfills (EEA 2021). However, the amount of sorting residues sent to landfill has doubled since 2010 (EEA 2021). Up to a third of all waste handlers in Europe have poor environmental performance. This includes how well the waste management sectors handle waste recovery, waste recycling, treatment of waste, and waste diversion. (Fikru 2014).

3.2.4 Waste handling case studies

Municipal solid waste (MSW) is categorized as a type of waste produced by households, hospitals, and businesses; it is the end-product of everyday items such as packaging from products, bottles, food scraps, unwanted textiles and furniture, lawn debris, appliances, and paint (EPA 2016).

Abeliotis (2011) provides a life cycle assessment of municipal solid waste. The life cycle of MSW begins with the production of an item to be purchased or consumed in some way. Once the item is disposed of it becomes municipal solid waste; which is disposed of in mixed bags, residential bins, curbside bins, commercial dumpsters, or municipal dumpsites. These receptacles are periodically emptied by waste management services and sent to waste treatment facilities to be sorted.

The sorting process involves separating plastic, glass, paper, metals, organic waste, and electronics (Abeliotis 2011). The recyclable materials are compressed into bales and purchased by facilities that use the materials to create new products (Abeliotis 2011). Compostable organic wastes may be sent to composting facilities (Abeliotis 2011). Some residual waste gets incinerated (Abeliotis 2011). The remaining waste, which includes non-recyclable materials, ashes from incineration plants, and non-compostable organic waste, are shipped to landfills (Abeliotis 2011). Plastic content makes municipal solid waste less desirable as a non-renewable energy source. The plastic can be sorted, recycled, and put back into the system. The emissions from burning plastics should also be taken into account, according to Horttanainen et al. (2013), before being burned for energy.

Life cycle assessments monitor the consumption of resources, the emissions to air, earth, and water, and the creation of products (Abeliotis 2011). Inputs and outputs, such as energy resources and emissions respectively, are taken into account during the life cycle inventory phase of life cycle assessments (Abeliotis 2011). Nearly all materials (plastics, paper, metals, glass, oil, some timber, and textiles (Abeliotis 2011)) may be recycled after their original use at a portion of the energy required to derive the material from their primary source (Henstock 1976). Amelioration of the environment and cheaper costs as a result of recycling materials as opposed to extracting new materials from finite sources renders the practice superior both environmentally and economically (Henstock 1976).

Despite the benefits of recycling, issues of waste separation remain common. The actual MSW generation per capita in the European Union was in recent years around 500 kg (Eurostat 2014). Logistics, costs incurred, the volume of waste and increasing population all complicate the process of waste recycling. Because of the negative environmental and health consequences associated with landfilling and burning, municipal waste management is considered improved by redirecting waste into recycling or composting. Therefore, more attention has been directed at measuring the efficiency of waste sorting. This can be achieved by first providing differential treatment channels for different types of waste (i.e. glass, plastic, paper, compost) and then developing a system for the waste to be sorted into these different channels.

The first step toward improved waste management is increasing the possible channels of waste treatment, so many municipalities measure progress by evaluating the increased percent of waste that is recycled. In 1994 there was a total of 763,500 tons of plastic waste; and 75% of that was buried in landfills in European countries (Braunegg et al. 2004).

In 1995, plastic waste packaging in Europe was on average 149 kilograms per capita annually (Braunegg et al. 2004). Although the percentage of plastic packaging used was 30%, the low density of the plastic made it difficult to recycle (Braunegg et al. 2004). By 2007, Austria was recycling 61% of its plastic packaging waste; Germany (63%) and Belgium (62%), were among the highest percentiles in the continent (Braunegg et al. 2004). Conversely, Greece had a recycling rate of 25%, Ireland had a rate of 18%, and Portugal had a 3% separation rate for plastic packaging (Braunegg et al. 2004).

Once the channels of waste treatment are available, improvement can be measured by the citizen's access to those channels. Abbott et al. (2011) evaluated the association between policy and recycling rates in 434 United Kingdom municipalities. A key factor in the UK's improved recycling performance has been the expansion of curbside recycling (Abbott et al. 2011). The highest and lowest rates of recycling within the East Midlands were 56.1% and 22.8%. In the North East of England, the highest and lowest rates of recycling in municipalities were 40% and 19.1%, respectively (figures from 2011). Discrepancies in recycling rates were due to differing budgetary allocations and curbside recycling availability. If curbside recycling was expanded in areas with lower separation rates, it may improve (Abbott et al. 2011). Braunegg et al. (2004) and Struk et al. (2017) also underscore the importance of easily accessible recycling bins throughout the country, and that the costs of collection and recovery are segregated accordingly (Braunegg et al. 2004).

The separation of waste is not limited to paper and plastic. In Torres et al. (2013), they analyzed the quality of waste oils and fats used in food preparation to their viability to synthesize biodiesel. The rate of usable recovered oils was about 83%, which demonstrates that the viability is quite high and a good alternative is the disposal of vegetable oils. If a collection scheme is well-designed and cost effective is created, synthetic biodiesel is a preferable alternative to conventional disposal methods and aligns with sustainable practices.

3.2.5 Variables of waste separation rates

In some cases, the access to recycling may not be enough and other factors may also matter, such as education and generational values and habits. Gaeta et al. (2017) selected data from 1521 municipalities in Lombardy, Italy to study recycling habits. Due to the large variance in recycled municipal waste (a range of 6 to 87% was found in 2012 data), the authors wanted to understand the causes of such variances. Knowing which variables are significant in waste separation gives policymakers an indication of what or who needs to be targeted for improvement. Their findings demonstrate that all variables which include demographics such as population age and size as well as the size of the household, socio-economic status, and spatial location were statistically significant. The positive correlations to municipal recycling rates in Lombardy, Italy: education, higher income levels, lower altitude, and waste tariffs (Gaeta et al. 2017). Gaeta et al. (2017) specify that Lombardy, Italy is among the wealthiest and most populated regions in the whole of Europe, and though its recycling rates are above average for Italy, they still fall behind European ambitions.

Separation for recycling may not be the only channel for improved waste management. In Horttanainen et al. (2013) a study compiled in South Karelia, Finland, sought to better understand the amount of recoverable energy in municipal solid waste. Citing three driving forces (EU directives, reduction of greenhouse gas emissions, and the need to move away from non-renewable energy sources), the authors wanted to see what amount of renewable energy exists already in the waste of their selected region. They found that due to the high plastic content of the municipal solid waste, the lower heating value as received was 19MJ/kg and the average amount of renewable energy was 30%.

3.2.6 Waste handling performance

Environmental performance is a measure used by researchers to test the environmental efficiency in which an industry operates (Fikru 2014). It can be measured as a ratio between emissions, pollutants, energy use, and other types of waste produced; versus prevention, recovery, diversion, and recycling of waste (Fikru 2014). If the ratio is higher in the latter group, the environmental performance of an industry is better. In Fikru (2014), environmental performance of waste handlers was tested. The authors developed two factors that indicate the environmental performance of waste handlers (Fikru 2014). The first indicator measures the relative amount a waste-handler plans to recover and recycle whereas the second indicator measures the efficiency of net material or energy use per normalized waste processing capacity (Fikru 2014).

Laws protecting identity and anonymity of people and businesses in Europe create difficulties in efficiently measuring environmental performances of waste handlers (Fikru 2014). Regulations on disclosure can be refined. One way may be to ensure input-variables and on-site waste treatment information is made available to researchers and the public (Fikru 2014). The findings of this paper suggest that waste-handlers perform slightly better when there are several nearby similar facilities with good environmental performance (Fikru 2014), a trend also seen in farmer behavior.

Regulating the sector is potentially beneficial. Austria created stringent regulations on waste handling and recovery, and though the practice is of some interest, completely banned burning municipal solid waste for energy recovery; so plastic packages had to be collected and recycled (Braunegg et al. 2004). The government of Austria had set up a system, Altstoff Recycling Austria (ARA) which was developed to regulate sorting, recycling, and recovery of waste packaging from both households and industries (Braunegg et al. 2004). The ARA is made up of three different and unrelated organizations; these organizations coordinate the sorting, recycling, and recovery of waste materials while considering cost and environmental safety (Braunegg et al. 2004). The ordinance also puts responsibility on the producers and importers of plastic goods and packaging - they are tasked with the proper collection and recovery of such materials (Braunegg et. al 2004). The amount of plastic waste accepted to landfills was 90,000 tons in 1998, and decreased to 60,000 tons annually by 2001 in Austria (Braunegg et al. 2004). In 1997, the total amount of collected plastic waste in Austria was 83,416 tons, 37.9% of all plastic waste in the country; and 45% of that amount was recoverable with the remainder being used for energy recovery (Braunegg et al. 2004).

A curbside collection was found to have the highest increased rates of waste separation, most notably for paper and plastic - improving rates by 40% when compared to drop-off sites (Abbott et al. 2011). Municipalities with more options for waste separation have higher rates of separation (Struk et al. 2017). Implementing an incentive program can double the existing waste separation rates (UN 2019), and was found to have a significant impact on the behavior of waste separation in citizens, mirroring the findings of Braunegg et al. (2004), Abbott et al. (2011). Mimicry of neighbors who have visible recycling bins in their yard was also a significant factor in increasing recycling rates in citizens; giving credibility to Wan and Shen (2013) state that behavior is often predictable and manipulatable given certain stimuli. Struk et al. (2017) recommend their results to municipalities that need to improve upon their recycling rates - that incentive programs specifically are an underutilized resource which, when well-composed, is an inexpensive way to increase waste separation rates of its citizens.

In Prague, as the trend for other cities, population and waste continues to rise; however, recently the amount of waste per person has started to decrease (Fig. 6). The peak amount of waste produced per capita in Prague occurred around 2006, with 200 kg per person. This cannot be linked to any one cause but is likely due to a collection of efforts by the city and awareness of citizens. Some of those city wide efforts are increased subterranean bins for waste and recyclables throughout the city (Vološinová et al. 2019, Prague Capital City 2018), increased curbside bins throughout the city (Vološinová et al. 2019, Prague Capital City 2018), and educational outreach (Circle Economy 2019). These results demonstrate that policy reforms and accessible recycling bins (Abbott et al. 2011, Braunegg et al. 2004, Gaeta et al. 2017, Struk et al. 2017, Vološinová et al. 2019) create definite change in waste handling efficiency.

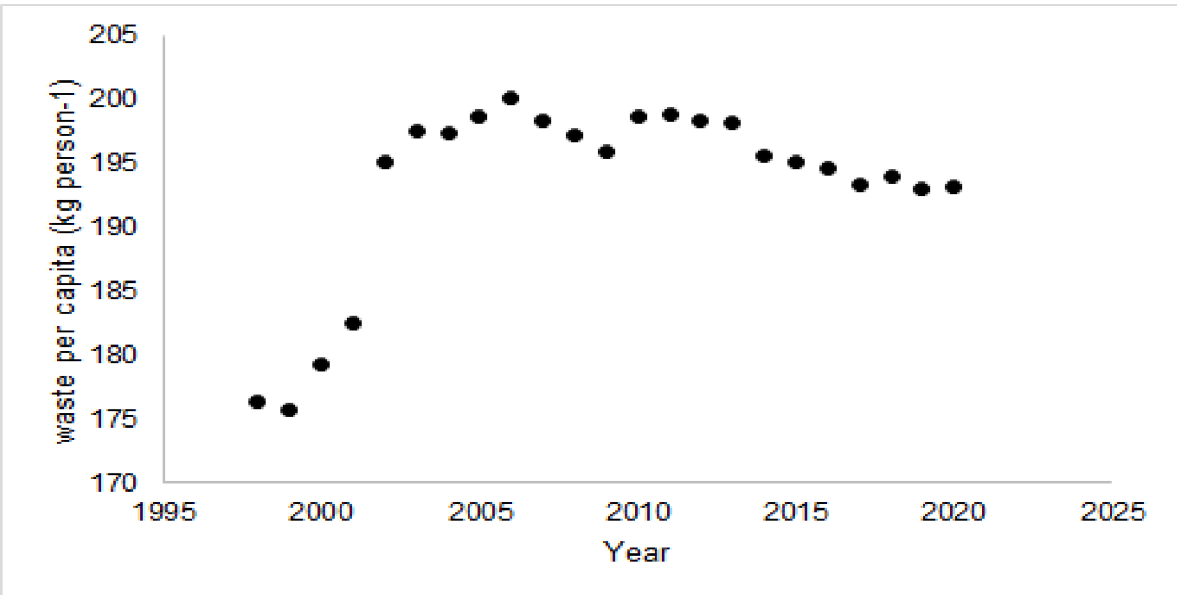

Fig 6 Prague waste per capita from 1998 to 2020. Waste data was retrieved from Prague City Hall, Department of Environmental Protection and Waste (2021). Population data was retrieved from the Czech Statistical Office.

As discussed, waste management improvements have been measured by rates of recycling and number of possible channels for waste separation and recovery. This has been implemented in Prague policy and the possible channels for waste recovery have increased from 3 to 7 channels since 2000 (Fig. 7). Waste separation in Prague is expected to change, with increased container capacities for each waste category and the development of subterranean storage units for waste disposal (Vološinová et al. 2019). Waste categories in Prague with the largest ecological impact are metals (47%) and plastics (33%) (Vološinová et al. 2021).

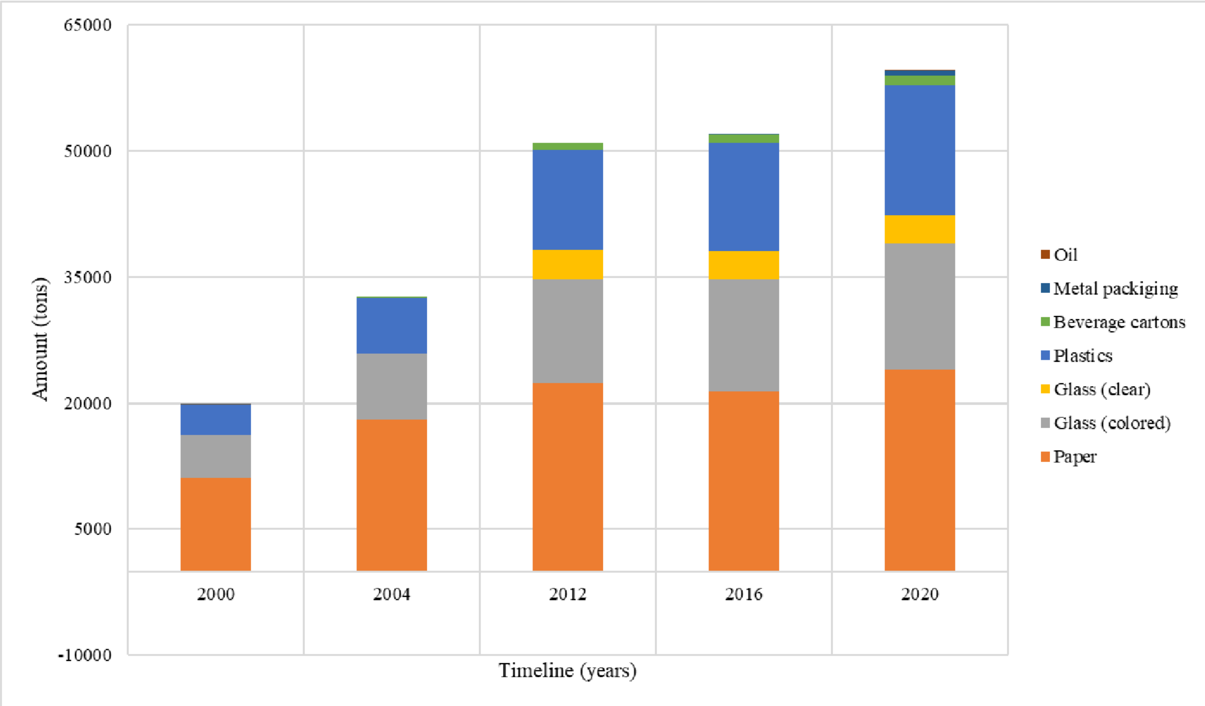

Fig 7 Waste separation rates by major categories of municipal solid waste in Prague from selected years. (Source:Prague City Hall, Department of Environmental Protection and Waste, 2021)

3.2.7 Moving forward

The 2030 Agenda for Sustainable Development, decided on by the United Nations in September 2015, laid out idealistic goals for fifteen years in which the developed and developing worlds should strive for a better, more sustainable way of life. Goal eleven, titled 'Make cities and human settlements inclusive, safe, resilient and sustainable' specifically comes to mind within the context of this paper. It covers many sub-goals including 11.6: 'By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management.' The waste management sector in both urban and rural areas still needs quite a bit of work before it reaches the level of sustainability laid out in Goal eleven. With eight years left, meeting those goals may be difficult, but action and policy are creating positive change.

3.3 Policy implementation

3.3.1 Circular economy

The general objective of the circular economy is to shift from a resource dependent economy to one which is more sustainable (European Commission 2022). Prague developed a plan for a circular economy: "Circular Prague" in 2019, with agendas for the socio-economic, construction, household, and utility sectors of Prague. In the 'circular economy' philosophy, waste should be treated like a raw material and put back into the cycle instead of disposed of (Circle Economy 2019). In a fully circular economy, no waste is produced and is instead reutilized in some way, through prevention of waste, waste recovery or incineration for energy collection (UN 2019, Circle Economy 2019).

According to Circle Economy (2019), the household consumption of biomass annually is above 950,000 tons, with 90% of that being food and drinks. Approximately 65% of household waste is collected through mixed streams of collection, which creates a problem for proper separation and therefore the full utilization of organic (and other) waste. If disposed of more sustainably, the negative impact that carbon-based waste has on the environment can be greatly reduced (Circle Economy 2019).

No modern city has achieved this type of economy, however, changes are occurring on policy levels ranging from supra-national, national, and municipal (Circle Economy 2019). There are also many community organizers which contribute to the realization of the circular economy, through direct action (for example, Kokoza in Prague, a community gardening and composting initiative) or through educational outreach.

3.3.2 Theory of planned behavior

Wan and Shen (2013) suggest that the ability policymakers have to use land and other natural resources in a sustainable way rests almost entirely on the relationship between citizens' attitudes and behaviors towards recycling. The authors argue that certain measures could serve as motivators of behavioral change in people, and that community leaders and authorities could influence good recycling behavior through educational outreach, incentivization, and mandating policy.

Wan and Shen (2013). argue that the Theory of Planned Behavior (TPB) is applicable here. The authors define this theory as: 1. Attitude is an individual's belief and subjective evaluation of behavior. 2. Subjective norm is an individual's motivation to comply with perceived social expectations for a behavior. 3. Perceived behavioral control refers to an individual's perceived ability to perform a certain behavior. (Wan and Shen 2013).

Understanding and utilizing the theory of planned behavior in parallel to policy implementation could give policymakers and community leaders more knowledge on how to increase the recycling rates of citizens (Wan and Shen 2013). The authors also lay out strategies to change the perception of policy effectiveness in citizens, which are: timing of the proposed policy, encouraging public participation, the choice of 'tools' (ie: rewards are better than punishments), and effective communication and access to information (Wan and Shen 2013).

3.3.3 Waste management policies

On the supra-national level, directives such as the Waste Framework Directive and the Landfill Directive were implemented by the European Parliament and European Council in 2008 and 1999 respectively (Costa et al. 2010). The Landfill Directive and the Waste Directive established by the EEA in 2008 mapped out standards that European countries should meet to improve the environmental impact of the waste produced. These guidelines help improve not only the health of the surrounding ecosystem, but human health as well. The Waste Directive sets out goals and guidelines to improve waste recycling, public health, pollution reduction and prevention, and environmental protection (European Commission 2008). The Landfill Directive's goals are similar: improve air quality, reduce and prevent soil and water pollution, and improve waste handling (storage and disposal) (European Commission 1999). These directives serve as guidelines for all EU member states in an attempt to homogenize waste handling behaviors and promote good praxis among members (Costa et al. 2010). The member states themselves are free to implement their policies or guidelines as it best suits their needs, but should operate under the umbrella of these directives (Costa et al. 2010). European Parliament and Council Directive 94/62/EC on packaging and packaging waste came into force. Its key issue is that each member state must take measures to set up take-back, collection, and recovery systems for used packaging by the year 2001. Part of the European countries have therefore decided to use the same system like Germany, and they also use the "Green Dot" as a sign. (Braunegg 2004).

Recognizing the unsustainable nature of previous waste management strategies, many European cities have tried to address it through local policies and incentives. Some strategies have targeted consumer habits and others businesses for collecting and disposing of waste. Waste management in Prague and other EU cities has become far more efficient over the last few decades - with recycling efficiencies and waste separation increasing (Abbott et al. 2011, Braunegg et al. 2004, Gaeta 2017, Struk et al. 2017), regulations on open dumps and landfilling procedures (Carvahlo et al. 2014), changes in the waste management business (Fikru et al. 2014), and policy changes to reflect the goals of European waste handling procedures (Braunegg et al. 2004, UN 2019).

Decision-makers know the impact of waste mismanagement, and therefore policy has been changing to reflect that. Foregoing landfilling for more sustainable practices such as prevention of waste, recycling, incineration for energy recovery, material recovery, and composting, the efforts of the EU reflect the policies and philosophies they tout. A regenerative economy initiative is shared by the whole of the EU, and the aforementioned policies are included to help shift from a linear economy to a circular one.

3.3.4 Policy in action

European policies were analyzed and discussed at supra-national (EU), national (country), and sub-national (regional/municipal) levels in Costa et al. (2010). The authors examine the effectiveness of policy using case studies which include Denmark, Switzerland, United Kingdom, and Portugal. Flexibility in policy with regards to the regulation of waste at national and sub-national levels coupled with more stringent economic regulations proved fruitful (Costa et al. 2010). Smaller governments have a more difficult time in the symbiosis of policy and implementation, and this should be addressed to achieve the goals of the EU and their own. It’s imperative that these policy makers remain open to change in order to operate as best they are able (Costa et al. 2010).

3.3.5 Recycling, prevention, and other methods of waste handling

Municipal recycling rates vary as do their drivers. In Romano et al. (2019) they investigated the municipal recycling rates in Tuscany, Italy. This region is of interest because it’s the first region in Europe to adopt a zero-waste strategy (since 2007) (Romano et al., 2019). Within the four-year study period, the authors found that over 85% of municipalities were under the allotted threshold of 65% of municipal solid waste produced. This demonstrates a necessity for policy upheaval and reinvigoration. A campaign of pro-environmental behavior which educates the citizens of the region would help improve recycling rates (Romano et al. 2019). Formal policy decisions which are developed with an understanding of attitudes towards recycling, the problems faced by waste-handling firms, and the consequences of waste mismanagement would greatly improve the situation in Tuscany, Italy (Romano et al. 2019). Adopting a zero-waste strategy is only effective if the decision-makers are educated and equipped enough to implement it.

3.3.6 Investigating life cycle of waste

Having addressed policy implementation and propositions on how to treat waste sustainably, there still remains a gap in the practical understanding of its life cycle. In Liikanen et al. (2017), the authors selected two cities, South Karelia, Finland, and Hangzhou, China, to assess the life cycles of municipal solid waste within them. A life cycle assessment is a method often used to understand the environmental impacts of a practice. Applied to municipal solid waste, the life cycle assessment gives insight into what stages a product goes through to ultimately become waste, and the environmental impacts it has. Though access to primary data is rare, a life cycle assessment of municipal solid waste can be carried out using secondary data (Liikanen et al. 2017). The authors note that the life cycle assessment is only reliably applicable on a case-to-case basis, a standardized method cannot be simulated due to the need to use differing parameters of case studies.

In South Karelia, the waste per capita was 493 kg in 2014, with a near equal amount of plastic, organic, and miscellaneous waste produced (Liikanen et al. 2017). In Hangzhou, the waste per capita in 2014 was 440 kg, with organic waste dominating the other waste categories at 56% (Liikanen et al. 2017). This shows clear differences in consumption patterns of both cities (Liikanen et al. 2017). Understanding variances of waste production types in municipalities is important. Municipalities in the same regions could collaborate to improve the sector (Bel and Fageda 2006, Liikanen et al. 2017).

3.3.7 Intermunicipal cooperation in waste handling strategies

A national strategy is important but successful execution depends on the municipalities themselves. One of the great challenges in municipal to national waste management is to align goals between municipalities. Often, municipalities are accounting for different local resources and this creates unequal opportunities for businesses throughout the region. Intermunicipal cooperation, as simple as cooperating in the municipal solid waste collection can improve efficiency and decrease costs (Bel and Fageda 2006). Scale economies, large, and small municipalities were examined. Smaller municipalities and economies of scale have decreased privatization and higher involvement of the public sector when inter-municipal cooperation takes place (Bel and Fageda 2006).

The average costs incurred by cooperating municipalities are about 20% lower than the costs of municipalities that operate on individual municipal provisions (Bel and Fageda 2006). Public firms which are established in municipalities can be factored into the cost reduction as well, and is particularly relevant for the collection of municipal solid waste (Bel Fageda 2006).

Intermunicipal cooperation appears to be a simple and transferable solution, but many factors can affect the success of the strategy, such as the population size and economic assets (Bel and Fageda 2006). Overall, cooperation between similar municipalities with shared interest work well, while dissimilar groups may have more problems (Bel and Fageda 2006; Guernni et al. 2017). Half of all municipalities in Spain with greater than 2,000 inhabitants manage municipal solid waste through inter-municipal cooperation, though there is heterogeneity between regions, with municipalities in Valencia and Madrid participating just 15% of the time, yet in Andalusia cooperation is at 70% (Bel et a. 2006). Privatization is best suited for larger municipalities; the cost to manage private businesses is generally too high for small municipalities (Bel and Fageda 2006).

Intermunicipal cooperation has its benefits where appropriate, but policy implementation and refinement work well in municipalities that wish to address the issue of proper waste handling too. In Scarlat et al. (2018) they describe municipal solid waste as a renewable energy resource that is underexploited. The authors note that on average, each person produced nearly half a ton of waste annually in Europe. This large scale consumption creates a problem wherein land use, public health, sustainability, and our capacity to treat waste is compromised (Scarlat et al. 2018).

3.3.8 Technology and waste management

Optimization of waste handling can be found not just in policy or management change, but potentially by utilizing databases such as web geographic information systems (Web-GIS) or technologies like radio frequency identification (RFID) (Rada et al. 2013). Though this approach holds potential, the handling of the residual municipal solid waste must be taken into consideration before implementation (Rada et al 2013). An economically stable system for waste handling is one wherein the participants pay for their disposal rates (Rada et al. 2013).

Using geographic information systems, Scarlat et al. (2018) plotted points where new treatment plants for waste to energy could be developed. They noted distributions of municipal solid waste in Europe. Their suitability analysis showed that an additional 248 waste to energy plants could be constructed in the EU, on top of the existing 512 plants already in use, bringing the incineration capacity for waste to energy up from 93 million tons to 130 million tons (Scarlat et al. 2018). Despite the questions of cost and proper implementation, Scarlat et al. (2018) note that waste to energy incineration could out-compete waste recycling, and it's important for policymakers to keep in mind. If budgeted for and carried out, this could be a great stride for the EU in the transition from a linear to a circular economy (Scarlat et al. 2018). Waste to energy plants are less desirable than prevention or recycling, as the carbon emissions from waste to energy treatment plants are too high to be environmentally sustainable (Scarlat et al. 2018).

3.4 Urbanization and waste management consequences to Rural Areas and Agriculture

3.4.1 Land use and urbanization

Afforestation and urban sprawl uptake agricultural land and waste mismanagement from densely populated urban areas cause serious environmental problems (UN 2019). Policymakers must address the issue of urbanization from a rural standpoint and protect arable land to remain sustainable, productive, and competitive (UN 2019); globalized agriculture is not always safe to rely on due to issues in supply chains, as seen during the COVID-19 crisis and more recently, the war in Ukraine (Millar, 2022). Policy implementation of waste handling and land use change are treated separately when they should be considered together to better address the problems of each (UN 2019, Circle Economy 2019).

The EU expansion in the 2000s included twelve new countries, mostly located in the eastern and southern areas of the continent, and expanded agricultural land by over 500,000 hectares (Stoate et al. 2009). The agricultural policies in the EU changed to account for the new member states; matters like production demands, environmental restrictions, climate mitigation, and resource management were reconsidered (Stoate et al. 2009).

Agricultural land use is more likely determined by whether existing farming technologies can be utilized on the land over traditional land suitability, peripheral locales over urban-adjacent ones, large agricultural conglomerates over small family farms, and globalization of farms over a wider spread of farms (Bakker et al. 2011). Measures for carbon mitigation and the urban dweller's right to access of green areas are influencing a greening of greater metropolitan areas, forcing farmers further away from cities (Bakker et al. 2011). These trends are only likely to change if the cost of agricultural products outweighs the benefits of afforestation, and the value of agricultural land is raised (Bakker et al. 2011).

3.4.2 Models for land use studies

Model creation of land use surveying could be improved upon and more frequently utilized. As mentioned in sub-chapter 1, Hersperger et al. (2010) proposed guidelines for model selection depending on the details of the study. They argue that standardizing models and using their proposed combinations of driving forces, actors, and land use change models can improve research on, and understanding of the patterns of land use change (Hersperger et al. 2010).

Without standardized models for researching causes of land use change, the data may prove unreliable. However, the possibility of standard models may not be possible due to the high variance of land use. Successful models may only be those at regional levels. Kuemmerle et al. (2013) point out three main reasons which illustrate the major lack of data on land use intensity. Firstly, that land use change and intensity is multifaceted which has no direct path for explanation; it can include everything from the fertilizer used by the farmer to the government subsidy provided to them. Secondly, measurement systems or approaches are not standardized - nor are the interpretations - they can vary by region. Third, satisfactory measurements of land use intensity and data consolidation among multiple disciplines are incomplete. Research going forward should include data aggregation of satellite imaging and ground based data, a general consensus of existing datasets, and a substantial and steady collection of time-series datasets. The authors suggest arranging land use systems according to the intensity in which they are used (Kuemmerle et al. 2013).

3.4.3 Industrial symbiosis

Understanding technological, institutional, environmental, and socio-economic drivers as they pertain to land use will improve the decisions of policymakers and can help guide us to more sustainable futures (Jepsen et al. 2015). In Costa et al. (2010), they suggest that industrial symbiosis, which is a cooperation among businesses whose aim is to follow environmentally friendly strategies, has the potential to improve sustainable practices. When governmental intervention is included, industrial symbiosis has the potential to become more robust, increasing the efficiency of the practice.

Reed et al. 2014 note that there are many restrictions and uncertainties with regard to sound policy implementation that addresses subsidies offered to landholders for meeting policy criteria, optimizing ecosystem services, and maintaining agricultural land. Landowners typically overlook the benefits of ecosystem services their land offers since they do not directly earn capital from it (Reed et al. 2014).

3.4.4 Influences of Common Agricultural Policy

The Common Agricultural Policy (CAP) is the agricultural policy for the whole of the EU. It allocates funds to the "two pillars" of the policy: the European agricultural guarantee fund, and the European agricultural fund for rural development (European Parliament, 2013). Rural development programs include advancing knowledge and innovations in forest management and land use, efficiently managing agriculture and resources, preserving biodiversity, and poverty reduction in rural areas (European Parliament, 2013). Modifications to CAP have undermined rural development programs by decreasing budgetary allowance; these areas are crucial for protecting and maintaining efficient land use (Reed et al. 2014).

Optimizing CAP to increase subsidies in rural areas which organize agricultural products and support farmers' earnings could improve the management of ecosystem services. (Reed et al. 2014). To ensure optimal land use, decision-makers should collaborate with land owners. (Reed et al. 2014). Developing and refining models which accurately assess the most favorable land management schemes on a case-to-case basis is necessary (Reed et al. 2014). Stabalizing the income of farmers can be carried out by: increasing the range of activities in farms, curtailing input intensity, farming in an environmentally sustainable manner, and payments to farmers from result-based agri-environmental schemes (Harkness et al. 2021).

3.4.5 Agri-environmental schemes

Subsidizing ecosystem services through agri-environmental schemes which reward landholders need a robust understanding of the sector to be optimally implemented. Drafting designs for such payments is in process (Meyer et al. 2015). Agri-environmental measures are most effective if: one environmental goal is focused on, one area or habitat is focused on, there is an easily accessible advisory system, the participation of the agri-environmental scheme is obligatory and/or the implementation is flexible (Meyer et al. 2015).

In the Netherlands, there is a collective of farmers committed to upholding agri-environmental schemes, dubbed 'Environmental Cooperatives' (Van Dijk et al. 2015). The communal action is hypothesized by Van Dijk et al. to increase the participation of such schemes, as a sort of social pressure amongst farmers and their peers (Van Dijk et al. 2015). The Theory of Planned behavior, explained by Wan et al. (2013), is applied here to explore what inspires the farmers to participate (Van Dijk et al. 2015). The findings imply that the collaboration itself was the most significant driving influence in participation (Van Dijk et al. 2015).

Agri-environmental schemes in Europe are the responsibility of the landholder to adhere to (Burton and Schwarz 2013). The purpose for creating and implementing agri-environmental schemes is to promote biodiversity, halt the degradation of the environment, prevent loss of wildlife, and keep cultural landscapes intact (Burton and Schwarz 2013). Experts in the field believe ecological outcomes are more successful when result-oriented approaches are applied (Burton and Schwarz 2013).

When landholders are given reign over the decision making of their properties, there is a freedom to implement these schemes with the knowledge they have of their land - knowledge that policymakers and environmentalists do not possess in such specificity (Burton and Schwarz. 2013). When the outcome of the farmer's action is successful, in that they meet the goal put forth in the scheme, they are compensated (Burton and Schwarz 2013, Harkness et al. 2021). If they are paid by action only, there is less incentive to make such schemes work, as they have already been "rewarded" (Harkness et al. 2021). Implementing result-oriented agri-environmental schemes creates a greater desire to achieve the outcome. Economic and ecological advantages are found in that compensation is not given without results (Burton and Schwarz 2013).

Agri-environmental schemes are most successful when behavior is adapted to consistently achieve results. Burton and Schwarz (2013) argue that the connections within rural communities, conservationists, and stakeholders are most strengthened when result-oriented schemes are implemented, as the community changes their behavior together to achieve results. Farms need to generate revenue in order to operate, and without monetary gain from changed behavior, farmers are more likely to revert to unsustainable practices (Burton and Schwarz 2013). Planting wildflowers, supplementing predator habitats, and increasing the diversity of fields are avenues of "ecological intensification" and thus good starting points for agri-environmental schemes (Harkness et al. 2021).

In Villanueva and Gómez-Limón (2015), agri-environmental schemes available to Spanish olive-growers were assessed. Whether or not the farmers chose to participate in the schemes hinged on a few variables: training, the volume of peer participation, and the option to adapt and adjust to the scheme were heavily influencing factors in rates of participation (Villanuevaand Gómez-Limón 2015).

Two CAP levels in olive farming with regards to producing environmental goods and services for the public: agri-environmental schemes and cross-compliance (Villanueva and Gómez-Limón 2015). The authors suggest intelligently designing more agri-environmental schemes may increase participation, as a variance in schemes may cover the preferences of more farmers (Villanueva and Gómez-Limón 2015).

Wide-scale change is encouraged but should be researched first, as a blanketed success of result-oriented agri-environmental schemes is not guaranteed (Burton and Schwarz 2013). The success of agri-environmental schemes, such as increases in biodiversity on farmland and a sustained behavioral change in the landholders is still disputable (Van Dijk et al. 2015).

3.4.6 Current land use trends

Trends in land use change in Europe seem to indicate that agricultural and rural landscapes will endure profound changes in as little as a few decades, as they have in the last 50 years (Busch et al. 2006). Specialized production, technological progress, competition on the national and international scale, and subsidies offered by CAP heavily influence both agricultural land use change and rural land use (Busch et al. 2006). Intensifying land use and specializing land to suit the demands of the market or receive subsidies affect the decisions of landholders and policymakers (Busch et al. 2006). To combat this, a combination of top-down modelling and region-specific modelling should be implemented when forming policy (Busch et al. 2006).

Modern instances of afforestation can be highly attributed to socio-economic and socio-cultural drivers (Lambin and Meyfroidt 2010). Perceived resource depletion or environmental degradation influences the action of policymakers, however, action is normally taken when budgetary constraints are lifted, markets are stable, and population changes (Lambin and Meyfroidt 2010).

Understanding patterns of land use today could give insight to future trends. An analysis carried out by Pazur et al. (2020) in Slovakia used existing patterns to predict agricultural land cover change up to the year 2060. Operating under the assumption that trends remain stable, land abandonment and recultivation are concentrated in mountainous regions, though recultivation also occurs in higher quality landscapes and climates (Pazur et al. 2020). Accounting for increasing temperatures due to climate change, regions that were once unsuitable for cultivation will be utilized (Pazur et al. 2020). Governmental support schemes at all levels could reinvigorate areas for cultivation, thus preventing losses in biodiversity, cultural landscapes, and grasslands (Pazur et al. 2020)

Humans have consistently changed the landscapes they live on to best suit their lifestyles. As society changes, so too does our environment. Technological advances have provided comfort, sanitization, ease of access to food, water, and shelter, as well as a plethora of social benefits. However, the consequence of urbanization is a disconnect to the impact that individual decisions have on the environment (Antrop 2005). Living within a city or a suburb can mask the magnitude of problems created by wasteful habits and unsustainable land use (Antrop 2005). Only recently has awareness of environmental degradation become mainstream; a hopeful direction.

4 Conclusion

- The drivers of agricultural land use change vary by region and must be considered individually to tailor local policy decisions.
- Land use assessments should take into consideration the permanence of landfills and change in urban and agricultural landscapes before policy makers effect change.
- Recycling and waste habits of certain regions is poor and should be corrected by better budgetary spending and rationing, educational outreach, and more accessible recycling receptacles. Curbside bins should be within walking distance of residential areas to establish proper waste disposal behavior of citizens.
- Best methods for waste recovery and "good" land use depend on regional level and a sweeping policy may not be possible. Top-down and bottom-up approaches of policy to both land use change and waste management ensure the most effective coverage of the sectors and protections for land and people.
- Reforms to EU Directives and policies to support rural areas necessary for retaining populations and protecting land; rural dwellers should be supported by CAP to decrease land abandonment.
- Understanding the behaviors of people may help policy makers create better alterations to existing policy to ameliorate land use and curve waste generation.
- Result based agri-environmental schemes improve land use when implemented by informed policy makers and landholders.
- Circular economy philosophy should be implemented more intensely for improvement of environmental health overall. Cooperation between supranational, national, and municipal policymakers as it pertains to land use change, population shifts, urbanization, and waste generation is necessary for the best outcomes.

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Data:

Table 1

Source: WorldBank, Food and Agriculture Organization. 2018. ID: AG.LND.AGRI.ZS. Available from https://data.worldbank.org/indicator/AG.LND.AGRI.ZS

Table 2

Source: Czech Office for Surveying, Mapping and Cadastre, Land use in the Capital City of Prague as at 31 December

Source: Czech Office for Surveying, Mapping and Cadastre, Land use in the Hlavní město Praha Region as at 31 December

Fig 1 Goldewijk KK. 2001. Estimating global land use change over the past 300 years: the Hyde database. Global biogeochemical cycles. 15(2):417-433. Available from DOI:10.1029/1999GB001232.

Fig 2 Meyer M A, Früh-Müller A. 2020. Patterns and drivers of recent agricultural land-use change in Southern Germany. Land Use Policy. 99:104 959. Available from https://doi.org/10.1016/j.landusepol.202a 0.104959.

Fig 3 Urban Atlas 2018, Land Cover in Functional Urban Areas in 2012 and 2018, Praha Czech Republic

Fig 4 LU/LC Delivery Report, CZ 001L2-Praha, Urban Atlas 2018, retrieved November 2021

Fig 5 Eurostat. 2017. EU28 = European Union (28 countries); data in % unless otherwise stated. Accessed November 2021

Fig 6 Prague City Hall, Department of Environmental Protection and Waste, in communication via email with Jitka Hofmanová, Specialistka odpadového hospodářství on November 22, 2021. Population data retrieved from the Czech Statistical Office, updated on March 24, 2021

Fig 7 Prague City Hall, Department of Environmental Protection and Waste, in communication via email with Jitka Hofmanová, Specialistka odpadového hospodářství on November 22, 2021.