Potential of Bioeconomy in Urban Green Infrastructure

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Abstract

In the course of the general discussion about sustainable urban development, there is currently a growing interest in urban greenery and the concept of green infrastructure, both at the national and international level. At the international level, the EU Green Infrastructure Strategy explicitly includes urban spaces. Urban green infrastructure offers a promising potential for bioeconomic activities. Bioeconomy stands for the structural change from a petroleum-based to a bio-based economy, which combines economic prosperity with ecological and social compatibility. The concept refers to the provision and use of renewable resources such as plants, animals and microorganisms, as well as the prevention of waste. The present contribution analyses the potential of bioeconomy in urban green infrastructure with a focus on a multifunctional biomass production, particularly focused on the production of food and feed through urban agriculture. The contribution discusses the potentials and challenges of urban gardening as well as urban farming approaches.

Keywords

Urban gardening potential · Urban farming potential · Bioeconomy · Urban green infrastructure · Nature-based solutions

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13.1 Introduction

In 1950, only 28.8% of the world's population lived in cities, compared with 49.9% in 2009. According to estimates by the United Nations Department of Economic and Social Affairs (UN DESA), by 2050, the proportion will continue to rise to almost 70%. Global urbanization poses enormous challenges to sustainable development. The demand for housing, food, infrastructure and energy is growing steadily. Only sustainable urban development can make its contribution to adaptation to climate change, energy and resource efficiency and sustainable mobility. Bio-based approaches can provide important impetus in terms of housing and urban agriculture, as well as the supply of energy or the use of waste.

Bioeconomy is based on the model of nature as a generally stable circular economy in which nothing is lost and everything is reused (Braungart and McDonough 2002). The concept refers to the provision and use of renewable resources such as plants, animals and microorganisms, as well as the prevention of waste. The principle has been known since time immemorial. Bioeconomy stands for the structural change from a petroleum-based to a bio-based economy, which combines economic prosperity with ecological and social compatibility. A social change of values in favour of sustainable forms of production, trade and consumption is also an indispensable component of the bioeconomy. Since the necessary raw materials for the bioeconomy come directly from nature, it also dictates to our economies basic rules, stipulations and limits. The bioeconomy already plays an important role in the food sector. New bio-based processes and ingredients have made products more versatile, healthier, cheaper and more sustainable. This characteristic forms the potential for bioeconomy in urban green infrastructure.

Green infrastructure is more than a summarising term for the green interior of cities with parks, playgrounds, sports fields or cemeteries. With green infrastructure is associated a strategic planning approach that aims to promote green qualities in the city as a whole. Here, individual areas are intertwined so that they complement each other in their effects, and in total new qualities can arise. Instead of monofunctional use, the focus is on multifunctionality. The concept of green infrastructure offers municipalities the opportunity to act strategically and to develop various ecosystem services.

According to the European Commission (2010), green infrastructure describes a strategically planned network of natural and seminatural areas with different spatial features on different scale levels. These biotope networks aim at preserving biodiversity as well as strengthening and regenerating ecosystem functions and the potential for providing ecosystem services based thereon. In principle, the implementation of green infrastructure aims for a sustainable use of nature. Green infrastructure is a network of natural and artificially created urban and rural vegetation and water areas. This positively affects the ecosystem, biodiversity and resilience of the areas and strengthens the health of flora and fauna as well as humans (Naumann et al. 2011). Green infrastructure is conceptually opposed to concepts of grey and brown infrastructure and offers a cost-effective and stable completion to purely dedicated grey infrastructure. Given the high risk of biodiversity loss in Europe due to intensive land use and fragmentation, the concept of green infrastructure is strongly promoted by the EU. Grey infrastructures such as roads, rainwater management systems, pitches as well as also roofs and facades can become a green infrastructure if they hold back and evaporate water, provide shade, become a place of human well-being, and foster biodiversity. Urban green infrastructure aims to connect multiple interests in cities. The green infrastructure's strategic approach is to understand the entire surface of the city as a potential green infrastructure that can and should deliver environmental and economic benefits.

Green infrastructure describes all elements of a network of connected green spaces and creates the spatial basis for the sustainable use of ecosystems and their services (European Commission 2013). Protected areas are integrated into a common system together with the existing landscape. Some of these elements can be reforestation, green bridges, roofs or walls. Strategic spatial planning deliberately gives nature space to promote the preservation of biodiversity and ecosystem services. Green infrastructure is a part of nature-based solutions, that means "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" as defined by the International Union for Conservation of Nature (IUCN) (Cohen-Shacham et al. 2016). Setting up multifunctional areas can also be a green infrastructure measure. Different, compatible usage methods are combined. In these areas, for example, the effects of climate change can be reduced and recreational and compensation areas created at the same time. In addition to the multifunctionality, economic arguments for green infrastructure can also be raised. Despite high costs, for example for a flood prevention program, the resulting costs for dike relocation and an associated restoration are relatively low compared to those caused by flood damage (European Commission/DG Environment 2009).

A special role does green infrastructure play in urban areas. Here, the disintegration of the green areas by sealing for traffic and building infrastructure and thus the loss of biodiversity is particularly pronounced (Neßhöfer et al. 2012). However, a variety of ecosystem services can be provided in cities, especially when the green infrastructure concept is pursued. For example, the air quality can be substantially improved through parks and green spaces. Even overgrown house walls can make a major contribution by absorbing the heat that comes from the sunlight on the houses. These green walls are helping to reduce the effect of the urban "heat islands" (Neßhöfer et al. 2012).

The present contribution analyses the potential of bioeconomy in urban green infrastructure with a focus on a multifunctional biomass production, particularly focused on the production of food and feed through urban agriculture. The total amount of biomass produced on a given area in 1 year is called net primary production (Singh et al. 2017). Having in view the growing global population, especially in large cities, agriculture already faces the challenge of using every hectare of arable land as effectively as possible in order to meet the demand for food and biomass. The gap between the growing population and scarcity of cultivated land could close urban agriculture. The contribution presents options for urban agriculture on different scales and assesses their potential in terms of bioeconomy.

13.2 Materials and Methods

The investigation is based on an in-depth literature review, the collection of case studies from the literature as well as field studies in Congo, Ecuador, Germany and Vietnam. These countries were selected to represent the variety of urban agriculture approaches around the world and on different development levels of the countries. The case studies show that everywhere in the world where are urban food production activities, the levels, approaches and scales are quite different. The term urban agriculture has been coined in recent times by Lohrberg (2001), to describe the agricultural use in the so-called intermediate city and in densification areas. The idea, however, goes back to reflections on urban food production in the 1920s by Migge (1929). Urban farming is often used interchangeably with urban gardening, but there is a significant difference in the scale: while urban horticulture is operated by subgroups of the total population for the purpose of self-sufficiency, urban agriculture has the goal, also on a commercial basis, to supply products for the entire population (Lohrberg and Timpe 2011). In addition, as mentioned above, urban agriculture also includes, at least theoretically, the breeding of (small) cattle in urban areas (Lohrberg and Timpe 2011).

The assessment of case study countries was done qualitatively and semi-quantitatively through a SWOT analysis. The SWOT analysis provides a framework concept, taking into account the internal and external influencing factors, thus allowing different aspects of the current state (David 1993; Helms and Nixon 2010). The SWOT analysis considered a method for systemic situation analysis, where S stands for strengths, W for weaknesses, O for opportunities and T for threats. For better illustration, the SWOT analysis is presented in a matrix comprising two dimensions: firstly, the opportunities and risks arising from the external environment and, secondly, the strengths and weaknesses of the scope in terms of resources. An overall overview is created that takes into account both positive and negative aspects. Urban agriculture usually is significantly different from conventional agriculture in rural areas. The following are overall types of urban food production considered in the present analysis: (a) urban gardening and (b) urban farming. Both differ particularly in their scale, dimension and breeding approaches.

13.3 Bioeconomy Options in Urban Green Infrastructure

13.3.1 Urban Gardening

Urban gardening exists as long as there are cities. Urban gardening is currently experiencing a high level of popularity and boom in the face of demographic change and increasing urban migration. Cities have high potential for unused land. Unused

Fig. 13.1 Urban gardening for food production and cultural purposes in Cuenca (Ecuador, left) and Hoa Binh (Vietnam, right)

areas such as rooftops and urban brownfields offer great potential for urban gardens. Apart from the advantage that up to now unused areas are upcycled, urban gardening offers that in a new way a socialization of culture and nature adjusts itself (Biedermann and Ripperger 2017); see Fig. 13.1.

Urban gardening is mostly done for the personal benefit of a person or a community. According to Lewis et al. (2018), there are three major motivations for urban gardeners: well-being, social aspects of gardening and the outputs (like vegetables) (Lewis et al. 2018). Both the contact with nature and the social and economic aspect play a role here. It is possible for city dwellers to experience nature through gardens in the city. The cultivation of vegetables in city gardens can also cover a certain part of the vegetable and fruit needs of the people involved. Urban gardening can contribute to food security (Rosol 2014). This plays a far greater role in developing countries than in developed countries. Food security is achieved when "all individuals can obtain a culturally accepted, wholesome diet through local, nonemergency sources at all times" (Gottlieb and Fisher 1996).

In addition to food security, especially the sociocultural advantage of urban gardens should be mentioned. Urban gardeners usually aim to improve the quality of life for themselves or for a community (Lohrberg and Timpe 2011). Commercial use is usually not associated with urban gardening. Gusted et al. (2017) shows a connection between garden size and usage. Thus, urban gardens are more likely to be referred to as small, micro or meso gardens claiming a subsistence or sociocultural use. Micro gardens are run by individuals or private households. Meso gardens are run often of associations or start-ups. Macro-garden uses in cities are more likely to be commercial and are counted to urban agriculture. Small garden approaches like allotment gardens, school gardens, roof gardens or community gardens are urban gardening (Fig. 13.2).

13.3.1.1 Environmental Potential

Urban gardens provide a habitat for a variety of animals and insects that would often be out of place in the city. The cultivation of plants can have a positive effect on the urban climate. Thus, urban gardening can partially counteract the increasing surface sealing and mitigate urban heat islands.

Strengths	Weaknesses
- Improving the quality of life - Intercultural exchange of experience - Contact to nature - Self-sufficiency in fruit and vegetables - Positive effect on city climate	- Space limited - Possible environmental pollution of the areas and thus also the food
Opportunities	**Threats**
- Integration in infrastructure city planning	- Commercialization through Companies

Fig. 13.2 SWOT analysis of urban gardening

13.3.1.2 Economic Potential

Since urban gardening is usually operated without profit, a resulting economic factor can still be named. Urban gardens have a significant share of ecosystem services in cities. For example, people can benefit from the production of food by plants, the pollination of bees and the urban climate regulation through planting, recreational areas and social cohesion (Langemeyer et al. 2016).

13.3.1.3 Social Potential

As mentioned above, urban gardening has a high social potential. People of different cultures and social environments can meet in urban gardens. Urban gardens can also have a positive effect on environmental education. People who would normally not be in contact with food production in a city can learn how to grow food.

Figures 13.3 and 13.4 provide impressions of special forms of urban gardening: community and private gardens in Magdeburg and Dresden (Germany), Fig. 13.3, and vertical gardens in Berlin (Germany) and Cuenca (Ecuador), Fig. 13.4.

13.3.2 Urban Farming

Urban farming is a generic term for various ways of primary food production in urban areas and their immediate environment for their own needs of the respective region (Lohrberg 2001). In addition to urban forms of horticulture, it also includes animal husbandry in urban areas. Urban farming has been rediscovered in recent years due to the following aspects:

Fig. 13.3 Community gardens in Magdeburg and private urban gardening in Dresden (Germany)

Fig. 13.4 Vertical gardens in Berlin (Germany, left) and Cuenca (Ecuador, right)

- Local food production and consumption is one of the ways to reduce transport routes (and to reduce the carbon footprint) (Halweil and Prugh 2002).
- Large-scale urban plant breeding can help to make transport-intensive and energy-intensive material cycles more local and economical by the direct use of (prepurified) wastewater for irrigation or fertilization purposes.
- Decentralization of food production and connected extensification for increasing food safety, although the risk of pollution from urban products might be potentially higher than that of products grown on healthy topsoil in the countryside.
- Growing interest in local food production goes hand in hand with social movements grouped around the knowledge, enhancement or preservation of local specialties (e.g. slow food).
- There is a growing need for food that is produced in an environmentally sound and socially equitable manner, which is often attempted through in-house production or local acquisition (Nairn and Vitello 2010).

13.3.2.1 Horticulture

Urban horticulture covers all methods of cultivation of plants in urban and peri-urban environments. It includes both the cultivation for food and ornamental plants (see Fig. 13.5). According to Orsini et al., urban horticulture is the most competitive branch of urban farming. The low CO_2 emissions and greater transparency of food

Fig. 13.5 Urban horticulture in Dresden, Germany

production reflect the modern urban lifestyle and make urban farming and horticulture particularly interesting (Eigenbrod and Gruda 2015). Urban horticulture ranges from traditional farming methods to highly innovative farming methods, such as controlled environment agriculture (CEA), organic vegetable cultivation in soil, hydroponics, vertical farming, rooftop use and more. For example, "Z-Farming" (zero-acreage farming) is a method where only space in cities is used which are not resealed but are already sealed and not used (like rooftops).

Due to the limited space in the city, vegetables with high water and fertilizer efficiency are particularly profitable (Orsini et al. 2013). These cultures often have a short growth cycle and are called high-value cash crop (de Bon et al. 2016). According to Thornbuch (2015), worldwide, one third of urban areas (regardless of suitability or availability) are required to cover the whole vegetable consumption of urban dwellers. Abegunde (2012) stated that urban horticulture is important in developing countries to boost food and ornamental plants production, provide job opportunities and promote green space development.

Environmental Potential

The current global greenhouse gas emissions caused by conventional agriculture are 20–30% (Eigenbrod and Gruda 2015). This is largely due to the large proportion of animal feed produced for meat consumption. In addition, large amounts of water and energy from fossil fuels are required for the production, processing and transport of conventional agricultural products. Renewable energy sources and circulation systems such as hydroponics or aquaponics can reduce the ecological footprint in agriculture (Ohyama et al. 2008). Here is a great potential for urban horticulture. Hydroponics can also be used, for example, where the soil is contaminated and unusable for direct planting. In recirculating hydroponics, up to 5–10 times less water is used than in conventional agriculture (Caplow 2009). This is a decisive advantage especially in countries with water scarcity.

Economic Potential

The urban horticulture market has grown steadily in recent years. The yields of the crops vary greatly depending on the type of cultivation. Indoor cultivation methods usually have a much higher yield compared to outdoor cultivation. As an example, in 2015, world crop yields of leafy greens averaged 339,800 lbs per acre in indoor farms. At outdoor lettuce, the average yield per acre was only 30,700 lbs (Agrilyst 2015). This is mainly due to the fact that indoor farms can grow food throughout the year and can be grown by, e.g., soilless cultures like hydroponics that promote faster plant growth. For instance, in 2013, the volume of the vertical farming market rose from USD 0.403 billion to USD 1.5 billion by 2016. According to GlobeNewswire (2015), the vertical farming market will reach USD 6.4 billion by 2023. On average, around 25–30% of urban dwellers work in the agricultural sector worldwide (Orsini et al. 2013)

Social Potential

Urban horticulture is mostly done as commercial. Nevertheless, there are also social advantages for city dwellers. Particularly in developing countries, food security plays an important role. With the help of efficient cultivation methods, food can be produced locally. The cultivation of ornamental plants and the integration of horticulture into architecture concepts can also increase the well-being of city dwellers (Specht et al. 2014) (Fig. 13.6).

13.3.2.2 Aquaculture

According to Hubold, aquaculture is the cultivation of a wide variety of aquatic organisms, such as fish, molluscs and crustaceans, in different artificial and natural forms of ponds and containers (Hubold and Klepper 2013). Aquaculture counts as urban farming when it is practised in the urban or peri-urban environment. For example, fish within a city can be cultivated in tanks, ponds, converted rice fields, borrow pits, lakes and reservoirs, multifunctional wetlands, sea or cages (Bunting and Little 2015). Worldwide fish farming is very popular, and the fish consumption

Strengths	**Weaknesses**
- regional and decentralized food supply in the city - short transport routes reduce CO_2 emissions - contribution to food security - using closed or semi-closed systems reduce the inputs like fertilizer or pesticides	- Possible health risks from polluted areas and the grown foods (Säumel 2012)
Opportunities	**Threats**
- creation of green spaces in the city - positive effects on microclimate of the city	- Overuse and pollution of the areas by intensive agriculture

Fig. 13.6 SWOT analysis of horticulture

increased with a growth rate of 5.8% during 2001–2016 (FAO 2018a, b, c). In 2017, the average annual per capita consumption of seafood worldwide was 20.5 kg (FAO 2018a, b, c). Especially in developing countries, the availability of aquaculture in the city can be a valuable option as a source of food and income as well as a source of high-quality protein (FAO 2011).

Environmental Potential

Urban aquaculture can help to save long transport distances. However, intensive aquaculture can cause increasing environmental damage such as eutrophication of water bodies. High stocking densities, the use of medicines and enormous water consumption entail environmental risks. Circuit-based systems such as aquaponics offer potential for improvement. In aquaponics, nutrients from fish excreta such as nitrate and phosphorus are used as fertilizers for vegetable cultivation. Recirculating aquaculture systems (RAS) or aquaponics have a significantly better ecological footprint than conventional aquaculture, mainly due to lower water consumption. Modern RAS require about 90% less fresh water than conventional aquaculture systems (Timmons and Ebeling 2013).

Economic Potential

According to the FAO (2018), global aquaculture production in 2016 was 110.2 million tonnes with a market volume of USD 243.5 billion. Of this, the share of fish as food is 80 million tonnes or USD 231.6 billion. The remainder is divided between aquatic plants (30.1 million tonnes) and nonfood products (37,900 tonnes) (FAO 2018a, b, c).

Social Potential

Aquaculture is mainly used to produce food. In developing countries, fish is often the only way for people to obtain animal protein. Worldwide about 20 million people are working in the aquaculture sector, in which 85% are from Asia alone and only about 0.5% in Europe (FAO 2018a, b, c). Depending on the urban environment in developing countries, a fishpond can deliver between 200 and 400 g Nil tilapia per square metre every 4–6 months, i.e., 0.4–1.2 kg/m^2 per year, depending on the scale of inputs and management practices (FAO 2011). Aquaculture can create a positive social impact for urban dwellers by contributing to food security and income and employment opportunities (White and Edwards 2015; Bunting and Little 2015) (Fig. 13.7).

13.3.2.3 Agroforestry

The term agroforestry refers to land use systems in which trees or shrubs are combined with arable crops and/or animal husbandry in such a way that environmental and economic benefits are obtained between the various components (Nair 1993). Usually in agroforestry systems, it is distinguished between the combination of (Nair 1985):

Strengths - Local product - Increasing market of fish products - Can contribute to food security - Simple source for high quality protein - Income and employment	**Weaknesses** - Pollution of water bodies at intensive aquaculture - Fish feed usually still consists of a large proportion of fish meal or oils from wild fish - Often high investment costs when environment friendly
Opportunities - International agreements and guidelines	**Threats** - inadequate waste water strategy

Fig. 13.7 SWOT analysis of aquaculture

Fig. 13.8 Agroforestry system in the Democratic Republic of the Congo

- Trees with arable crops (silvoarable systems)
- Trees with animal husbandry (silvopastoral systems)
- Trees with arable crops and animal husbandry (agrosilvopastoral systems)

Since the age, distribution and arrangement of woody plants can vary, there are many different forms. Typical of all types of agroforestry are deliberately used interactions between woody and arable crops (Fig. 13.8). For example, earlier forests were also used for pig fattening. The orchard is a traditional agroforestry system that can still be found nowadays in Europe. So the meadow next to the fruit growing still serves as pasture or hay. The diversity of agroforestry systems in terms of their design, species composition and management is large and ranges from shifting cultivation and homeguard systems, particularly in the tropics and subtropics, to aquaculture in mangrove forests (Nair 1985), to water protection strands (Vought et al. 1995) and windbreak hedging systems (Brandle et al. 2004) in North America and Canada and to Knicks and short-drive alley cropping systems (Grüenewald et al. 2007), particularly in Central Europe.

Environmental Potential

Across the world, there has been a growing awareness in recent years that intensive agriculture causes many environmental problems such as soil, air and water pollution, food depletion and soil fertility (McNeely and Scherr 2003). Based on this insight, the concept of multifunctionality of agriculture developed. Agroforestry systems protect the soil from erosion by wind and water and can stabilize and improve the yield of annual plants. In addition, the field strips planted with trees form habitats and retreats for plants and animals.

Economic Potential

In agriculture, there is an increasing field of tension between ecological and economic requirements. For Europe, the potential of agroforestry in the extensive EU project SAFE (Silvoarable Agroforestry for Europe) could be demonstrated by means of models (Dupraz et al. 2005). The ecological advantages of perennial woody crops on agricultural land are the increased structural diversity and thus the positive effect on biodiversity (McNeely and Scherr 2003), the aesthetic enhancement of the landscape, reduced erosion and increased protection against water pollution and flooding. The economic advantages are in particular the higher average productivity of silvoarable tree systems compared to the separate cultivation of trees and crops. Initial economic calculations indicate that farmers with agroforestry systems in Europe in the longer term even achieve greater profit than with farming method's traditional agriculture (Dupraz et al. 2005).

Social Potential

In comparison with pure stands, crops with plants of different stature heights use the solar irradiation on the surface more comprehensively. There is a larger photosynthetic surface, so more biomass can be formed. For example, at the trial sites in Southern France, where single-row walnut strips were combined with wheat, a yield could be achieved on 100 ha of arable land, which would have required a comparatively 140 ha in pure stands. The trees took only 5% of the area. There are many possibilities for adapting this type of land use to the demands of farmers but also to the conditions of the respective location. Maintaining the permanent crops takes place primarily in the winter months and is thus in low competition with the working time requirements of other agricultural activities (Fig. 13.9).

13.3.2.4 Urban Beekeeping

About 15–30% of all food produced depends on pollinators (Greenleaf and Kremen 2006). According to the Food and Agriculture Organization of the United Nations (FAO) 2018, the value of agricultural products from pollinators is estimated at between USD 235 and USD 577 billion per year. Among all pollinators, the honeybee (*Apis mellifera*) is the one that most frequently visits crops worldwide (Hung et al. 2018). The number of hives continues to decline due to various interrelated effects such as climate change, parasites, the use of pesticides and the loss of habitats (Sass 2011). On the other hand, beekeeping has been increasing in cities for several years (Fig. 13.10).

Strengths	Weaknesses
- Provision of highly demanded woody bioenergy sources on agricultural land - Improved area-related energy balance and improved nutrient use efficiency - Positive yield effects and higher yield stability in annual crops due to improved microclimate (e.g., by windbreaking tree strips) - Improved protection of arable crops against weather conditions - Promotion of beneficials in the field - Creation of rest or extensive zones in agricultural areas - Creation of wildlife retreats (especially small game)	- Higher establishment costs of agroforestry systems compared to annual crops - Higher effort and higher management costs - Competition between woody plants and crops for light, nutrients, water and habitats with negative effects on plant growth
Opportunities	**Threats**
- Extension of the agricultural product range (product diversification) - Improvement of income function (especially in low-income locations) - Creation of regional markets for agroforestry products and processing - Strengthening rural regions by promoting regional material cycles and regional added value - Sustainable energy supply	- Long-term capital and area bonding through the comparatively slow-growing trees - In special cases: woody roots can penetrate existing soil drainage systems and destroy / clog them up

Fig. 13.9 SWOT analysis of agroforestry

Fig. 13.10 Urban beekeeping in the zoo of Magdeburg (Germany). The beekeeping station is additionally used for educational purposes on ecosystem services

A bee colony always consists of three different groups of bees. There is generally one queen whose only job is to mate and lay eggs. Furthermore, the beehive consists of drones which are always male and whose task is to mate with the queen. The third group are the working bees. They are the ones who collect nectar and pollen from flowers and make wax and honey from them. The workers are always female but are not able to mate and reproduce. Furthermore, the workers are responsible for the care of the brood, the cleaning, the honeycomb building, the search for food and the guarding of the beehive (Cramp 2008).

Environmental Potential

Over 80% of all flowers and 75% of all fruits and vegetables are pollinated (Rose et al. 2016). Pollination thus contributes significantly to biodiversity conservation and has a key role in ecosystem services. Bees play a role in these tasks because they perform the skin part of pollination (Bradbear 2009). As Marinelli (2017) pointed out, urban green spaces today have to fulfil several functions, such as verdant getaways, playgrounds or gathering spots. Green spaces must also be a place for native plants and animals in order to preserve diversity.

Economic Potential

In 2017, the worldwide production of honey was 1,860,712 tonnes and for beeswax 42,307 tonnes and has been rising for years (FAO 2019a, b, c). The export of honey alone had a trade volume of US$ 2.1 billion this year (Workmann 2018). The honey produced and traded comes mainly from commercial production. A single hive produces between 11 and 27 kg per season (BBKA 2019), depending on the local conditions for the bees. In order to make a living, a beekeeper must have many individual hives, which is why the price of non-commercial honey is usually higher than that of commercial honey. However, people in countries such as Germany prefer regional products (Statista 2019a, b) and are willing to spend more money on them.

Social Potential

Urban beekeeping is a hobby rather than a commercial activity due to its low-financial profits. Therefore, the social benefits are the enjoyment and fun of the hobby. This concerns the individual, the family or the community in which the beekeeping is carried out in order to produce healthy food or to sell part of it (GNSW 2000). Further, it can be combined with educational activities, providing cultural ecosystem services (see Fig. 13.11).

13.3.2.5 Insects Farming

Insects have been consumed for thousands of years. Worldwide about 1400 species are known to be used by humans as food (Durst and Shono 2010). Consumption takes place in over 100 countries around the globe, with most known species coming from the African, Asian and American continents (Johnson 2010). Depending on the circumstances, the insects are regarded as a staple food or delicacy. In front of the background of an increasing world population, the FAO assumes that livestock production will increase by 60% compared to today's production (Hanboonsong et al. 2013). In this context, 80% of agricultural land is already being used for livestock farming (FAO 2019a, b, c).

In general, there exist two types to get edible insects. In the past, the insects were harvested in wild, but with the development of farming techniques, the insects will

Strengths	Weaknesses
- Pollination services for biodiversity - Sheltered from pesticides - Bee survival is high in cities - Sale of local products - Low space requirement for hives	- Limited number of hives for honey production - Honey production depends on plants in the neighbourhood - Honey production isn't possible during the whole year
Opportunities	**Threats**
- Improve local material cycles - Interacting with other urban gardening activities	- Disturbing for other residents - Allergic reactions due to stitching

Fig. 13.11 SWOT analysis of urban beekeeping

be more and more breeding on farms (Hanboonsong 2013). While insect-eating in Asian countries is very popular and common, in western countries, it is the main focus on feed production for animals (Jansson and Berggren 2015). However, the current state of European countries is changing, and insect breeding could change from animal food to human food. At the beginning of 2018, the EU Regulation 2015/2283 on novel food changed. Since then, it has been permitted on the European market to sell certain insects as food for humans. This has been accompanied by the establishment of start-up companies and increased research. Furthermore, insect breeding isn't only for food production. Bioconversion into energy like biodiesel is feasible as well (Surendra et al. 2016).

Environmental Potential

The feed conversion ratio, this means how much feed is needed to produce a 1 kg increase in weight, is very high in conventional meat production in contrast to insect farming. Smil (2002) wrote that a chicken needs 2.5 kg, a pork 5.0 kg and a cattle 10 kg of feed to increase their own weight about 1 kg. Furthermore, at the end of conventional production for a chicken and a pork, 55% of weight are edible and for beef just 40% of weight. On the other hand, insects need 1.7 kg or less of feed to gain their weight about 1 kg (Collavo et al. 2005). With the focus on land consumption and water use, 1 kg of beef requires 8–14 times more land and 5 times more water compared to mealworms (van Huis and Oonincx 2017). In 2012, Oonincx and de Boer examined the global warming potential (GWP) and found out that in contradiction to mealworms the GWP value for a chicken is 1.3–2.6 times, for pork 1.5–3.8 times and for beef 5.5–12.5 times higher.

Economic Potential

In 2018, the global market value of edible insects is about 406 million US$. According to estimations on Business Wire (2018), the market will reach up to 1.18 billion US$ by 2023. This includes the whole insect itself as well as further processing from insect breeding to meal, protein bars or bake products. Alone the market in the USA is projected to reach 50 million $US for flour, protein bars and snacks (Statista 2019a, b). Tao and Li (2018) found out in this context that 72% of American people definitely or probably would eat insects.

Consumer Behaviour

Food acceptance is controlled by affective, personal, cultural and situational factors, but motives are based mostly on sensory/pleasure considerations and health. Humans are inclined to avoid unfamiliar foods (neophobia), particularly when they are of animal origin.

With these novel foods, humans exhibit both an interest in (obtaining a wide variety of nutrients) and a reluctance to (the possibility that these foods may be harmful or toxic) eating them (the omnivore's dilemma). Neophobic reactions towards novel foods of animal origin may be decreased by lowering individuals' perceptions of their disgusting properties (Van Huis 2012) (Fig. 13.12).

13.3.2.6 Molluscs Farming

As part of aquaculture, molluscs farming is one of the major components in this area together with fish, crustaceans and plants (FAO 2014). Today, if we exclude a small number of land snails, only marine bivalves (mainly oysters, clams, scallops and mussels) are farmed with great success, utilizing methods sometimes old of centuries (Cattaneo-Vietti 2016). Although they have been cultivated for centuries, recent technological advances in the field of mollusc farming have allowed increasing their production significantly (Olivares-Banuelos 2018).

Strengths	**Weaknesses**
- Protein, fat, mineral and vitamin source - Feed conversion ratio - Low GWP and land consumption	- Distaste again edible insects - High energy consumption (heating in cold countries)
Opportunities	**Threats**
- Innovated business markets in western countries - Source for bioenergy	- Resistance to try new food (especially in western countries)

Fig. 13.12 SWOT analysis of insects farming

Environmental Potential

Filter feeding by populations of bivalve molluscs is reviewed with respect to their ability to act as an estuarine filter, increase clarity of coastal waters and facilitate the removal of nitrogen and other nutrients from eutrophic coastal waters. Most species of cultured bivalve molluscs clear particles from waters at rates of 1–4 l/h, and populations of shellfish in healthy assemblages can filter a substantial fraction of the water in coastal estuaries on a daily basis. Actively growing shellfish incorporates nitrogen and other nutrients into their tissues as they grow. On average, 16.8 g of nitrogen is removed from estuaries for every kilogram of shellfish meats harvested (Rice 2001).

Economic Potential

The most heavily traded bivalve mollusc species are mussels, clams, scallops and oysters, and the vast majority are farmed. China is by far the largest exporter of bivalves, exporting almost three times as much as Chile, the second largest exporter, in 2016. China also has significant domestic consumption, although the European Union is the largest single market for bivalves. Bivalves are widely promoted as healthy and sustainable food items, and demand has been rising in recent years. The world farmed food fish production amounted to 54.1 million tonnes of finfish, 17.1 million tonnes of molluscs and 7.9 million tonnes of crustaceans in 2016 (FAO 2018a, b, c). Only for the European Union, the value of molluscs farming reached 902.7 million euros, in 2014 (Eurostat 2018).

Social Potential

If aquaculture is planned as grow-out operations using a feedlot concept, then the benefits to communities are small. However, if aquaculture is planned as community-based development of a highly integrated, local operation, then employment opportunities and the potential for positive community impacts increase dramatically. Aquaculture can play an important economic role by creating new economic niches by generating employment in areas where there are few alternate job choices, by providing local sources of high-quality food and opportunities for attractive investments for local entrepreneurs to invest in the local economy, thereby increasing local control over economic development (White and Edwards 2015) (Fig. 13.13).

13.4 Options for Brownfield Rehabilitation

Most of the gardens are located on former urban brownfields. According to Tobisch (2013), who made a respective investigation in Germany, 69% of the gardens are located on urban brownfields. At first glance, urban gardening proves to be an extremely adaptable instrument that can and will be practiced on inner-city brownfields with various uses and varying periods of non-use. One example is the currently running research project “productive green infrastructure for post-industrial urban renewal” (proGIreg), where “productive green infrastructure for the regeneration of old” refers to industrial cities. Nature-based urban development measures in

Strengths	**Weaknesses**
- Increasing consumption of seafood - Consumer confidence in local products	- Harvest can´t reach a marketable size - Slow growth
Opportunities	**Threats**
- Efficient biological treatment of water - Export potential	- Needs a constant salinity level - Disease outbreak can destroy the harvest

Fig. 13.13 SWOT analysis of molluscs farming

disadvantaged districts of Dortmund (Germany) is one of the three cities in which the green infrastructure is to be realized, and the other two cities are Turin (Italy) and Zagreb (Croatia).The mammoth project is funded by the European Union with more than 10 million euros. At a conference in Dortmund-Huckarde in September 2018, the official launch of the large-scale project began, which is expected to run until the summer of 2023. Horizon 2020 is the EU's Research Framework Programme, which will provide € 75 billion in research projects between 2014 and 2020.

Many after use ideas are often not implemented on brownfields, because investors have to reckon with hidden costs in an unknown amount because of their constructional-structural defects (Tobisch 2013). Classically, these deficiencies include the sanitation measures like soil and groundwater remediation, foundations or other building residues, contaminated sites that pollute the soil and compensatory measures that investors must carry out in return for their construction. These obstacles are met by urban community gardens with great adaptability (Tobisch 2013). To build a communal garden, the initiatives need space to garden on, either open or undeveloped, as they can be planted in mobile containers without soil. On many areas of the surveyed urban gardens, there are various remnants of pipes, foundations or building components left over from previous uses. As long as there is enough acreage and the gardeners are safe enough, the garden initiatives can react extremely flexibly to these remnants (Tobisch 2013).

13.5 Economic Considerations

As a community-based venture, urban agriculture provides the products, in most cases, directly to the neighbourhood. Small businesses have the potential to stimulate the local economy through job creation and income generation. Beyond this, additional support business has the opportunity to occur on the cultivation, progression and distribution stage (Vitalyst 2017). Due to limited space, urban farmers faced other conditions as conventional farmers that leads to innovative ideas like vertical farming, microgreen operations, aquaponics, etc. in the past with the possibility to create new ideas in the future (Lanarc and Golder 2013).

As its nature, urban agriculture highly depended on local conditions. Business challenges and opportunities can be very different; for instance, sites like Berlin, New York or Vancouver would not compare to Nairobi or Havana (Hallett et al. 2017).

13.5.1 Havana (Cuba)

In Havana, the idea of urban agriculture is based on "production in the community, by the community, for the community". With a total area of 721 km^2, the city used 41% of its land for agriculture production. Thousands of people work either directly in urban farming or in supporting sectors like popular councils, service networks or research institutions (Novo and Murphy 2000). Nowadays, one of the key reasons for entering gardening is a better chance for more income (French et al. 2010) that can reach many times over the average government salary (The Economic Times 2008).

13.5.2 Brooklyn, New York (United States)

In 2009, Gotham Greens was found through inspirations of innovation and technology in agriculture systems. It was the first commercial rooftop greenhouse in the USA and the state of the art in greenhouse facility in 2011. With the opening of the second greenhouse, they integrated a supermarket and expanded greenhouse space. Up to now, they are located in New York and Chicago with a totalling space of 170,000 ft^2 (approx. 15,800 m^2) (GothamGreens 2019).

The two examples of Havana and New York show that under economic considerations, urban farming can be implemented everywhere. However, it must be distinguished in terms of the economic value, meaning on the one hand, the production for self-consumption and on the other hand the production for sale. Both increase the income for the people and lead to a better economic welfare.

In a depressed economy with high unemployment, urban agriculture can create jobs, generate income and promote financial stability (M-NCPPC 2012). According to the Food and Agriculture Organization (FAO 2019a, b, c), 800 million people worldwide practise urban agriculture that helps low-income urban residents to save money. The OECD (2010) estimate that Detroit could generate 200 million US dollars in sales and approx. 5000 new jobs. Vitiello et al. (2010) investigated the urban framing area in Camden, New Jersey, and estimated the value of USD 64,756 by 48 gardens. Another study came to the estimation of USD 4.9 million for the summer vegetable production in Philadelphia (Vitiello and Nairn 2009).

The sample illustrates the economic potential of urban agriculture as well as the potential for multifunctionality. In the frame of green infrastructure, a multifunctional urban agriculture will deliver a large potential of ecosystem services like the following:

- Production of raw materials and food
- Design and maintenance of cultural landscapes
- Design and maintenance of diverse natural habitats and climate mitigation zones including heat buffers
- Provision of equalization areas to agglomerations (for instance, in the form of green belts)
- Provision of space for social life in urban areas

Further, there is a large potential for industrial symbiosis in order to further develop the economic potential. Industrial symbiosis refers to a business collaboration wherein residuals from one enterprise serve as inputs to another. Referring to the circular economy approach, a further scope should be to close all material cycles. A first material cycle analysis for the following options of urban agriculture in the city of Magdeburg was given in Plat et al. (2018):

- Use of fallow land and brownfields with aquaponics
- Use of fallow land and brownfields with organic farming
- Rooftop with aquaponics
- Rooftop with organic farming
- Vertical farming with aquaponics
- Vertical organic farming

According to Plat et al. (2018), the results showed that the variant "vertical farming with aquaponics" has the highest implementation potential for Magdeburg.

A recent investigation by Schneider et al. (2019) underlined the environmental potential of urban agriculture. The study investigated the resource-saving potentials in the frame of industrial symbiosis through insect farming (Berlina et al. 2015). The results showed a resource-saving potential of up to 2 powers of 10 that can particularly be proven regarding the impact category "fossil resource depletion". The economic potential of industrial symbiosis in the frame of urban agriculture is not estimated yet, but the results of Schneider et al. (2019) indicate the resource-saving dimension to be expected.

13.6 Conclusion

A sustainable bioeconomy can potentially help to replace the era of fossil resources and supply a growing world population. The transformation to such a bio-based economy is characterized by economic, ecological and social opportunities but also by risks. The possible potentials, based on the key objectives of the 2030 Agenda and the Sustainable Development Goals (SDGs), and challenges have been illustrated in the present contribution. The World Community has set itself 17 ambitious SDGs with the scope to preserve the earth for future generations and to improve the lives of those who still live in hunger and poverty. It is in the interest of climate protection as well as for humanitarian reasons, across sectors and across the entire production chain, to transform to sustainable food production approaches.

Bioeconomy in the form of urban green infrastructure is one pillar to establish sustainable and multifunctional food production solutions on different scales of a community in developing as well as developed countries. Developing countries have the chance and challenge to include bioeconomy solutions in the frame of urban green infrastructure in the spatial planning and consider multifunctionality already during the urbanization process. But also developed countries have a chance and challenge for transformation in the direction of bio-based solutions during the process of urban renewal. Urban communal gardens can respond very flexibly to obstacles to the reuse of brownfield land and be implemented in places that have no potential for other uses. First of all, urban gardens serve as places for community cultivation of food and the experience of nature. In the beginning, attractiveness plays a minor role from the food growing perspective. Nevertheless, the gardens make the area used more attractive and usually even lead to a higher property value. Also the ecological improvement and upgrading of an area is a central motivation of the garden initiatives. With their focus on the community, the new urban gardens differ in design and outward form of allotment gardens and private gardens. The social component plays a central role in the urban gardening movement. Social motives and the desire for community activities in the horticultural sector are central motivations for the majority of gardeners for participating in the gardens. Although urban community gardens do not focus on the economic development of an area, they not only reactivate fallow land on an ecological and social level but usually also lead to an economic revival.

Urban agriculture and closed resource cycles are by no means short-term phenomena. Corresponding initiatives should therefore be adapted locally and sustainable system solutions developed. Historical crops of cereals or legumes need to be returned to the field to ensure long-term agricultural biodiversity. Here, the bioeconomy can provide opportunities to develop new products from original crops, making it worthwhile to grow them again. In general, defining community gardens as a planning tool for urban development would give basic planning security to projects, giving them the opportunity to develop and exploit their great social and economic potential for the city, as well as its ecology and its inhabitants (Tobisch 2013).

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