Could Organic waste be a solution for food security in India?

An interview study on the opportunities and barriers of city compost adoption in Maharashtra

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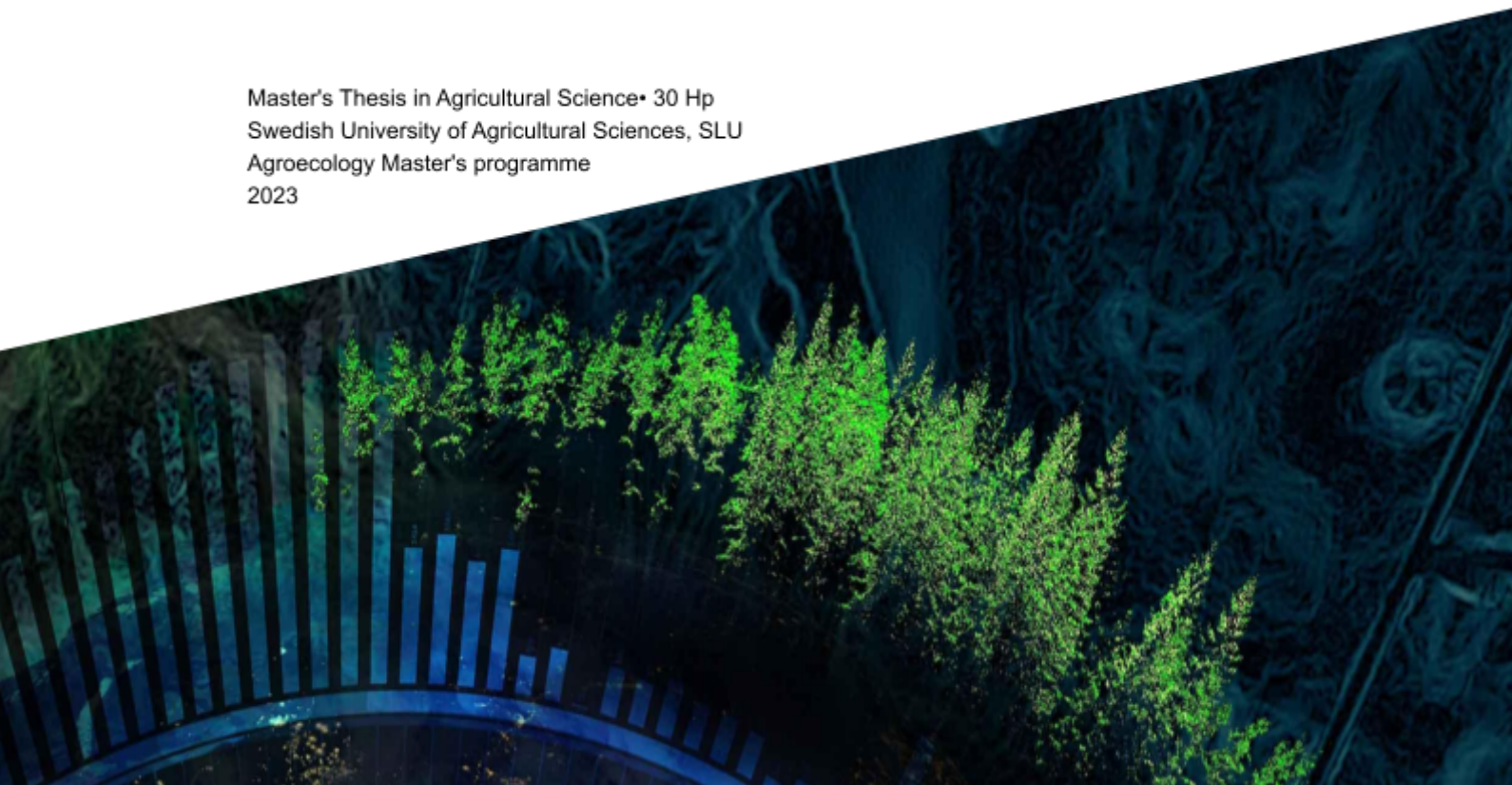

Could Organic waste be a solution for food security in India?

An interview study on the opportunities and barriers of city compost adoption in Maharashtra

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Foreword

Before I began my master studies in agroecology at SLU I had the opportunity to work and learn on several farms across the world. The experiences and the insights that I got during this time motivated me to reflect more on the advantages and disadvantages of different farm systems and gave me the opportunity to get a glimpse into the perspective of the farmer and the farm workers. I started to truly understand that in order for something to be sustainable it can not only be focused on the environmental perspective but also has to involve both social and economical dimensions. I had heard this definition of sustainability several times during my bachelor studies in agricultural economics but had never really been able to comprehend the real life implications of it. After truly internalising this reflection I decided to study agroecology since it seemed to me like the holistic nature of agroecology would enable me to further understand what is necessary to create sustainable farm systems.

During my studies I found the topic of soil management and ways to maintain the fertility of soils especially interesting and decided to focus on learning more about circular systems that enable the recycling of nutrients within food systems. After immersing myself in the topic I decided to try and look for projects that might be working on this topic to learn more about the practical implications of what I had learned. I managed to get in contact with the Urban Rural Nutrient and Carbon Cycle project (URNCC) during an internship at the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). After several exchanges with the colleagues working on the project, I was offered the opportunity to do my master thesis research on the topic of finding strategies that can increase compost adoption by farmers in URNCC project regions.

This opportunity gave me the chance to try to combine the different things I had learned into one final research project which not only made me grow professionally but also enabled me to widen my personal horizon by spending time in Maharashtra and interacting with the locals trying to further understand their reality.

I hope that the insights from my study will make a contribution to the creation of sustainable farming systems in Maharashtra and provide a small insight into the developments happening in India and the possibilities and hurdles of creating circular soil management systems.

“To forget how to dig the earth and to tend the soil is to forget ourselves.” - Mahatma Gandhi

Abstract

The purpose of this study was to identify different barriers and opportunities that might be influencing farmers in their decision to adopt city compost. To identify relevant factors I conducted semi structured interviews with farmers and relevant stakeholders. My findings suggest that the main barriers for compost adoption are a lack of political initiative, the influence of fertiliser companies and the preference of farmers towards using other compost products. Furthermore, the low availability of city compost also needs to be addressed to avoid supply problems if adoption rates were to increase. Apart from this the promotion of Integrated nutrient management and organic farming as well as the increased use of soil testing were identified as potential opportunities to increase city compost adoption. The implications of my study suggest that farmers in Maharashtra are in need of further guidance and information about city compost to be convinced to implement it within their fertility management practices.

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Abbreviations

URNCC	Urban Rural Nutrient and Carbon Cycle
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
SDG	Sustainable Development Goals
FCO	Fertiliser Control Order
AIS	Agricultural Innovations Systems
NGO	Non Governmental Organisation
NPK	Nitrogen Phosphorus Potassium
INM	Integrated nutrient management

1. Introduction

The current population of India is estimated to be around 1.4 billion and is projected to increase to 1.64 billion by 2050 (UNFPA 2022). Many soils found in India naturally contain low levels of organic carbon and are commonly deficient in nitrogen, phosphorus and other important macro- and micronutrients vital for efficient plant production (FAO 2005). These two factors created the need for nutrient management strategies that can sustainably provide food security on the Indian subcontinent. Since the beginning of India's green revolution in the 1960s, both policy makers and researchers have been focused on promoting the use of mineral fertilisers as the main strategy to improve the level of soil nutrients and agricultural productivity (Tripathi & Prasad 2009; Dantwala 1978). This one-sided focus on chemical soil properties has led to the neglection of fertiliser practices that aim at improving biological and physical soil functions which are vital for the long-term preservation of the productive capacity of soils (Kassam & G. Basch 2014; Fleißbach et al. 2007; Ghosh et al. 2012). Several long-term fertilisation experiments in different regions of India have reported universal reductions in soil fertility (NAAS 2009). These alarming developments have been found to be caused by the overuse of mineral fertilisers coupled with a neglect of other fertility management practices.

Considering these negative developments, it will be necessary to deploy new fertilisation strategies that are equipped to sustain Indian agricultural productivity. One way of preventing the decline of soil fertility is the increased use of organic fertilisers like compost or animal manure. A widespread adoption of organic fertilisers would add carbon rich organic matter to the soil and restore both biological and physical soil functions (Indoria et al. 2018).

1.1 Using compost to increase soil fertility

One potential readily available source of organic fertilisers in India is compost made from different forms of organic waste. The use of compost derived from organic waste has been shown to be beneficial for the restoration and maintenance of soil fertility (Hargreaves et al., 2008; Fließbacha et al., 2007; Leifeld et al., 2009). Compost can improve the physical, biological and chemical properties of soils by increasing soil pH, providing macro- and micronutrients, establishing better C/N ratios as well as increasing the overall carbon content of soils (García-Gil et al., 2000; Crecchio et al., 2004; Hargreaves et al., 2008; Srivastava et al., 2016). To make compost a viable way of addressing the problem of decreasing soil fertility in India, there is a need to establish well-functioning value chains that can supply farmers with high quality compost in sufficient quantities (Harper et al. 2004). Furthermore, it will be essential to coordinate the work of different levels of government, extension agents, researchers and relevant members of the private sector in order to enable the widespread provision of compost to farmers.

To facilitate the development of compost value chains, the Indian government has launched several projects and incentives dedicated to promoting the use of compost in several Indian states.

1.2 Urban-Rural Nutrient and Carbon Cycle project

As a response to land degradation in the state of Maharashtra, the Indian government and GIZ launched the URNCC project in 2015. URNCC is structured to be a cross-sectoral circular economy approach that considers organic waste as a resource in the agricultural value chain. The project aims to address the challenges of depleting rural agricultural soils and urban waste management simultaneously by promoting the use of compost. To achieve this organic waste from urban areas is recycled and processed into compost which can be used on farms in rural areas to restore and increase soil fertility. The project markets the finished product as city compost which distinguishes it from other compost products.

The URNCC initiative is part of the Indian government's agenda for sustainable development on land degradation neutrality, which aims to restore 23 million hectares of degraded land by 2030, which would amount to approximately 15% of the arable land available in India today. In its current state the URNCC project seeks to increase the number of farmers that are using city compost since low adoption rates have become the bottleneck for upscaling compost systems in Maharashtra. In order to formulate strategies to promote city compost adoption, there is a need to gain a deeper understanding of the perception that farmers have of city compost. To generate first insights into what factors influence the adoption of city compost by farmers in Maharashtra, my thesis will be focused on investigating which opportunities and barriers associated with using compost from the farmers perspective.

Since the scope of a master thesis is limited, it was decided to structure my thesis as a pilot study. The goal of my thesis work will be to generate data to provide a primary base for further research and development of compost systems in Maharashtra.

1.3 Project district

The district of Pune located in the central west of Maharashtra, was the URNCC project district where the research for my master thesis was conducted. The URNCC project and GIZ have been very active in the Pune district and have been able to establish a compost supply chain in the region. Hence, the district of Pune provided the opportunity to interview both farmers and relevant stakeholders to enable an analysis of barriers and opportunities for compost adoption. Furthermore, the GIZ colleagues that supervised my thesis work proposed Pune as a well-suited project region since they are well connected in the area which facilitated the organisation of my study.

Agriculture plays an important role in the district of Pune and is a big part of the local economy. Crop cultivation is done in accordance with the three major cropping seasons known as Kharif, Rabi and the summer season. The application of compost varies depending on the location of the farm and the cropping systems used. As a rule of thumb there are three different windows for compost application; one as a preparation for the summer cropping season from January to

February, one between September and October for the rabi season (winter season) and one in June as part of the preparation for seeding for the Kharif season (rainy season).

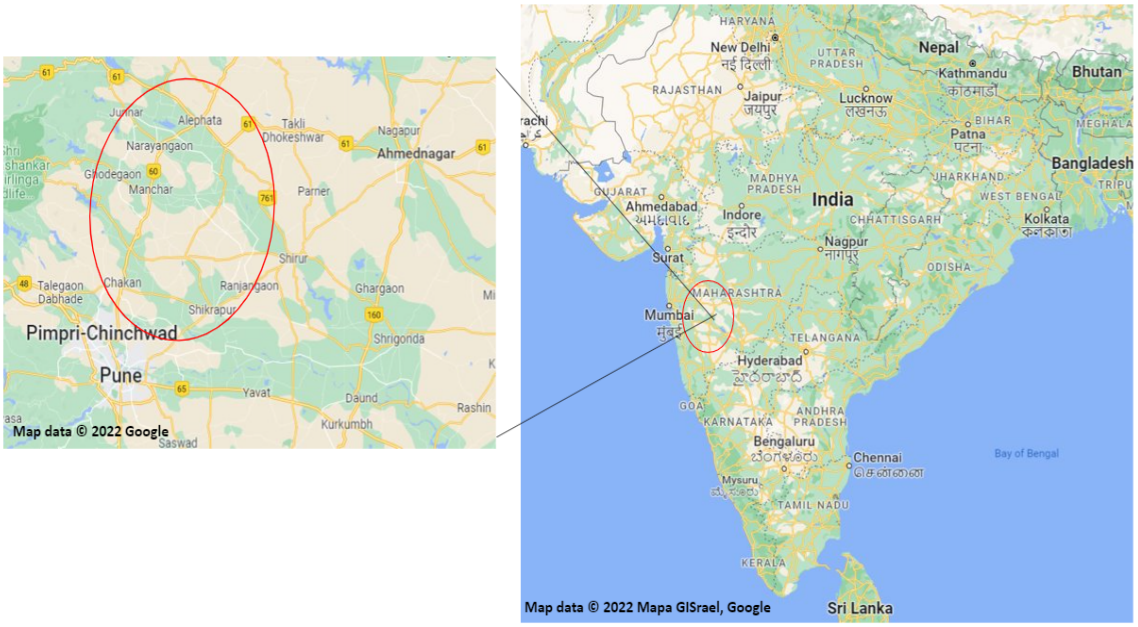

Figure 1: Location of the study region

1.4 Purpose and aims

The aim of my thesis was to further understand what opportunities and barriers are associated with using compost by farmers and different stakeholders involved with the compost value chains in Maharashtra. The identification of possible barriers and other factors influencing compost adoption generated valuable insights for the formulation of strategies that can increase city compost application, which in turn contributes to the creation of more sustainable farm systems in Pune and other URNCC project regions.

1.4.1 Research questions

The following research questions constituted the foundation of my thesis:

- Which internal and external barriers are farmers confronted with when wanting to adopt compost in the district of Pune?
- Are there any opportunities for increasing compost adoption in Pune?
- What perception do farmers have of compost? Are they in line with scientific perceptions?
- Are farmers aware of ways to learn about compost application and potential advantages and disadvantages of using compost?

1.4.2 Research contributions to achieve the sustainable development goals

The insights generated by my thesis research can potentially help to design strategies that promote compost adoption by farmers in the URNCC project regions. Increased compost usage in the agricultural system of Maharashtra would redound to reach four sustainable development goals (SDGs). Primarily, the increased use of compost would contribute to achieve the zero hunger (SDG2) target by increasing the long-term stability of rural food supply by means of enhancing soil fertility. Furthermore, the promotion of local nutrient cycles would help to secure the local availability of farm inputs, increase the resilience of local farm systems and expand the use of more sustainable production practices. Moreover, increased compost demand in rural areas would facilitate the implementation of sustainable cities and communities (SDG 11) by providing higher demand for the construction of compost production facilities in urban areas. This would enable sub-targets 11.3, 11.6, 11.a and 11.b by creating sustainable ways of disposing organic waste and supporting the creation of economic, social and environmental links between urban and rural areas. Furthermore, the provision of technically and economically sound waste management solutions can increase the adoption of sustainable targets in the development of new policies. Additionally, the increased use of compost would add to creating more responsible consumption and production patterns (SDG 12). More specifically the adoption of compost would aid the implementation of sub-targets 12.1, 12.2, 12.4, 12.5 and 12.a by promoting the sustainable management of soils, enabling a sustainable way to manage and recycle food waste and support the Indian government in implementing sustainable consumption and production patterns. Lastly, an expansion of compost application would facilitate the restoration of degraded soils which would contribute to achieve sub-target 15.3 (SDG 15: Life on Land).

2. Frame of reference

In this chapter, relevant studies and theories will be present to provide a theoretical framework for the interpretation of the collected data. Furthermore, insights from previous research will be outlined to provide the necessary foundation for discussing the study findings.

To enable a holistic assessment of different factors influencing the adoption of city compost this chapter will provide the reader with an introduction to the state of Indian agriculture today. In addition, an outline of political developments will be provided to enable the analysis of the findings in a historical context. Furthermore, this chapter will contain an introduction to the agronomic properties of compost to convey an understanding of the advantages and disadvantages associated with using compost as a fertiliser.
In addition to this, an outline of previous research investigating the adoption of compost by farmers in various regions of the world will be provided.

2.1 The Setting

The Indian subcontinent contains multiple climate zones which provide a vast number of agroecological areas enabling the cultivation of a large variety of crops. India globally ranks first in the production of milk, pulses and jute. Furthermore, India is the second largest producer of rice, wheat, sugarcane, groundnuts, vegetables, fruits and cotton. Moreover, India is also one of the leading producers of fish, spices, poultry and plantation crops (FAO 2022). India has the largest proportion of arable land in the world which in total amounts to 195 million hectares. In contrast, only 65 million hectares are covered by forest (FAOSTAT 2022).

Photo 1: Indian agricultural landscape

The agricultural sector in India is of great importance since almost 75% of Indian families depend on incomes generated from agricultural activities. Furthermore, India's food security is highly dependent on the maintenance of the country's domestic production of cereals as well as the sustainable increase of the

production of fruits, vegetables and milk to meet the increased demand caused by population growth and rising incomes (World bank 2012).

Since India reached its independence in 1947 developments in the agricultural sector have enabled the country to diversify its production as well as reaching food self-sufficiency. However, there is growing concern for the future sustainability of the Indian agriculture sector since it is very resource intensive and too narrowly focused on the cultivation of cereals (FAO 2022). As the potential expansion of land under agricultural production in India has been reached, further output increases will have to be managed by increasing the productivity per unit of land. In order to tackle this problem, there is a need to promote new agricultural methods whilst also reforming the current research and extension system. Moreover, better management systems for water resources need to be developed in order to balance the growing demand for water from industry, agriculture and domestic use.

Other important factors that need to be considered to grant the sustainable development of Indian agriculture are the reduction of soil erosion, the increase of the absorption of rainfall and the effects of climate change. There are many promising solutions that can be used to address these problems, however there is still a need to find ways for scaling up initiatives that promote the adoption of sustainable practices in agriculture (World bank 2012). Since the increased use of compost is one potential solution to many problems outlined above, the study of compost adoption is of great relevance when trying to formulate future strategies for sustainable development of agriculture in India.

2.1.2 Historical perspective on agricultural development in India

To further investigate potential barriers and opportunities for compost adoption in the Pune district it is important to be aware of historic developments that have shaped soil fertility management in India. The awareness of historic developments is relevant for this study since they might still have an impact on the fertilisation choices that farmers are making today. Moreover, an understanding of different policy measures impacting fertility management is helpful when trying to formulate future development strategies.

Developments of the Indian agricultural sector can be divided into four main development periods. The first stage of development took place from the declaration of India's independence in 1947 to the mid 1960s and was mainly driven by reforms that gave land rights to farmers, the development of cooperative credit systems and the implementation of major irrigation projects (Tripathi & Prasad 2009). The second major development stage was characterised by the initiation of a green revolution which promoted the adoption of new agricultural technologies such as high yielding varieties, mechanisation and the use of mineral fertilisers and pesticides. During this time the emphasis of agricultural reforms was put on developing national research institutions, extension services, input supply chains, marketing strategies and price support systems all geared towards increasing the adoption of new technologies by Indian farmers (Parayil, 1992). The subsequent development phase mainly occurred during the 1980s and was characterised by policies promoting the diversification of agricultural production. Diversification was incentivised by elevations in agricultural subsidies which led

to increased investments by farmers in new production systems equipped to produce a wider range of crops and especially develop horticultural systems. The fourth phase of Indian agricultural reform took place from 1991 and was mainly characterised by economic reforms seeking to liberalise trade in accordance with WTO guidelines (Tripathi & Prasad 2009).

2.1.2.1 Effects of development measures on soil fertility management in India

Murgai (2001) argues that many of the agrarian policies implemented in India since 1947 have led to a bias towards the use of mineral fertilisers. According to Murgai these positive biases have perpetuated a decline in the possibilities to implement other methods of fertilisation by policy makers and farmers in India. Murgai also states that the positive biases towards mineral fertilisers have led to an over valuation of their long-term effects on yield increases leading to a distorted view of their efficiency (Murgai 2001). The statements made by Murgai are in line with the findings of Indoria et al. (2018), who found that the exponential increases of mineral fertiliser application in Indian farm systems have not resulted in the long-term increase of yields but instead have led to a decline in the marginal utility per added unit of mineral fertilisers.

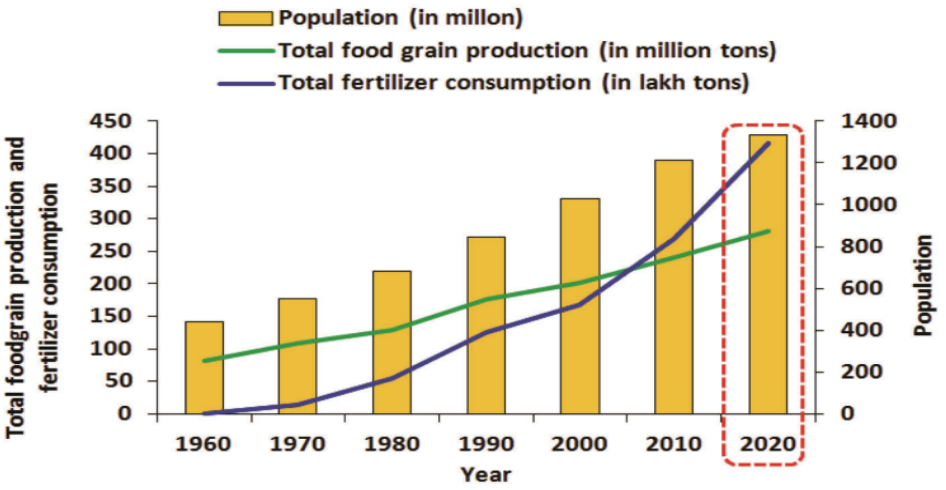

Figure 2: Graph showing trends in fertiliser consumption, grain production and population growth in India from 1960 to 2020. Source: Indoria et al. 2018

As outlined in the introduction chapter, an increased use of organic fertilisers could reverse the negative effects of the unbalanced application of mineral fertilisers. Around 2015 the Indian government launched several support programs and subsidies aiming to increase the use of organic fertilisers in Indian farm systems. One of these incentives was a policy scheme designed to promote the use of city compost under which subsidies as well as programs promoting the general use of compost were implemented (Department of fertilisers 2022). The subsidies were mainly aimed at decreasing the production cost of city compost and by doing so, lowering the end price that farmers pay for city compost. It is important to note that subsidies and other incentives for the production and sale of

complex mineral fertilisers were implemented simultaneously to the city compost program creating potential conflicts of interests. Similarly to the subsidies on city compost, the fertiliser subsidies on complex mineral fertilisers are also aiming to indirectly lower the price that farmers pay by lowering the costs of production.

2.2 Introduction to compost

Compost can be a beneficial fertiliser as it has various properties that can improve both soil conditions and crop yields. Furthermore, compost offers both economic, agronomic and environmental benefits (García-Gil et al., 2000; Crecchio et al., 2004; Hargreaves et al., 2008; Srivastava et al., 2016). However, it is also important to note that the use of compost can cause drawbacks when compared to other commonly used fertilisers (Rynk et al. 2022). To further understand the agronomic potential of compost it is necessary to be aware of potential opportunities and drawbacks associated with using it. Since this can make it more comprehensible to understand why farmers might choose to adopt or reject using compost as a fertiliser. Hence, this chapter will provide an overview on compost production and the potential of using compost as a fertiliser.

2.2.1 Composting - the process of making compost

The etymological origins of composting stem from the Latin word compositum which means mixture. Scientifically composting can be defined as the deterioration of a mixture of different solid substrates carried out by various microbial communities under aerobic conditions (Insam & De Bertoldi 2007).

Composting is an exothermic reaction in which organic materials are oxidised by different chemotrophic microorganisms. The process can be divided into two main stages: the decomposition stage and the curing stage (Bernal et al. 2017). During decomposition 3 phases occur in coherence with the activity of different groups of microorganisms. The phases are defined by groups of microorganisms that thrive at different temperatures (Keener et al. 2000). Firstly, there is the mesophilic phase (20-45°C) during which various bacteria and fungi start to deteriorate simple compounds sugars and amino acids. The biological activity causes a rise in temperature which eventually leads to the initiation of the thermophilic stage (50-70°C) during which more complex compounds such as fats, cellulose, hemicellulose and lignin are deteriorated. In addition to further deterioration, different pathogens and weed seeds can be destroyed during the thermophilic phase (Bernal et al. 2017). Once a large proportion of the feedstock has been oxidised the microbial activity decreases, which initiates the last step of decomposition known as the cooldown phase (Keener et al. 2000). At the end of the cooldown phase the substrate reaches ambient air temperature which marks the beginning of the second main stage known as the maturation process. During the maturation process microbial activity is low and the organic material in the compost starts to humify (Castaldia et al. 2005). Once the maturation is completed and the substrate has been stabilised the composting process is completed (Bernal et al. 2017). The finished product is called compost and can be defined as the stabilised product yielded from the process of composting that is suited to benefit plant growth (Insam & De Bertoldi 2007).

2.2.2 Benefits of compost

2.2.2.1 Economic and agronomic benefits of compost

Composting organic waste materials brings several economic benefits both from a waste handling and an agronomic perspective. Using composting to treat for example food waste offers the possibility to generate revenue from tipping fees as well as the manufacturing of a marketable product (Rynk et al. 2022). Applying compost to fields brings potential economic benefits as it enables farmers to decrease the input of mineral fertilisers that have become more costly recently and are expected to become even more expensive in the future (Jack & Thies 2006). Moreover, the continued application of compost can increase long-term soil fertility which stabilises yields and the economic longevity of farming operations (Rashid & Shahzad 2021).

In current agricultural systems, it is common to apply mineral fertilisers as the only way of adding nutrients back to the soil after harvest. The sole use of mineral fertilisers often has negative effects on soil fertility causing a decline in essential soil functions (Bitew & Melkamu 2017). It has been found that the addition of compost to agricultural land can prevent a decline in soil functions such as better nutrient cycling and an increase in the soil's ability to retain both water and nutrients (Rynk et al. 2022). These effects are mainly caused by the positive effects that compost has on soil organisms via the addition of carbon and other significant nutrients (Bitew & Melkamu 2017). Furthermore, plant growth can be affected directly by an increase in the activity of bacteria that secrete plant growth hormones like auxin. Additionally compost often benefits arbuscular mycorrhizal fungi which have been reported to increase plant growth by forming symbiotic relationships (Jack & Thies 2006).

Compost application has also been found to have potential positive effects on yields and the nutritional quality of crops (Martínez-Blanco et al. 2013). Apart from this, multiple studies have found that compost has positive effects on soil pH, soil aggregation, provision of macro- and micronutrients, better cation exchange capacity and better water conservation capacity (García-Gil et al. 2000; Crecchio et al. 2004; Hargreaves et al. 2008; Srivastava et al. 2016; Rynk et al. 2022; Bitew & Melkamu 2017). Moreover, compost is also beneficial from an agricultural perspective because it has disease suppressive properties. This is because of the effect that compost can have on plant vigour and the fact that compost provides beneficial living conditions for fungi that benefit plants through mycorrhizal symbioses or beneficial microorganisms that regulate plant pathogens (Jack & Thies 2006; Rynk et al. 2022).

2.2.2.2 Environmental benefits of compost

Compost application also leads to several positive outcomes for environmental parameters influenced by agricultural production. By the suppression of soil borne diseases the application of compost can cause a reduction of pesticide use which can reduce both environmental pollution and greenhouse gas emissions (Rynk et al. 2022). Furthermore, the application of compost has been reported to increase soil aggregate stability which reduces the risk for erosion whilst also increasing the soils capacity to hold moisture and retain nutrients preventing leaching and the destruction of habitats (Martínez-Blanco et al. 2013).

Besides the direct positive effects on ecosystems connected to agricultural systems, the possibility of using compost application to sequester carbon is an additional environmental benefit (Rynk et al. 2022; Martínez-Blanco et al. 2013). It is important to note that the production and application of compost only captures carbon in the soil temporarily since the sequestered carbon will be released back into the atmosphere eventually. This makes compost a short to midterm solution for directly reducing greenhouse gas emissions (Enzo & Hogg 2008). Nevertheless, increased compost application would also have indirect effects on greenhouse gas emissions since it would reduce the need of mineral fertilisers which require high amounts of fossil fuels during the production process (Enzo & Hogg 2008; Rynk et al. 2022).

2.2.3 Potential drawbacks of using compost

Despite the benefits associated with composting and compost there are also some drawbacks that should be considered. From a production perspective the initial investment necessary to start a composting operation is a common barrier preventing the expansion of the use of composting as a waste treatment method (Harper et al. 2004). Furthermore, the establishment of composting facilities requires large areas of land making it difficult to establish in areas where suitable plots are scarce (Rynk et al. 2022). Another drawback of compost production is the necessity to manage the emission of odours produced during the deterioration of organic materials (Ayilara et al. 2020).

When compared to other organic fertilising methods the use of compost has the disadvantage of not providing enough readily available nitrogen to the soil. The reason for this is that nitrogen is bound in different complex forms during the stabilisation stage of the composting process making it unavailable to plants in the short term (Bernal et al. 2020). Consequently, it is often recommended to supplement compost application with other organic or mineral fertilisers in order to provide the necessary amount of readily available nutrients. Hence, the supplementation of compost with other fertilisers is of special importance when starting to use compost to prevent yield reductions (Bitew & Melkamu 2017). In contrast to this the continued application of compost can provide between 50 and 80% of total nitrogen demand of most crops as more nitrogen is made available to the plant by being mobilised as the organic compounds deteriorate. This makes it possible to reduce the amounts of necessary supplementary fertilisers in the long term (Rynk et al. 2022).

2.2.4 The importance of compost quality

When planning to use compost to improve the economic, agronomic or environmental dimensions of a farm system it is important to consider compost quality. Due to the wide range of possible feedstocks that can be composted, and the complexity of the composting process, compost quality can be very variable (Bernal et al. 2017). Therefore, it is important to measure and monitor certain quality parameters both before, during and after the composting process to know what effects the finished product might have when applied to a field. Possible measures for the quality of matured compost are the N-NH3 to N-NO3 ratio, the C/N ratio, the content of humic substances and the soil cation exchange capacity (Azim et al. 2018).

Along with the organic qualities of compost it is important to assess whether the compost might be contaminated with heavy metals, pathogens, plastics and other inert materials (Bernal et al. 2017). In order to enable better quality control for different compost products many countries have implemented standards for both composting and compost. A study conducted in India investigating the fertilisation potential and the contents of contaminants in different compost products, found that there is a low availability of high-quality compost on the Indian market. According to the authors an increase in the availability of high-quality compost will be necessary to fully utilise the potential of compost both as a waste treatment method and fertiliser (Saha et al. 2010).

The Indian government has defined quality standards under the Fertiliser Control Order (FCO) which was implemented in 2009. According to FCO compost must meet limits prescribed for physical and chemical parameters as well as concentrations of arsenic, cadmium and zinc (Indian department of agriculture 2009). Despite the implementation of FCO the findings of Saha et al. (2010) are still relevant to consider since many plants still do not send samples to approved laboratories. Furthermore, the laboratories often observe significant issues with the received samples causing difficulties during the analysis. The URNCC project has recognised the issue of sampling and have implemented standard operating procedures to be used at compost production facilities within their project regions.

2.3 Relevance of technology adoption for agricultural development

The adoption of beneficial production methods is an integral part of improving agricultural systems. In order to formulate strategies that promote the adoption of innovations it is necessary to understand what factors influence the diffusion of innovations to farmers. Consequently, the following section will focus on the development of research focusing on the diffusion of innovations within agricultural communities.

2.3.1 Compost as an agricultural innovation

Innovations are commonly defined as new methods, practices or devices used to perform new tasks (David & Zilberman 2001). Following this definition, it can seem counterintuitive to consider compost as an innovation since the first records of sophisticated composting were made in templar knight settlements during the thirteenth century (Diaz & Bertoldi 2007). Zagata et al. (2020) highlight the importance of reintroducing old practices within modern agricultural systems to increase their sustainability. These practices can be labelled as retro-innovations and can be used to integrate the positive effects of traditional agricultural practices within modern farm systems.

To further enable the integration of retro-innovations within the modern agricultural systems of today it can be useful to view retro-innovations like compost as one part of agricultural innovations systems (AIS) (Klerkx et al. 2012). AIS can be defined as “a network of organisations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organisation into economic use, together with the institutions and policies that affect the way different agents interact, share, access, exchange and use

knowledge" (Hall et al. 2006). Despite the fact that compost is not a new invention, it is relevant to consider the re-introduction of compost in agricultural systems through the lens of the AIS concept, since this enables the analysis of compost adoption from a more holistic perspective. Moreover, seeing compost as a part of an AIS will be useful when trying to identify and analyse different factors and stakeholders that might have an impact on compost adoption in the district of Pune.

2.3.2 Developing the framework for researching adoption

Ryan and Gross are seen as two of the pioneering authors on the topic of farmers' adoption of innovations. Their work focused on the adoption process of hybrid corn in the state of Iowa between 1936 and 1939. Their research focused on the time that it took for different farmers to adopt hybrid corn and how different sources of information helped spread the new technology. Furthermore, Ryan and Gross outlined different characteristics of farmers that chose to adopt the new seed. Their study found that there were different rates of adoption relative to the time of introduction of hybrid corn among farmers in the studied communities. Moreover, Ryan and Gross identified salesmen of hybrid seeds as important sources of information for early adopting farmers. It was also found that later adopters were using neighbours that had already adopted hybrid corn seeds as their main source of information. These findings consequently enabled the identification of different characteristics that facilitate the adoption behaviour of farmers. According to the findings of Ryan and Gross younger more educated farmers were more prone to be early adopters of new innovations. Moreover, farmers with larger operations that are active members of different farmers organisations were found to be more likely to be early adopters of new technologies (Ryan & Gross 1950).

2.3.3 The diffusion of innovations

Rogers later synthesised the findings of Ryan and Gross and other researchers into his theory of the diffusion of innovations. In his theory Rogers divides the adopters of an innovation into five different categories: the innovators, early adopters, early majority, late majority and the laggards. According to Rogers initial theory, the adoption process of an innovation goes through five stages which are characterised by the number of adaptors relative to the time that the innovation has been available on the market (Rogers 1962). According to Rogers the process of diffusion starts with a period of low adoption rates when an innovation first becomes available. This is then followed by a take off period during which the marginal rate of adoption increases. The take-off is followed by a period of saturation during which the marginal rate of diffusion starts to decline, and the potential adoption rate reaches its peak (David & Zilberman 2001).

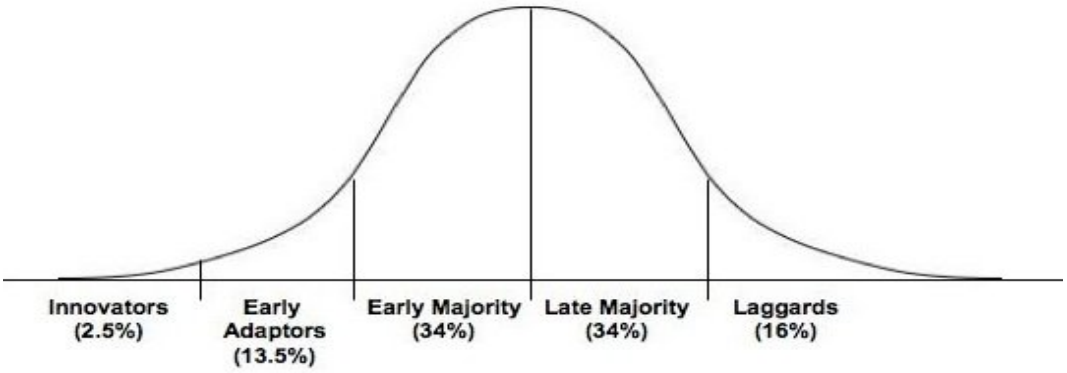

Figure 3: The rate of adoption of an innovation in relation to the time when the innovation was introduced Source: Rogers (1962)

According to Rogers there are five characteristics that an innovation should have to enable the widespread adoption in farming communities. Firstly, the *relative advantage* of a technology compared to other substitutes is relevant for the rate of diffusion. Secondly, the *compatibility* of a new technology with an existing production system and the *complexity of integrating* and using it within an existing system have an impact on the diffusion rate. Lastly, the *trialability* and the *observability* of the possible advantages of a new technology play an important role in spreading its adoption (Rogers 1962). Moreover, Rogers also outlines different mechanisms that shape the individual's decision process. According to Rogers, diffusion is the process by which the use of an innovation is spread by promotion through different channels of communication within a social system (Orr 2003). Following these insights Rogers claims that the individual's decision process can be divided into five steps:

I. Knowledge – the individual becomes aware of a new technology and its benefits and functions
II. Persuasion – the individual forms a favourable or unfavourable attitude towards the new technology
III. Decision – the individual engages in activities that lead to an adoption or rejection of the new technology
IV. Implementation – the individual starts using the new technology
V. Confirmation – the individual evaluates the results of the new technology

Roger's theory has been widely applied in the research and development of agriculture and has been the basis for several policy and extension schemes aiming to promote technology adoption in rural communities (Sunding & Zilberman 2001).

2.3.4 Flaws of the diffusion of innovations theory

Despite the general acceptance of Rogers theory on the diffusion of innovations it is important to note that the theory is not flawless. Rogers himself pointed out flaws in later publications and emphasised four potential problems resulting from the application of his theory (Rogers, 1995). Firstly, there is the risk for a pro innovation bias that does not account for the fact that all innovations might not be

beneficial in all farming contexts. Hence the adoption of an innovation is often dependent on local contexts. Consequently, it is important to consider the farmers perspective when trying to implement solutions for agricultural problems. Secondly, Rogers points out that there is a risk of an individual blame bias through which the problem of non-adoption is seen to be solely caused by the reluctance of farmers to accept technological change. As a result, other reasons for non-adoption like insufficient extension services or the inappropriate design of an innovation are not seen as determining factors of adoption. Finally, Rogers outlines that his theory might cause issues of equality and emphasises the importance of considering potential negative socioeconomic effects that might occur in connection with the implementation of a new technology (Stephenson 2003).

Apart from the flaws that were pointed out by Rogers himself other authors have also highlighted potential complications that might occur when applying the diffusion of innovations theory. Gross (1979) observed that the theory was not well equipped to be applied in developing countries since its application causes undesirable effects like increasing the inequality in rural communities, further marginalising farmers that are struggling to adopt new production methods as well as increasing competitive disadvantages of non-adopters (Gross 1979). According to Cook et al. (2021) agricultural research and extension need to apply more holistic methods like systems thinking and participatory methods to be able to circumvent the problem of further excluding marginalised farmers in developing countries. Moreover, development programs should consider problems of governance, potential power imbalances and historical developments that act as barriers for technological adoption. Instead of the commonly applied top-down approach of technological development and implementation in agriculture, Cook et al. (2021) advocate for development schemes based on humanistic and socio-economic principles. Apart from this, the theory of the diffusion of innovations can exacerbate problems if the promoted technology causes negative effects that were not considered during the development or implementation process of said technology (Stephenson 2003). Considering the negative external effects caused by the increasing use of mineral fertilisers in India it seems relevant to reflect on possible negative casualties when trying to implement sustainable change by introducing new technologies in agricultural production systems.

When trying to increase the adoption of an innovation by farmers it is also important to note that the agricultural sector is heterogeneous. This implies that when studying the diffusion of an innovation it is important to know that the incentives to adopt can vary depending on the agroclimatic, economic, social and personal conditions of each individual farmer (Chavas & Nauges 2020).

2.4 Studying barriers and opportunities of compost use in URNCC project districts

In order to further expand the use of compost among farmers in the different project regions of the URNCC initiative it will be important to identify different barriers that hamper the expansion of compost adoption by farmers. Furthermore, it will be interesting to investigate whether farmers perceive any benefits or opportunities in adopting compost, since this might help to identify possible

pathways for an accelerated expansion of compost use. This part will outline the findings from previous research on potential barriers that hamper compost adoption. The results presented come from studies performed in various regions of the world and enable the synthesis of a research framework for the study of compost adoption in and around the district of Pune.

2.4.1 Findings from previous studies on compost adoption

According to Akenroye et al. (2021) the adoption of sustainable practices such as the use of compost is dependent on internal and external factors.

2.4.1.1 Internal factors

Internal factors describe the internal characteristics of a person, social factors that influence decision making as well as societal pressures (Dessart et al. 2019). Viaene et al. (2016) used the theory of planned behaviour to investigate the beliefs of farmers on the effects of compost and whether these might hamper adoption. The theory of planned behaviour assumes that the attitude and beliefs of an individual can influence their behavioural intentions (Ajzen 1985). Social learning where individuals learn from each other by exchanging ideas or learning by observing actions of others has been demonstrated to be facilitated through farmers organisations which in the past have been used to catalysed sustainable agricultural development in India (Chaudhuri et al. 2021; Vaidyanathan 2013).

Akenroye et al. (2021) argue that knowledge and skills also should be considered as internal barriers impacting farmers' adoption of sustainable practices. In their study on the adoption of compost in the European union Viaene et al. (2016) found that a lack of knowledge and experience was one of the main barriers to compost adoption.

Moreover, Akenroye et al. also consider rationality factors as potential internal barriers for compost adoption (Akenroye et al. 2021). If an individual must make decisions in the context of a complex system, their course of action would always fall somewhere in between the extremes of being fully rational or irrational. In other words, a person's decisions can never be optimal nor total nonsense (Rouwette et al. 2004). The ability of an individual to find a rational solution to a problem is limited by the information, knowledge and experience in dealing with said problem. In the case of compost adoption, different factors can influence a farmer's ability to make more rational decisions. An example would be the notion that mineral fertilisers are superior to compost since they give fast results. It can seem rational to assume this position if you are unaware of the negative long-term effects of the sole use of mineral fertilisers.

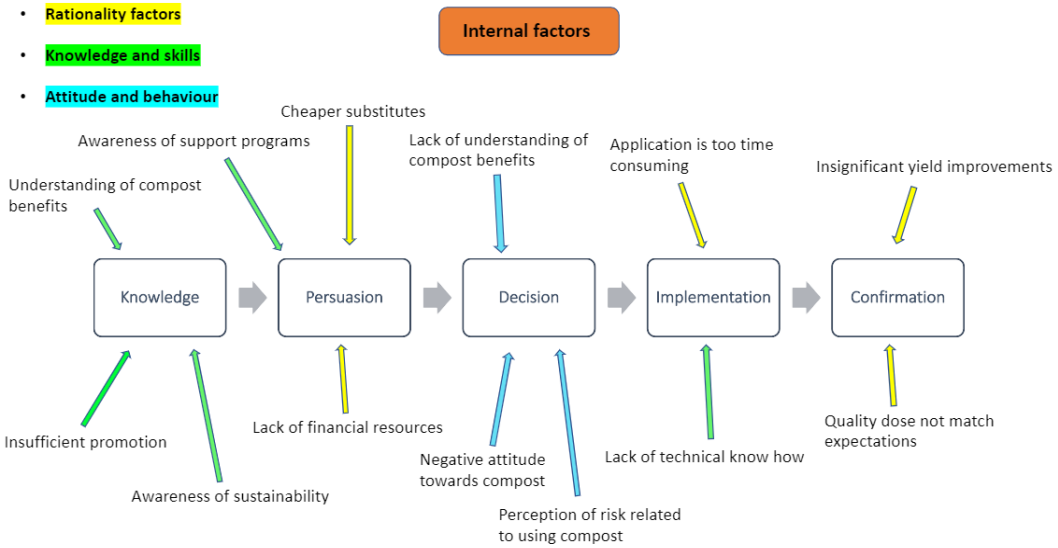

Figure 4: Possible internal barriers to compost adoption and their potential impact on the individual's decision process to adopt or reject compost Sources: The graph was inspired by the theories of Akenroye et al. 2021 and Rogers 1962

2.4.1.2 External factors

Apart from internal factors Akenroye et al. (2021) also outline external barriers that can influence farmers adoption of sustainable practices. External barriers can be divided into three groups: institutional, circumstantial and infrastructural factors. Previous studies on compost adoption of European, Malawian and Cameroonian farmers concluded that all external factors outlined by Akenroye et al. (2021) had an impact on farmers compost adoption. In all cases the promotion of mineral fertilisers, a lack of infrastructure for compost transport and application as well as missing extension services and promotion of compost were identified as main barriers for compost adoption. Furthermore, all three studies found that the price of compost transportation also hampers wide scale compost adoption (Cai et al. 2019; Folefack 2015; Viaene et al. 2016). These findings are in line with the arguments made by Harper et al. (2004) who argue that a successful implementation of a functioning compost system is mainly dependent on economic factors such as competitive pricing, adapting the products properties to the demand of the market and developing well suited marketing and distribution strategies. Moreover, Harper et al. (2004) also mention the importance of quality when trying to upscale compost adoption.

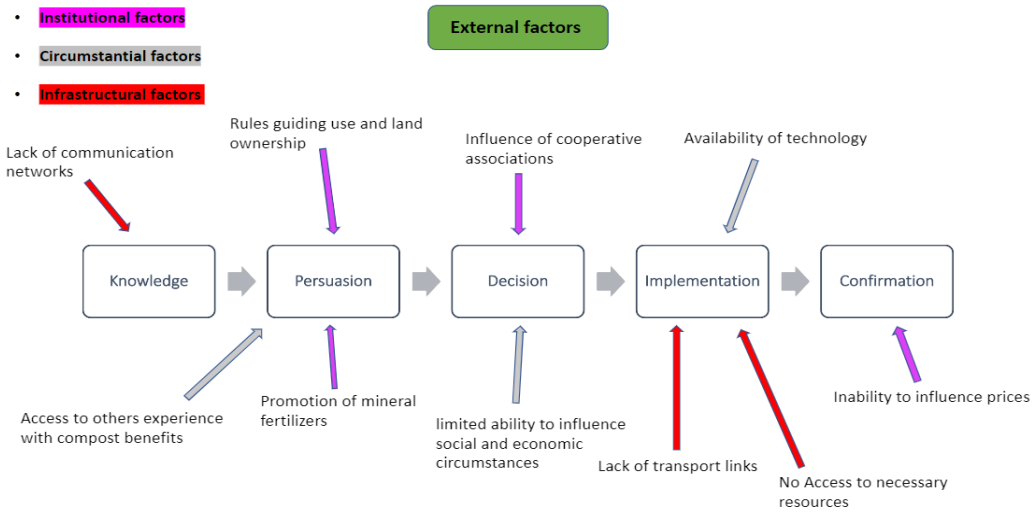

Figure 5: Possible external barriers to compost adoption and their potential impact on the individual's decision process to adopt or reject compost Sources: the graph was inspired by the theories of Akenroye et al. 2021 and Rogers 1962

2.4.2 Syntes

In order to formulate strategies to increase the adoption of compost in the Pune district it is important to further understand what factors and actors might have an influence on farmers decision-making processes. Considering the findings outlined in the previous chapters the different factors and stakeholders outlined in the diagram below could have an impact on adoption rates of compost by farmers in and around the Pune district.

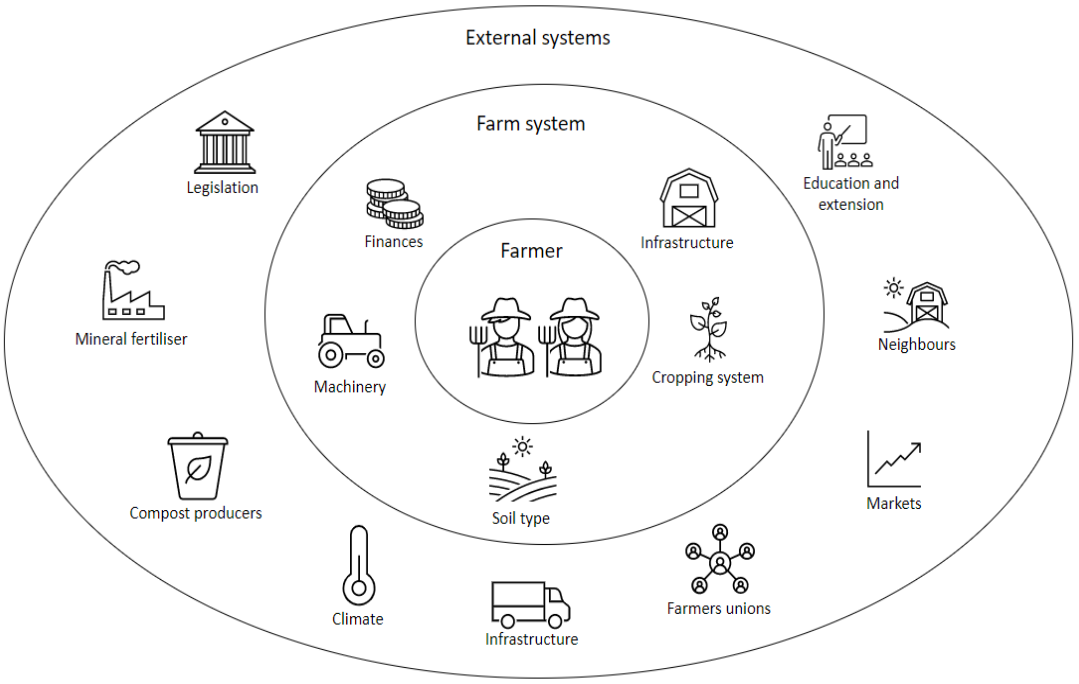

Figure 6: Diagram describing different actors and factors that might be impacting farmers decision to adopt compost

3. Methods

Qualitative research methods were used to find answers to the research questions outlined to guide my thesis research. The aim of using a qualitative approach is to make room for an open and personal exchange of thoughts and views that hopefully will generate insight into the decision-making processes motivating farmers to choose to use compost (Jürkenbeck et al. 2019). Furthermore, qualitative methods like semi-structured interviews open the possibility for new themes to emerge which have previously been unknown whilst simultaneously offering the capability to confirm findings that have already been described in the literature (O'Keeffe et al. 2016). Many researchers have used semi-structured interviews or focus group sessions to further understand the reasons for why farmers choose to use compost (Folefack 2008; Cai et al. 2019; Akenroye et al. 2021; Viaene et al. 2016).

3.1 Semi-structured interview

A widely implemented method used to gather qualitative data are semi-structured interviews. This method of sampling data gives researchers the opportunity to gain a deeper understanding of the interviewee's perspective on the issues that are to be studied (Fylan 2005). In the case of compost adoption, semi-structured interviews can help to identify opportunities that promote the adoption of compost whilst also uncovering potential barriers (Viaene et al. 2016).

To provide a structure for the interviews in this study, an interview guide was created by following the five phases outlined by Kallio et al. (2016): (1) reflecting on why semi-structured interviews will be necessary; (2) finding and applying previous knowledge; (3) formulating the preliminary interview guide; (4) testing the guide; and (5) making necessary changes and completing the interview guide. The aim of the interview questions was to generate answers that reflect the interviewee´s personal feelings and opinion towards using compost. Two main questions were formulated to answer the research questions of my study. In addition to the main questions, follow-up questions were prepared to provide further structure to the interviews and to give the opportunity to refocus the conversation if necessary (Kallio et al. 2016).

An interpreter was needed to translate both the questions and the answers, as many farmers in the Pune district do not speak English. The use of interpreters can cause issues when trying to correctly interpret and analyse data, since translation errors can lead to misinterpretations (Temple and Edwards 2002). One way of addressing the issue would be to use back translation. Unfortunately, this was not possible as it would be too time-consuming and costly. Instead, the number of translation errors was reduced by discussing the interview guide with the interpreters to ensure a common understanding of the meaning and purpose of the questions before conducting the interviews. Furthermore, close attention was put on the necessity of clarifications or misinterpretations both during the interview process and in the formulation of the follow-up questions. Potential errors were discussed with the interpreters once the interview was finished.

Apart from translation errors, the problem of non-sampling issues is prevalent when using semi-structured interviews. For example, the respondents could

mis-recollect, misunderstand, or answer the questions dishonestly. Moreover, a courtesy bias can lead respondents to alter their answers to accommodate the researchers' objectives. It has been suggested that interviewers should try to use interactive opportunities such as asking questions about the farming system, or the region before and during the interview to break down barriers between the interviewer and the respondent as well as reduce potential tensions (While 1994).

To address these problems during the data collection for my thesis, I tried to create a safe interview atmosphere in which the respondents could feel as comfortable as possible. To further increase the comfort of the farmers, the interviews were held on the farmers fields or at their farm. Additionally, Transect walks were done to further understand the farming context into which compost is supposed to be integrated. The walks were implemented as part of the semi-structured interviews to enable more ways to stimulate the conversation apart from the pre-written interview guide. Another advantage of the combined use of interviews and transect walks is that it puts the farmer in a more comfortable position and breaks up tensions that might occur if the interviews were to be held in an unfamiliar location (While, 1994). Moreover, transect walks offer the possibility to trigger reflections by both the researcher and the participant based on observations and impressions from the surroundings. The method also enables researchers to get a better understanding of farmers´ views as they are immersed in their daily reality. This gives the opportunity to collect context-based data that is continuously validated by linking what is seen to what is heard (Jerneck and Olsson 2013).

3.2 Data sampling

Interview participants were selected by following a purposive sampling approach. This way of non-random participant selection was chosen as it provides a resource efficient way of finding participants with relevant characteristics for answering a research question. Purposive sampling relies on the researcher's selection of participants willing to provide information based on their knowledge and experience (Etikan et al. 2016). In accordance with the time frame and budget that was available to conduct the study the target was to get at least 10 interviews with farmers. Additionally, it was planned to conduct stakeholder interviews but since it was difficult to identify and contact relevant interviewees beforehand no predetermined target for the number of stakeholders was defined during the planning of the study.

To gather the necessary information to investigate compost adoption by farmers in the districts of Pune both compost using and non-using farmers were interviewed. This generated data with which different dimensions influencing compost use in the region could be assessed. Moreover, different regional stakeholders relevant for the development of the compost value chain were interviewed to provide a more holistic picture.

3.3 Data analysis

The data will be analysed through the by Braun & Clarke (2006) established method of thematic analysis, which has been successfully applied in several other qualitative studies. The first step of thematic analysis is to become familiar with

the data by reading the interview transcripts multiple times whilst highlighting important passages. After the familiarisation phase, the highlighted results will be grouped in different themes. As the data collection and coding will be performed by one person, a mixed approach of inductive and deductive coding will be used. Deductive coding will make it possible to match patterns that are found in the data to findings from previous research. For this study, the findings outlined in chapter 2.4.1 “Findings from previous studies on compost adoption” were used as sources for possible themes. Inductive coding was applied to identify potential emerging topics that have so far not been reported by other researchers (Thomas, 2006). By continuously revisiting and refining the categories, patterns emerged that could explain what motivates and prevents farmers in Pune to adopt compost.

3.4 Reliability and validity of qualitative research

Qualitative research approaches are normally applied in the context of complex environments and try to generate data that helps in understanding intricate problems outside of the realms of controllable settings. This rather unpredictable way of data collection naturally calls for ways of validating the reliability of the collected data (Golafshani, 2003). In order to increase the reliability of the data gathered in this study, the method of triangulation was applied by using multiple sources for data collection and cross-referencing the findings with data from previous studies (Denzin, 1970). To increase the validity of the data used for my thesis research both methodological and theoretical triangulation were utilised. (Thurmond, 2001; Golafshani, 2003; Akenroye et al., 2021)

3.5 Characteristics of study participants

The interview process of the data collection phase of this study consisted of two stages. Firstly, 10 farmers were interviewed to generate an understanding of barriers and opportunities of compost adoption from the farmers perspective. Five of the interviewees were sourced from a list of potential interview partners that was provided by a local NGO. The other interviewees were randomly selected by spending a day at a greengrocer and asking farmers that were delivering their produce if they were open to participate in the study. Secondly, interviews with relevant stakeholders were set up based on the emerging themes from the farmer interviews. Among the stakeholders interviewed for this study were a founding member of a farmer producer company (Q1), three local politicians, a research associate from a mineral fertiliser company (Q2), a subject matter specialist for soil science (Q3), an agricultural economist (Q4) and a former extension agent focusing on the sale of city compost (Q5).

All farmers that were part of this study were males and their ages ranged between 18-65 years. Education levels of the participants varied substantially as two of the participants dropped out of primary school to pursue farming and three other participants had finished bachelor's degrees in arts and science before becoming full time farmers. The level of education seemed to be dependent on age since the older participants generally had a lower educational level than the younger participants. All the interviewed farmers owned their land and the farm sizes varied between 2 to 35 acres, although most participants were cultivating 10

to 12 acres of land. Irrigation was used by all study participants and a majority were using both drip irrigation and traditional irrigation methods.

The farmers grew a variety of crops and depending on regional conditions the main crops differed. In the first round of interviews onions and tomatoes were grown by all participants. Many were also growing pearl millet, cauliflower and marigold. Two participants from the first round were growing fodder crops like pigeon pea and maize to feed their livestock and one farmer was growing orchards with pomegranate and custard apple. In the second round of interviews vegetables like cauliflower, capsicum, cabbage, bitter gourd and cucumber were grown as main crops along with sugarcane which is a very established cash crop at farms in close proximity to sugar factories. Furthermore, two interviewees from the second round grew coriander and ginger as they had seen good market opportunities for both crops.

3.6 Relevant precautions for ethical and safe research conditions

When using qualitative methods for the collection of data the observation of ethical standards becomes particularly important due to the in-depth nature of the personal exchanges (Mohd Arifin, 2018). In order to grant the protection of interview participants, certain objectives have been outlined to ensure that a study is equipped to follow ethical standards.

During the planning and implementation of a qualitative study, the provision of privacy and confidentiality should be acknowledged. This means that no personal details or information that could reveal the identity of a participant is to be published or shared by the researcher or other actors involved. Furthermore, study participants need to be informed of the possibility to retract their consent to participate in interviews or other parts of the study. The understanding of the researcher's role is dependent on a thorough reflection of politics and power dynamics that might influence the participant´s answers might also impact the readiness to participate (Allmark et al., 2009). To follow the ethical considerations outlined above, names and other identity revealing factors were exchanged by pseudonyms or excluded from any shared documents. Exact geographical locations of farms or other sensitive data were also excluded from any written material open to the public. To enable potential participants to make an informed decision of consent, detailed information on the research topic was provided. Moreover, the participants were informed that they can choose to not answer questions if they deem them to be inappropriate or compromising. Since the researcher was not thoroughly acquainted with local norms and culture, the questions were discussed with members of the URNCC project and necessary adjustments were made if deemed necessary.

4. Results

This chapter will focus on presenting the findings derived from the interviews conducted during the data collection phase of this study. Different results will be presented in text, tables, photos and figures to communicate the findings to the reader. Paraphrased quotes from the interviews will be provided to further illustrate the individual views of the different study participants. The final interview guide used during the interviews can be found in the appendix.

4.1 Fertilisation methods used by the interviewed farmers

All 10 farmers that were interviewed for this study were using mineral fertiliser. For the basal fertilisation NPK and urea were commonly mentioned as well as the application of micronutrients through drip irrigation systems.

In the first round of interviews done with farmers from the list provided by the NGO, most of the participants were using some sort of organic fertiliser. Most of them were using their home-made compost from different manures and waste products left after harvest. Furthermore, the addition of different microbes to speed up the decomposition process was mentioned by three participants. Four participants answered that they only use city compost if their home-made compost is not available in sufficient quantities. Two of the interviewees mentioned that they were using soil tests to assess the nutrient levels of their soils. Moreover, one of the farmers said that he does not believe in soil testing and instead uses his observations to determine the amounts of nutrients that need to be added for optimal plant growth.

In the second round of interviews every participant was using mineral fertilisers in similar fashion as the farmers from the first round of interviews. Three of the interviewees mentioned that they are doing soil testing to find out what nutrients their soils need. The remaining two said that they get information on their nutrient needs from fertiliser companies. Most of the interviewees from the second round were only using organic fertilisers that they could produce on their own farm. Only two of the respondents mentioned that they buy organic fertilisers from outside sources and only one was buying city compost.

4.2 Results relevant for addressing the research questions

In this section findings from the interviews that give answers to the research questions will be presented. Relevant answers will be presented as paraphrased quotes made by the different study participants.

4.2.1 Research question 1: Which internal and external barriers are farmers confronted with when wanting to adopt city compost in the district of Pune?

4.2.1.1 Availability and quality of city compost

Three of the interviewed farmers mentioned that they did not know how to acquire city compost. All that mentioned a problem of compost availability were

from the second round of interviews. This was somewhat counter intuitive since their farms were closer to well established infrastructure when compared to the participants from the first round of interviews.

"I do not know where I can buy city compost."

"I have been considering using city compost, but I have not found it to be readily available."

"The availability of city compost should be improved."

During the interview with Q5 the lacking availability of city compost was also mentioned as a barrier to compost adoption.

"There is a lack of high-quality compost available on the market."

"In my experience the availability does not match the demand."

"I see availability as the biggest problem standing in the way of scaling up city compost."

Apart from the availability, the quality of city compost was also mentioned as one limiting factor to scaling up both production and use of city compost. During the first round of farmer interviews many mentioned that they feel that the quality of homemade compost exceeds the quality of city compost.

"I think that my own compost is of higher quality than city compost."

"My compost is superior to city compost."

"I would only buy city compost if I had no other option."

During the stakeholder interviews quality was also mentioned as a major obstacle to scaling up city compost adoption. Q1 mentioned that there is a problem of standardising procedures in the compost production process.

"Some compost producers provide low quality products. There is a need to further standardise the supply chain."

Q3 mentioned that he recommends compost but pointed out that there are issues with heavy metal contamination. He mentioned two companies that he would recommend to farmers since they are implementing good quality standards. In his opinion the quality standards of most of city compost providers are too low for him to recommend them to farmers.

"City compost is also recommended but there are issues with heavy metal contamination."

"There are several providers but most of them have low quality standards."

"In my opinion the preparation of city compost is the main problem. If the quality issues are solved city compost could be promoted at a larger scale."

Quality issues were also mentioned during the interview with the Q5. He mentioned that the major issue of compost supply is the poor organisation of many compost production facilities. According to him this is especially the case in more rural areas.

"The quality produced in some of the plants is not good."

"There are only a few plants that have been certified to provide good quality. There are only three projects that are working well which are in Aurangabad, Ahmednagar and Sanganer."

"I have visited 6 projects in rural areas that could be considered as failed"

According to the Q5 the main issue causing the failure of many rural production sites is the absence of well-functioning waste collection and separation systems. Plastic contamination is a big issue since most households mix plastic with their organic waste when throwing them away.

"Plastic contamination is the biggest hurdle for scaling up compost production. There is no way of separating the garbage at the compost plant once it has been mixed."

"There is a need for people to change. Waste needs to be separated in the households to improve compost quality"

"In the location of the well working plants the waste separation at the household level is well established."

During the data collection period I had the opportunity to visit one compost production facility which was close to where most of the farmers from the second round of farmer interviews were located. During the visit it became evident that the facility is not able to produce marketable city compost since the household wastes are not separated during the waste collection process. This makes it impossible to produce plastic free compost since it is not possible to efficiently separate organic materials from plastics.

Photo 2: Plastic and organic waste is not separated at the household level which creates issues at the compost production facilities

Photo 3: Separation machinery

Photo 4: Finished product with visual plastic contamination

Photo 5: Random sample from finished compost bag with visible plastic contamination

4.2.1.2 Farmers favour the use of homemade compost

Many farmers mentioned that they prefer to use homemade compost or different manures over using city compost. The use of homemade composts made from various organic materials as well as the use of different animal manures was mentioned by all interview participants. The use of cow dung was mentioned by most of the interviewed farmers.

> *"I am not using city compost, instead I use different manures and plant matter to make my own compost."*

"I make compost out of the manure of cows and sheep. I only buy city compost when my supply of homemade compost is not sufficient."

"I will not buy city compost since I believe in the power of cow dung and vermicompost."

"I see my own compost as having superior qualities when compared to city compost."

"I have my own cows and use their manure as a fertiliser. If my own supply of cow dung is not enough I by cow dung from outside sources"

"I am very familiar with using cow dung. I am unsure about the effectiveness of city compost."

Farmers preference to choose homemade compost over city compost was also mentioned during two of the stakeholder interviews. During the interviews conducted with Q1 and Q5 the preference towards cow manure was seen as problematic.

"Farmers' preference towards using other organic fertilisers instead of using city compost is preventing widespread adoption.

"The use of cow dung is very popular."

Using the manures from cows and other animals has a long-standing tradition in Indian agriculture and seemed to be a very established practice amongst the farmers that were interviewed for this study. The main problem of using cow manure as organic fertiliser from the farmers perspective was the availability and price.

"Most of my neighbours use compost. The difference in the amount of compost used is depending on the financial means of farmers."

"Having more livestock would not be economically viable so I use city compost as a substitute"

"I would wish for a better and cheaper supply of cow dung"

Photo 6: Pile of homemade compost from one of the interviewed farmers

One farmer mentioned that changes in family structures will change the number of livestock that can be kept. Traditionally the chores necessary for animal husbandry are done by younger family members in Indian farming families. Many families choose to send their children to urban areas for education or employment opportunities instead of encouraging them to stay in the agricultural sector.

> *"Younger family members are not interested in animal husbandry anymore. This is causing a decrease in the number of livestock which has an impact on the availability of manure as a source for organic fertilisers."*

These developments were also mentioned by the interview that was conducted with Q1. Moreover, the increased mechanisation of different agricultural processes was also mentioned as a factor that leads to a decline in the availability of cow manure since it reduces the need to use animals to pull agricultural machinery. These developments have led to increasing prices due to the lower availability of animal manures.

> *"Changes in family structures have caused a reduction in the number of livestock kept by farming families."*

> *"Increased mechanisation has also led to a reduction of the numbers of animals on farms."*

> *"Both of these developments have caused increases in the price and availability of animal manures."*

When asked about possible improvements that can be made to increase the use of compost, four out of five farmers interviewed in the first round of interviews only mentioned changes that would improve their homemade compost production.

> *"The construction of concrete pits would be beneficial to produce homemade compost" (Mentioned by three farmers in the first round of interviews and one in the second round)"*

"Using bacterial cultures to increase decomposition rates of homemade compost could be beneficial"

"There is a need to improve the knowledge on how to make homemade compost in rural areas"

Only one of the farmers that were interviewed for this study was a big proponent of city compost and thought of city compost as being superior to other compost products.

"I order compost from a reputable company in bulk with ten neighbouring farmers to reduce the price. The compost is delivered directly to me."

"I believe that farmers generally do not have enough knowledge to make high quality compost on their own."

During the interview with Q5 the problem of inferior quality of homemade compost was mentioned.

"Farmers' mentality of preferring homemade compost over city compost needs to change. Often the homemade compost is not fully decomposed which can cause problems with diseases and reduces the fertilisation effect."

"It is important that farmers are informed that certified city compost is 100% decomposed and that their homemade products might only be partially decomposed"

When asked about homemade compost the Q3 advocated for increased extension efforts to increase the adoption of homemade inputs by farmers. Furthermore, he mentioned that farmers should be taught how to make high quality compost at home.

"The majority of farmers are using cow dung and waste from sugar production as their main source of organic fertilisers."

"To improve the efficiency of these resources the production of homemade compost should be promoted."

"Many products can be produced by farmers themselves. The knowledge of how to do this properly should be spread."

During the data collection phase, a small-scale compost production facility was visited, and the owner was interviewed. Their compost was made by mixing cow and chicken manure with waste products from sugarcane production and other agricultural value chains in the area. After mixing the different raw materials and adding some organic additives like lime the mix is decomposed for three to five months depending on how favourable the weather conditions are. Demand for their product is steadily growing and is currently exceeding the facilities supply. At the beginning there were problems with convincing farmers to use their

product but once farmers experienced positive results, they became steady customers.

"Currently the demand for our product is exceeding our supply."

"We are very happy with our business and are looking to expand our production."

One bag of regular compost is sold at 350 INR and discounts are available when a farmer places a bulk order. The company also has started to market a refined compost product to which neem extract is added. This compost is sold at 500 INR per bag and has beneficial effects on pest control. Farmers' interest in the refined product is growing since many have experienced positive effects after usage.

"Once farmers have experienced the positive effects of our products most of them become regular customers."

The visited facility seemed to be well run and the finished product was free of any visible plastic contamination and did not give off any foul odours.

Photo 7: Compost rows at different stages of the composting process

Photo 8: Finished compost ready for sale

Photo 9: Random sample free of plastic contaminants

4.2.1.3 Lack of awareness about city compost and the benefits that it causes

A lack of awareness of city compost was mentioned as a barrier to compost adoption during four of the stakeholder interviews. Q1 said that strategies to attract farmers towards using city compost need to be formulated. Furthermore, he mentioned that there is a need to spread testimonials of farmers that have had positive experiences with using city compost. This would help to spread awareness and increase adoption rates in his opinion.

> *"There is a lacking awareness amongst farmers about city compost."*

> *"Farmers need to be pulled towards city compost by being presented with other farmers' positive results."*

"There is no marketing structure for city compost."

Similar points were raised during the interview with the Q2.

"Marketing strategies for organic fertiliser will be important to increase adoption."

"Farmers' awareness of the beneficial effects of organic fertilisers need to be increased."

During the interview with Q3 it was mentioned that only 10-15% of farmers are using city compost. According to the interviewee there is a need for a larger information campaign to increase awareness and adoption. Based on the stakeholder interviews it seemed like there are many misconceptions about city compost amongst farmers.

"To increase adoption of city compost it will be necessary to develop mass extension programs in order to further extend awareness."

In addition to this the extension agent and compost salesman mentioned that there are many misconceptions about city compost amongst farmers that need to be addressed.

"Many farmers have misunderstandings of city compost. Many think it is a bad product since it is made from urban waste."

"Farmers are often not aware of the many benefits that city compost can provide."

"In order to reach farmers, there is a need to have face to face discussions to provide farmers with information and address their worries when thinking of using city compost."

"The organisation of field trials could help in changing the minds of farmers."

4.2.1.4 Mineral fertiliser marketing systems

Another barrier that was mentioned in both rounds of farmer interviews and by many of the stakeholders was the influence of mineral fertiliser companies and their marketing strategies. Some of the farmers that were interviewed mentioned that mineral fertiliser sales representatives only focus on selling their own products and do not advocate for the use of organic fertilisers.

"People that sell chemical fertilisers only promote their products and do not recommend compost or other organic fertilisers."

"No salesmen have recommended using compost to me."

Furthermore, a couple of farmers mentioned that some sales representatives tell farmers that the use of compost is not as beneficial as using their products and that they won't achieve good results without them.

"Some chemical extension agents conduct gatherings where they tell farmers that compost does not provide instant results. Instead, the farmers should be using their products since they give instant results. This creates misconceptions amongst farmers."

"Farmers think that the amount of yield that they can get is only going to be good if they use chemical fertilisers."

"Chemical fertiliser companies hammer their message into the heads of farmers."

One farmer also mentioned that he thinks that it is hard for farmers to get information about organic fertilisers because the marketing of organic methods cannot compete with the well-established mineral fertiliser marketing system.

"There are alternative organic products, but their marketing cannot compete with chemical products."

The influence of fertiliser companies was also mentioned as a barrier during many of the stakeholder interviews. Q1 mentioned that it is difficult to implement the use of organic fertilisers because the promotion of mineral fertilisers is too well-established in the region.

"Organic fertilisers are competing with a very well established marketing structure for mineral fertilisers from big fertiliser companies"

Similar points were made by Q3. He pointed out that the green revolution laid the foundation for the current status quo of fertiliser distribution in India. Moreover, he mentioned that chemical companies are not interested in promoting the use of integrated nutrient management (INM) and that farmers are mainly dependent on retailers for fertiliser recommendations.

"During the green revolution farmers were pushed to mainly use NPK and other chemical fertilisers. Only after 2013 farmers have been encouraged to use other fertilisers."

"The marketing policies of chemical companies is to only promote their own products. They are not interested in promoting INM."

"Farmers are mainly depending on agricultural service centres for their fertiliser recommendations."

Q2 mentioned that it will be difficult to address the influence of fertiliser companies since they are an essential part of the Indian economy.

"Reducing the use of mineral fertilisers would also reduce employment opportunities within the agricultural sector. This is a common political argument standing in the way of regulating the activities of fertiliser companies."

He further stated that the establishment of the current fertiliser distribution system was built on the political narratives used during the green revolution. Moreover, he added that said narratives are currently standing in the way of farmers' adoption of compost and that the current monopoly of fertiliser companies needs to be broken to establish more sustainable farming practices in India.

"During the green revolution the narrative was adopted that only fertiliser responsive high yielding hybrids could provide sufficient yields."

"Strong placements of narratives by fertiliser companies stand in the way of the adoption of compost."

"The monopoly of chemical fertiliser companies needs to be broken to make a change."

4.2.1.5 Availability and use of soil testing

During both rounds of interviews one farmer mentioned that they do not use soil testing to analyse which nutrients are missing in their soils.

"I do not use soil testing. I add chemical fertilisers based on my observations."

"I do not use soil testing. I rely on the recommendations given to me by the agro malls."

Q3 mentioned the lack of soil testing done by farmers as a barrier to compost adoption. In his opinion the increased use of soil testing by farmers would also increase the adoption of organic fertilisers since farmers would become more aware of the carbon deficits in their soils.

"Only 65% of farmers in our region use soil testing."

"Farmers mainly depend on the agricultural service centres for fertiliser recommendations."

"The current infrastructure of testing labs is not sufficient to cover the demand."

4.2.1.6 Bad Governance and policy making

Another commonly mentioned theme during both rounds of farmer interviews was the dissatisfaction with the work of different governmental bodies. The main issues that were raised were the slow responses to problems faced by farmers, the need to address the problem of rising fertiliser prices and the political focus on promoting mineral fertilisers.

"We feel that the government process is very slow and that many things could be improved."

"The government needs to control the prices of fertilisers."

"The prices of fertilisers have increased too much, and the government should find ways to address this problem."

"The government needs to be more active in promoting the use of organic fertilisers."

"The government's information app mainly promotes the use of chemical fertilisers."

"I think the government should take charge and create initiatives that educate farmers and clear up misconceptions about using different fertilisers."

During the interview with the Q2 the lacking engagement and corruption problems within the governmental structure were mentioned to be problematic.

"The government must create central initiatives that the districts can follow."

"Corruption is standing in the way of changes in the agricultural sector."

Missing restrictions on the use of fertilisers and badly distributed substitutions were mentioned as further issues in the governmental structure during the interview with Q3.

"There are no restrictions on the use of fertilisers in India, farmers can use fertilisers as they please according to their knowledge or the guidelines provided by different outlets."

"The government should give subsidies for the use of organic fertilisers and provide more funding for farmer training."

The lack of regulation of fertiliser usage was also mentioned as a barrier to compost adoption during the interview with Q5.

"The government should make it mandatory to use city compost and regulate the use of chemical fertilisers. I think it would be beneficial to enforce a law that makes it compulsory to buy city compost in order to purchase chemical fertilisers."

Furthermore, Q4 mentioned that there are economic issues standing in the way of increasing the use of city compost. He mentioned the low willingness to pay for city compost by farmers relative to the high cost of compost product and the conflicting subsidies as the main economic issues that are preventing wide scale city compost adoption.

"Funding of city compost is a problem since the production is expensive and the willingness to pay is low."

"Conflicting substitutions on City compost and fertilisers like Urea stand in the way of adoption."

The issue of fertiliser subsidies was also mentioned during the interview with Q1. He pointed out that the removal of the subsidy on city compost has had negative impacts on adoption. Furthermore, prices for different fertilisers and potential loopholes in new legislations aiming to increase the use of organic fertilisers among farmers were brought up as potential barriers.

"Subsidies on city compost have been removed since the adoption rates were not high enough to justify the subsidy politically."

"The price increases since the subsidy was removed have caused further decreases in adoption of city compost."

"The price of compost increased from 150 INR/acer to 300 INR/acer. Cow dung currently costs 250 INR/acer."

"Complex chemical fertilisers sell for about 1200 INR/20kg bag"

"The government recently passed a law that requires vendors to sell mineral fertilisers in combination with organic fertilisers."

"This law has led mineral fertiliser companies to sell organic soil amendments. They still do not market the use of organic fertilisers."

During interviews with two local politicians, it became evident that the promotion of city compost or waste handling were not on the local agenda.

"We are not aware of city compost."

"We focus on improving the electric grid, roads and fitness facilities. Farming and waste handling is not on our agenda."

In contrast to this the mayor of a bigger municipality that was also interviewed for this study was aware of the city compost project and is currently planning to build a biogas plant that will make organic wastes into electricity. The remaining digestate will be used as fertiliser on farms. He further mentioned that in order to successfully implement the project, there is a need to implement a waste separation system in his district.

"We will be starting a biogas project in about 6 months."

"We are trying to implement waste separation where organic waste is separated from plastics by the households. This will reduce the cost of separation at the plant level."

"We are aware of quality issues in city compost and will be advised by experts that have successfully implemented a similar project in Nashik."

Moreover, the mayor mentioned that the increased use of organic agriculture is a part of their strategy. They were aware of adoption problems of city compost and attributed it to the farmers' need to get fast results when using fertilisers. There was no concrete plan on how to increase adoption but the necessity of raising awareness amongst farmers was mentioned.

"Increasing the use of organic production methods is part of our strategy for sustainable development."

"Adoption of organic fertilisers is a problem and I think that farmers need to be made more aware of the benefits."

4.2.2 Research question 2: Are there any opportunities for increasing compost adoption in Pune?

4.2.2.1 Beneficial effects of compost perceived by farmers

Throughout the interviews it became evident that once farmers had used compost long enough to see the beneficial effects, they became permanent users. In the first round of interviews all farmers were using compost and three major benefits could be identified. It is important to note that the positive effects listed in the table below were mentioned by both homemade compost users and city compost users.

Benefits of regular compost application		
Quality	**Effects on soil fertility**	**Increases in plant vigour**
"My tomatoes and onions have better quality than my neighbours that do not use compost."	*"Using compost in combination with mineral fertilisers is beneficial for sustaining yields."*	*"Plants become more adoptable to changes in climate when using compost."*
"The storage capacity of onions and tomatoes increases when compost is used regularly."	*"Compost is benefiting microorganism activity especially when compared to chemical fertilisers."*	*"Nutrient grasping capacities of crops is increase when using compost."*
"When using compost my produce becomes tastier."	*"Adding compost makes the soils well drained gives it better structure."*	*"Crops are less susceptible to diseases when using compost."*
	"Using compost decreases the water need of his fields."	

Table 7: Positive effects of compost application noticed by farmers

In the second round of farmer interviews the use of compost was not as prevalent when compared to the first round. Nevertheless, the farmers that had used compost for a longer time had experienced similar effects to the ones mentioned in the first round and did not add any additional benefits.

4.2.2.2 Creation of Organic markets in India

In the first round of interview one farmer mentioned that he thinks that the creation of a well-functioning organic certification system would increase adoption rates of compost. So far, organic supply chains are not very established in India especially in rural areas. The establishment of organic markets that provide certified farmers with premium prices for their products could incentivise the adoption of organic production methods such as compost application.

"The establishment of organic markets and certification would increase compost use."

"Conventional and organic products are sold at the same price and segment in most parts of India."

"The infrastructure and supply chain for organic products are not developed in India."

"The demand for organic products is currently higher than the supply in India."

During the interview with Q3 the establishment of organic markets was also mentioned as a possible way of increasing compost adoption.

"Only 5-10% of farmers are using organic production methods that could get certified as organic."

"The establishment of organic markets can help to promote the use of organic fertilisers. To achieve this better certification infrastructure will be necessary to make this possible."

4.2.2.3 Use of bacterial cultures to speed up positive effects of compost

In both rounds of interviews, the use of decomposing microbes was mentioned as a possible way to reduce the time it takes for the positive effects of compost to set in.

"I add bacterial cultures to my fields to boost microbial activity and decomposition."

"I recommend the use of bacterial cultures together with compost to increase the positive effects."

"I add microbes to the soil to help mobilise nutrients."

Q3 also mentioned the benefits of using bacterial cultures in combination with compost. He also pointed out that bacterial cultures could help to spread the use of homemade compost amongst farmers.

"Bio stimulants can be used to increase the availability of nutrients and speed up the positive effects of organic fertilisers."

"60% of farmers in our district are using bio stimulants."

"Producing compost from farmyard manures normally takes about 1 year with bio-stimulants; the process can be done in 2 months."

4.2.2.4 Awareness of sustainability and the preservation of soil fertility

One of the farmers interviewed during the first round of interviews mentioned that he is concerned about the sustainability of his farming practices.

"I have been trying to improve the sustainability of my farming practices so that the next generation will be able to farm the same land."

The concern of sustainability amongst farmers was also mentioned during the interview with the Q2.

"Farmers' mentalities are changing due to bad experiences with conventional methods."

During the interview with Q3 the necessity of further increasing the awareness of sustainable practices amongst farmers.

"Farmers are becoming more aware of the decline of soil fertility."

"50% of soils found in Maharashtra contain less than 1% of carbon. In our region soil carbon levels range between 0.3 to 0.43%."

"60% of farmers are using some kind of organic fertiliser, the remaining 40% only use chemical fertilisers."

"Mass training will be necessary to increase farmers' awareness."

4.2.2.5 Increasing cost of mineral fertilisers

During both rounds of interviews farmers mentioned that they are having problems in adapting to the rising costs of inputs. One farmer mentioned that they would like to have more guidance on how to manage to farm successfully despite the rising cost of inputs.

"The cost of buying chemical inputs has increased."

"Input costs have been increasing but the yields have stayed the same."

"Since the cost of farming is increasing, I would like to have more guidance on how to adapt to this."

4.2.2.6 Integrated Nutrient Management

Spreading the awareness amongst farmers about the concept of integrated nutrient management (INM) was mentioned as an opportunity to increase the adoption of organic fertilisers by Q3. INM promotes the balanced use of organic, mineral and biological fertilisers in accordance with soil testing results. The use of INM can help in addressing the problem of decreasing soil fertility whilst also reducing the cost of inputs for farmers. In his experience farmers become convinced of INM once they see the positive effects.

"According to INM at least 30% of the fertilisers used should be organic."

"The positive effects of INM normally set in 2-3 years after implementation."

"Using INM should reduce the cost of chemical fertilisers by 25%."

"The Government should make the use of INM mandatory in order to reduce soil fertility losses."

In addition to this Q4 mentioned that many farmers are unaware of how to calculate their costs and maximise their profits. According to him this makes promotion of INM more difficult.

"Economic unawareness amongst farmers is often a hurdle to INM adoption."

4.2.2.7 Mechanisation as a way of increasing adoption of compost

The use of machinery for handling compost was mentioned by three farmers as a change that would make using compost as a fertiliser more attractive to them. Two of the farmers said that the use of machinery for compost spreading might not be economically feasible at the current size of their farm. Most of the farmers that were interviewed were spreading compost by hand and only used machinery to transport the compost to their fields.

"I see mechanisation as a good way of improving the way we use compost. Although I doubt that it would be economically viable in my current situation."

"I would like to use a mechanical way of spreading compost."

"The logistics of compost spreading are a hurdle to scaling up the use of compost in my opinion."

In a conversation with a salesman for agricultural machinery it became evident that the development of a well-suited mechanical solution for compost spreading on the Indian market is not attractive considering the current economic conditions.

"It is not financially viable to use machinery on the small plots of land that most Indian farmers cultivate."

"Mechanised spreading of organic fertilisers does not make sense in the local economic conditions."

4.2.3 Research question 3: What perception do farmers have of compost? Are they in line with scientific perceptions?

During the interviews the farmers were asked what positive and negative effects they associate with using compost. All of the effects mentioned by the interviewed farmers are also mentioned in the scientific literature on the beneficial effects of compost application. The positive effects that were mentioned are compiled in the figure 8 below.

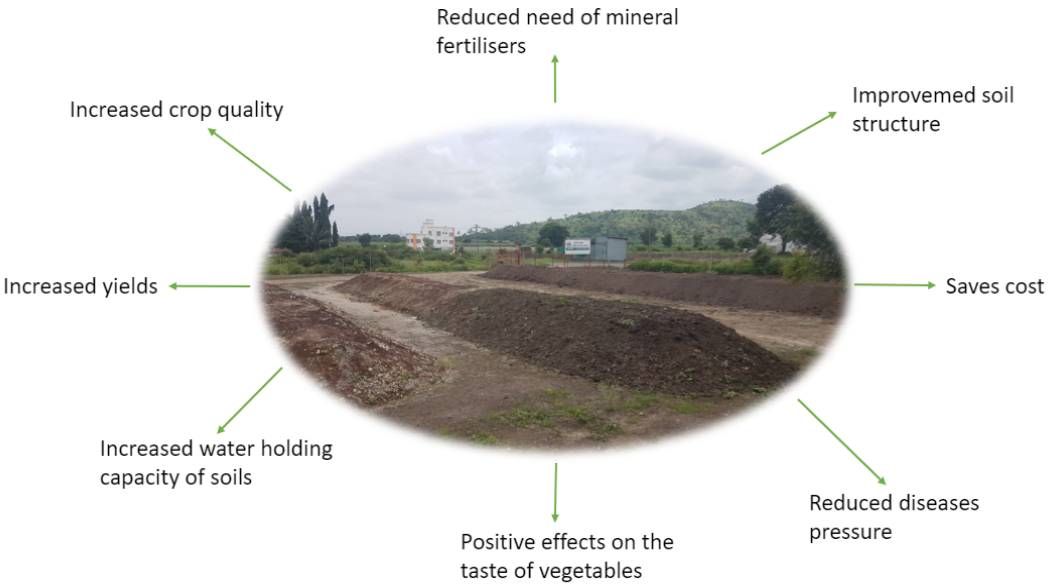

Figure 8: Perception of positive effects of compost by the interviewed farmers

None of the farmers interviewed mentioned that they have had any negative experiences with using compost. It is interesting to note that farmers that were not using any form of compost also did not mention any potential negative effects of using compost.

4.2.4 Research question 4: Are farmers aware of ways to learn about compost application and potential advantages and disadvantages of using compost?

4.2.4.1 Sources of information mentioned in the first round

During the interviews the farmers were asked what sources of information they use to learn about new farming methods to improve their operations. The frequency with which an information source was mentioned is displayed in the figure below.

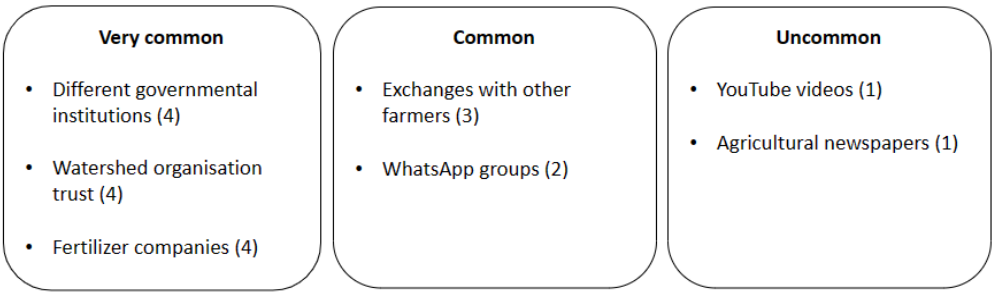

Figure 9: Sources of information used by farmers from the first round of interviews

4.2.4.2 Sources of information mentioned in the second round of farmer interview

During the second round of farmer interviews the farmers were more dependent on the information from representatives from fertiliser companies.

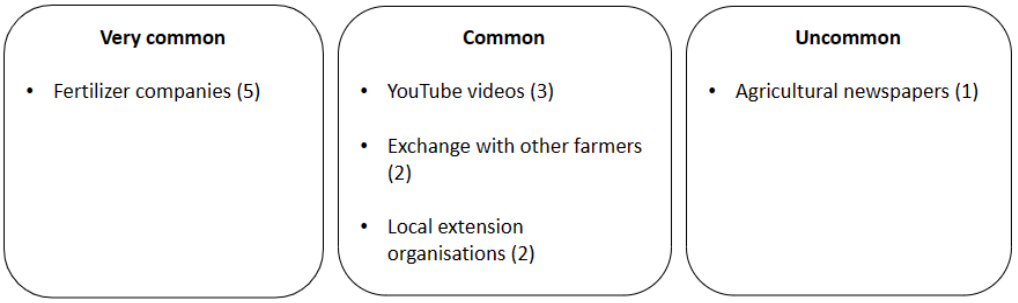

Figure 10: Sources of information used by farmers from the second round of interviews

5. Discussion

In this section key findings from my study will be analysed in the context of relevant literature and the collected data. Furthermore, possible implications and recommendations derived from the study findings will be outlined.

5.1 summary of key findings

According to the interview results the adoption of city compost seems to be stuck in the early adopters stage of Rogers diffusion curve (Rogers 1962). The findings point towards three main barriers that might be preventing increases of adoption rates (Figure 11). Firstly, a lack of political initiative to reform the Indian agricultural sector could be suppressing opportunities that could be used to increase city compost adoption. Secondly, the strong influence of fertiliser companies might be having an impact on the perception that farmers' have of city compost. Thirdly, the low supply of high-quality city compost could also be preventing potential increases in adoption rates. The result of these issues is a lacking awareness of the availability and benefits of city compost amongst farmers. Which creates barriers that might be keeping farmers from implementing city compost within their fertilisation programs. .

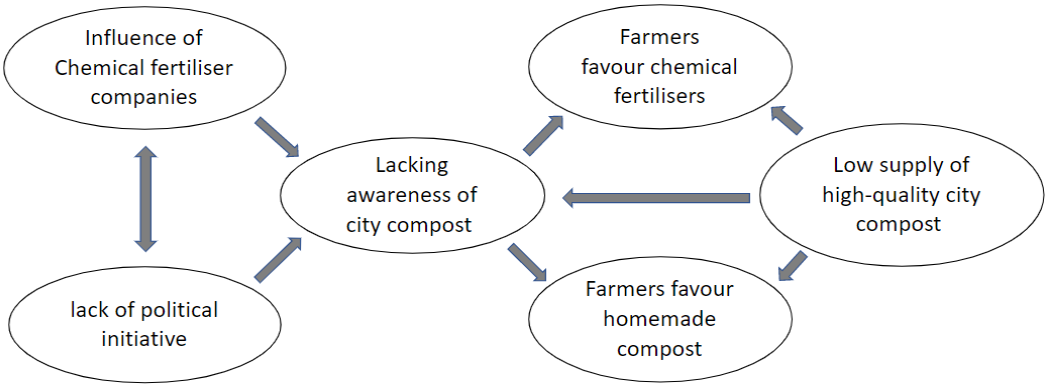

Figure 11: Graph showing different barriers to adoption and their implications

Different opportunities that could increase farmers' adoption of city compost were also identified during the interviews. The main opportunity to increase the use of city compost might be the fact that all farmers that were interviewed had positive opinions about compost. Other identified opportunities were the promotion of Organic farming, INM and the use of bio-stimulants. Furthermore, the growing awareness amongst farmers of the negative effects and increasing costs of mineral fertilisers could also boost the adoption of city compost.

5.2 Interpretation of study findings

It was surprising to find that despite the positive attitudes towards using compost amongst the interviewed farmers the overall adoption of city compost was rather

low. This indicates that the low adoption of city compost might not be caused by the negative perceptions that farmers have of city compost but instead can be explained by other factors. Viaene et al. (2016) found that the main reason for low adoption of compost by European farmers was not caused by the farmers attitude towards using compost but instead could be attributed to financial, institutional and informational factors. Considering the findings from the interviews conducted for my study it seems like institutional and informational factors might be of special relevance in the context of the URNCC project.

5.2.1 Governance and regulation

During the interviews it became clear that many farmers were not satisfied with the support that they are receiving from different governmental institutions. For example some of the interviewed farmers mentioned that the governmental institutions responsible for regulating and supporting farmers have not provided them with proper solutions on how to deal with the increasing costs of mineral fertilisers. Moreover, it was mentioned that there is a lack of governmental direction on how fertilisers should be used to gain optimal results. In general farmers were not very pleased with the work of governmental agencies and would appreciate more guidance and support. Furthermore, governance issues mainly related to fertiliser subsidies and extension services were highlighted during the stakeholder interviews.

The relevance of these findings is underlined by the results from other researchers that have also identified the actions of governmental institutions to be important factors for increasing farmers' adoption of compost in various other regions of the world (Cai et al. 2019; Folefack 2015; Viaene et al. 2016).

The findings are also in line with the arguments made by Cook et al. (2021) who point out that low rates of technology adoption in agriculture many times is not caused by the reluctance of potential adopters but can mainly be ascribed to governance issues. Besides the importance of governance, Cook et al. (2021) also emphasise that power imbalances and historic barriers could be relevant factors causing reductions of compost adoption rates.

5.2.2 Influence of the fertiliser industry

Historically Indian agricultural policy has been focused on the promotion of mineral fertilisers which has enabled fertiliser companies to establish a strong position on the Indian market (Venkateshwarlu & Sen 2002). Regarding the historical developments, and the fact that farmers in the Pune area are highly dependent on fertiliser companies when wanting to acquire the inputs and information necessary to manage their crop production, it seems like historical developments and power imbalances might create barriers that prevent compost adoption. One of these barriers is the influence that marketing schemes that promote mineral fertilisers have on the design of farmers fertilisation practices. This became especially clear after several farmers mentioned that fertiliser salesmen often use the comparison of the short-term results to convince farmers that using mineral fertilisers is superior to using compost.

Since the full spectrum of benefits that can be achieved by using compost as a fertiliser are not visible in the first harvest after the application, a focus on the short-term effects of different fertilisers might lead farmers to think that compost

is inferior to mineral fertilisers. Similar marketing tactics based on highlighting the short term benefits of different fertilisers has been described by other researchers investigating compost adoption in India (Harper et al. 2004). Additionally, researchers studying compost adoption by farmers in Malawi also identified the influence of fertiliser companies and the promotion of mineral fertilisers as one of the main barriers to compost adoption (Cai et al. 2019).

Another barrier that might be caused by the factors outlined by Cook et al. (2021) are the well-established supply chains for mineral fertilisers which make the use of mineral fertiliser more convenient than using compost. During the farmer interviews some participants mentioned that they would be interested in using city compost if it would be as accessible as mineral fertilisers.

Considering the findings from the interview with Q2 it might be difficult to address the influence of fertiliser companies in India since they are an essential part of the Indian economy. These findings all point towards power imbalances that could be causing political lock-ins which make it difficult for different stakeholders to create incentives and programs that promote a reduction of mineral fertilisers in Indian agriculture (IPES-Food 2016).

5.2.3 Lack of Information campaigns and marketing strategies

The results of the farmer and stakeholder interviews suggest that the adoption process of city compost is in the persuasion and decision stages (Rogers 1962). Some farmers seem to be aware of the benefits that compost could provide but there still is a need to further prove and demonstrate the positive effects of city compost to persuade farmers to implement it within their fertility management.

Viaene et al. (2016) found that one major barrier to compost adoption in the European context is a lack of knowledge and skills of how to make and use compost efficiently amongst farmers. Interestingly enough, compost use was more common amongst the participants from the first round of farmer interviews. The higher adoption rates might be explained by the extension efforts and guidance provided by the NGO that helped in arranging the first round of interviews. Several of the interviewees mentioned that they had received help from the NGO which might be one of the reasons why the use of compost was more prevalent amongst the participants from the first round of interviews. Since the NGO is dedicated to promoting soil fertility in Maharashtra and one of their fields of activity is teaching farmers how to use compost it would seem plausible that the findings made by Viaene et al. (2016) also are relevant in the context of my study. During the interview with Q3 it was mentioned that mass extension efforts would be necessary to educate farmers about compost to increase adoption.

Other factors that might be relevant to increase city compost adoption are the price, marketing and distribution of compost products (Harper et al. 2004). According to the results discussed above, the availability and distribution of mineral fertilisers seems to be one factor that influences farmers' fertiliser choices. This indicates that the development of distribution networks to increase the availability of city compost might be necessary to position city compost as a competitive alternative to mineral fertilisers.

5.3.4 Fertiliser prices

During the stakeholder interview with Q1 the price of city compost was mentioned as one important factor influencing adoption. In the past a subsidy caused the price of city compost to stabilise at 150 INR/acar. Since the subsidy did not cause significant increases in adoption rates of city compost it became politically infeasible to support the price of city compost. This led to the abolishment of the subsidy which caused the price of city compost to increase to 300 INR/acar. According to Q1 the price for cow manure is only 250 INR/acar making it more attractive to farmers when compared to city compost. In the context of compost pricing it is interesting to note the prices that were mentioned by the small scale compost producers during the visit at their production facility. According to their statements they are managing to sell their regular compost products for 350 INR/bag and are selling a premium product for 500 INR/bag. These findings are interesting since they unveil that farmers might be willing to pay higher prices for compost products once they have experienced the positive effects. As a reference point Q1 mentioned that mineral fertilisers cost around 1200 INR/20kg bag.

5.3.5 Farmers preference of animal manure over compost

Following the arguments of Harper et al. (2004) it might be necessary to formulate marketing strategies that are well equipped to communicate the benefits of city compost to farmers. In the context of marketing it is also interesting to consider that many of the interviewed farmers seemed to prefer using homemade compost over city compost. A possible explanation for this is that there is an established tradition of using composted cow manure as an organic fertiliser in Maharashtra. This has led farmers to become familiar with the use and effects of composted cow manure which makes it difficult to establish new compost products like city compost on the market.

During the farmer and stakeholder interviews two potential issues with the use of composted cow manure were identified. Firstly, the quality of homemade compost often is often inferior to certified city compost since it often is not fully decomposed. Secondly, the supply of cow manure is decreasing due to changes in family structures and increased mechanisation. The scarcity is already leading to increases in cow manure prices and might in the long run motivate farmers to search for alternatives. Considering the potentially superior quality and the potential availability of city compost it might be interesting to formulate marketing strategies that can position city compost as a viable substitute for homemade composts.

5.3.6 Compost marketing opportunities

When trying to formulate strategies for spreading information about city compost to farmers, it will be necessary to identify well suited channels of communication. According to the farmer interviews the main sources of information are representatives of the fertiliser companies, different governmental and nongovernmental extension efforts, the exchange with other farmers and videos posted on YouTube. Other researchers investigating the adoption of agricultural technologies have identified salesmen to be one of the major drivers of adoption (Ryan & Gross 1950). During the stakeholder interviews with Q1 and Q3 the

importance of creating marketing strategies that can compete with the marketing efforts made by fertiliser companies was highlighted. Some of the opportunities that were identified during the farmer and stakeholder interviews could be used to support potential marketing efforts. For example, the implementation of policies that promote the use of organic practices or INM approaches might make the adoption of city compost more attractive for farmers. Furthermore, investments in the expansion of soil testing infrastructure could lead to a higher awareness amongst farmers for the economic and soil fertility benefits of different fertilisation methods. If farmers simultaneously become more aware of the availability and benefits of city compost adoption rates might be increased.

5.3.7 Lacking supply of high quality city compost

To fully exploit these potential opportunities it might be necessary to increase the output of certified city compost. During the interview with Q5 and the visit at a city compost production facility it became evident that the production of high-quality city compost is not yet very established in many parts of Maharashtra. According to the interview conducted with Q5 the management and organisation of many production facilities is not sufficient to produce marketable city compost products. Apparently the organisation of well functioning compost production processes is especially difficult in rural areas due to missing know-how and infrastructure.

The main barrier for producing high quality city compost seems to be the absence of well-functioning waste collection and separation systems. In India it is still very uncommon to separate wastes at the household level which often makes it impossible to efficiently separate inert materials from organic materials in compost production facilities (Zurbrügg 2004). These findings are in line with the statements made by Q5 who mentioned that the production of high-quality city compost is only possible if waste materials are separated at the household level. According to Q5 the only facilities in Maharashtra equipped to produce marketable city compost are located in areas where waste separation is well established. Consequently, it will be necessary to implement functioning waste separation schemes across Maharashtra in order to increase the supply of city compost.

5.3 Implications of findings

The findings outlined above imply that multiple issues need to be addressed in order to increase city compost adoption. One of the biggest barriers standing in the way of increased adoption rates seemed to be the farmers' hesitation to attempt using city compost. To get to the bottom of what is keeping farmers from adopting compost it might be helpful to look at the characteristics of city compost that could be impacting adoption (Rogers 1962). The interviewed farmers seemed to be aware of the relative advantages of compost compared to mineral fertilisers. However, it seemed like most farmers were not aware of potential advantages of city compost when compared to homemade compost. None of the interviewed farmers seemed to have struggled with implementing compost within their production systems. This indicates that compost is compatible with the existing production systems and no investment in additional machinery or other modifications should be necessary for adoption.

According to the results of my study, trialability and observability of city compost effects might be the most challenging characteristic slowing down the rate of compost adoption. Since farmers are hesitant to adopt compost, other stakeholders will be necessary to provide field trials or documentation needed to convince farmers to use city compost. Potential stakeholders equipped to finance and organise field trials are different governmental agencies, private companies, NGOs, different extension service providers as well as farmers unions and other organisations actively engaged with farming communities.

By viewing the diffusion of city compost adoption through the lens of an AIS it is possible to gain an understanding for the roles that different actors might play in influencing farmers adoption decisions. Moreover, it becomes possible to contextualise what actions might increase the adoption of city compost and what actors are able to implement them. According to the results of my study, different governmental bodies can play a key role by implementing legislation and distributing funds to institutions dealing with research and extension. Research done by Cai et al. (2019) points out the relevance of developing communication methods that are well equipped to provide training and knowledge to farmers from scientists and extension agents. Furthermore, they emphasise the importance of involving farmers by enabling participation and encouraging them to use compost by involving them in the research and development process. Other actors that could prove to be important are different members of the private sector and international donors and development agencies.

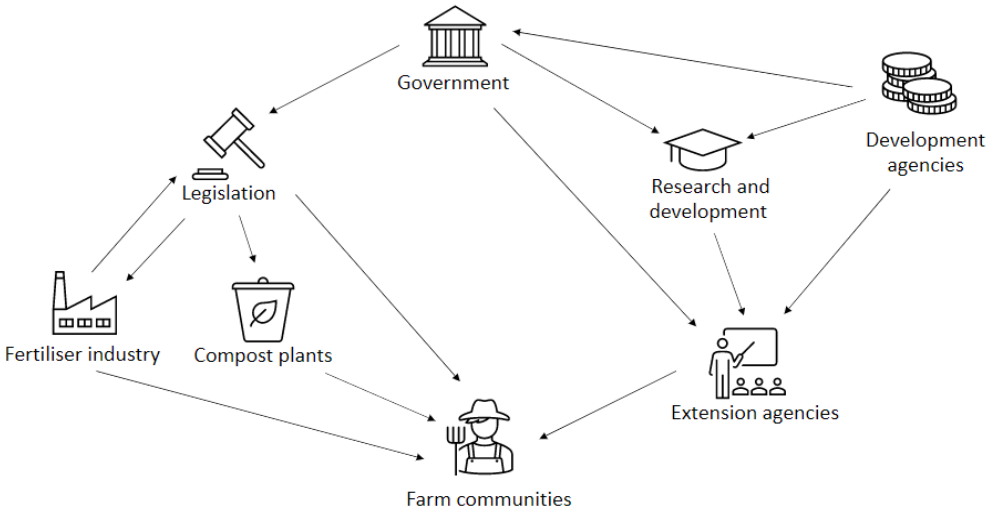

Figure 12: Graph showing different actors that are part of the city compost AIS and the possible ways that they can influence each other.

The different actors are equipped with various possibilities to influence farmers' fertilisation decisions. Government institutions can implement legislation and distribute funding to influence the actions of the different actors involved in the compost AIS depicted in Figure 12. Fertiliser companies and compost producers have the ability to influence farmers fertility management via their marketing and distribution systems. One key difference between compost producers and the producers of mineral fertilisers is that the latter might have the ability to influence legislation. Research institutions can help in developing technologies and

providing data that can influence farmers adoption of city compost. The developed strategies can then be communicated to farmers via extension agents. Development agencies and international donors can play an important role in providing financial and other resources that might facilitate the role of other actors that are part of the AIS.

In order to concretize possible actions that the different stakeholders involved in the city compost AIS can take to increase adoption rates we can look at the different opportunities identified throughout the different interviews. The integration of INM principals within fertility management practices used in Maharashtra might be one of the most promising opportunities to increase city compost adoption. Because of the holistic nature of the INM concept the principles offer the possibility to provide a structure for the reformation of fertility management spanning from the farm level to the political arena. Furthermore, the concept offers the prospect of integrating several of the opportunities for increasing city compost adoption identified throughout the interview process under one conceptual umbrella.

For example, the Increasing prices of mineral fertilisers seem to provide the opportunity to promote INM and the use of city compost to farmers as a viable economical alternative. In this context it is important to consider findings made by Kishore et al. (2021) that suggest that increases in the relative prices of mineral fertilisers only lead to small changes in farmers' fertiliser consumption. Considering the statement made by some of the interviewed farmers and Q4 the slow reaction to fertiliser price changes might be explained by a general lack of economic understanding coupled with the missing awareness of alternative fertilisation methods. During the interview with Q3 it was mentioned that a proper implementation of INM should reduce the need for mineral fertilisers by 25%. Hence, the adoption of INM principals could help in providing farmers with solutions on how to deal with increasing prices of mineral fertilisers. Furthermore, if the promotion of INM principals was to be coupled with the promotion of city compost, increased adoption of INM could also lead to the increased adoption of city compost.

In order to utilise this potential synergy it will be necessary to find ways to convince farmers of the benefits of adopting both INM practices and City compost. Considering the results from the interview with Q3 and the farmer interviews there is a growing awareness amongst farmers about the decline of soil fertility. Despite the growing concern 40% of farmers are still only using mineral fertilisers to add nutrients to their soils. In order to change this there is a need to find efficient ways of reaching out to farmers and providing them with the necessary information and support to change their fertility management practices. According to Choudhary et al. (2013) the successful implementation of INM practices is dependent on the development of appropriate technology transfer models. In their study of INM adoption in northern India the use of participatory rural appraisal techniques proved to be well suited to implement changes in fertility management practices. In addition to this, the establishment of soil testing facilities and the promotion of bio stimulants could help extension agents as tools to showcase and accelerate the benefits of using city compost. Especially the use of soil testing could prove to be an important factor in changing fertilisation management since many farmers do not have scientific information on plant

nutrient requirements (Kishore et al. 2021). By including soil fertility parameters like the soil carbon content or microbial activity the benefits of using city compost could be demonstrated to farmers. Several studies investigating possible ways of changing fertiliser management in India have shown that regular visits by extension agents and the use of information that is simple to understand have proven to be effective when trying to implement change in farmers fertility management practices (Singh et al. 2018; Cole & Sharma 2017).

According to the findings of my study the most common sources of information for the interviewed farmers were different extension agents from fertiliser companies, governmental agencies and NGOs. Some of the younger farmers that were interviewed mentioned that they use WhatsApp or YouTube as digital sources of information. International organisations like the World Bank have been advocating for the use of different technologies such as cell phones and apps to provide extension and promote sustainable agricultural practices (World bank 2016). The main benefits associated with using digital tools for agricultural extension are their wide reach and the possibility to dramatically reduce transaction costs. Despite the promising potential of digital extension tools, they have so far not been shown to be well equipped to break down barriers to development and technology adoption in agriculture (Deichmann et al. 2016). Research done by Singh et al. (2018) shows that there is a need for repeated field visits by extension agents in order to have an impact on farmers' understanding of soil fertility and their attitudes towards changing their fertility management practices.

In order to utilise any of the opportunities outlined above there is a need to identify which actors from the city compost AIS are well equipped to facilitate development processes. Furthermore, it might be important to establish networks that enable the exchange between the different actors to coordinate potential changes.

If the demand for city compost would be increased through extension efforts, marketing campaigns and legislation the production of high-quality city compost needs to be increased. The biggest hurdle for increasing production are missing waste separation systems that can provide organic waste that is well suited for compost production (Annepu 2012). Historically it has been difficult to establish waste separation systems in India and the problem is often neglected by the responsible authorities. In order to address the issue of waste generation forecasts, Information dissemination systems as well as collection and transport systems need to be established (Sudha 2008). Consequently, it will be necessary that the actors responsible for establishing waste separation systems are provided with the resources to implement necessary changes.

Zurbrügg et al. (2004) argue that small, decentralised compost facilities run by actors from the private sector might be the best way of increasing the resource use efficiency of compost value chains in India. If municipal authorities could support small scale private compost producers with the collection of waste and the provision of land necessary for expansion it might be possible to establish decentralised compost production networks. Considering the findings derived from the visit at the small-scale compost production facility it might be plausible to integrate waste streams from surrounding cities and villages to increase the

facilities current output. Nonetheless the municipal waste would still need to be thoroughly separated to be viable as a substrate for small scale producers. Zurbrügg et al. (2004) conclude that if the national compost market in India is not expanded and promoted further the composting of urban wastes will not be viable for small or big scale compost producers.

5.4 Limitations and the need for further research

Like most qualitative pilot studies the goal of my research was not to generalise but rather to provide a contextualised picture of barriers and opportunities for city compost adoption in Maharashtra. Nevertheless, it could be argued that my findings carry relevance since they are in line with what other researchers have found investigating compost adoption in similar contexts. To verify my findings there is a need for quantitative research focused on investigating the relevance of the different barriers and opportunities by gathering data from larger populations. Furthermore, quantitative data might give insights if some of my findings are more relevant than others.

In addition to quantitative studies it might be interesting to organise group discussions where different stakeholders and farmers could exchange their opinions on how to make use of the opportunities and deal with the barriers identified during my study. The documentation and analysis of these discussions might yield interesting results for the design and implementation of strategies aiming to increase compost adoption.

6. Conclusion

My research unveiled several barriers and opportunities that might be impacting the adoption of city compost in the state of Maharashtra. By getting an understanding for the different factors that might be impacting farmers adoption decisions, appropriate strategies for promoting city compost adoption can be developed. Main barriers that were identified were a lack of political initiative, the influence of fertiliser companies and the preference of farmers towards using other compost products. Furthermore, the low availability of city compost also needs to be addressed to avoid supply problems if adoption rates were to increase. Considering that there seem to be multiple barriers preventing adoption it would be reasonable to find holistic solutions equipped to address several issues simultaneously.

According to my findings the integration of INM principals into policy, research and extension could lead to a general change in fertility management practices. If the implementation of INM was to be coupled with the promotion of city compost it might be an opportunity to increase adoption rates. In order to promote city compost and INM there is a need for the relevant stakeholder to take charge. Different governmental institutions and development agencies might play the most important role in pushing developments since they have the opportunity to influence fertilisation management by regulation as well as supporting extension efforts aiming to promote both INM and city compost. Considering the findings from my study, the most important issue at hand is an overall improvement of communication and education efforts aimed at providing farmers with the necessary information to make good fertility management decisions. Moreover, it is necessary to strengthen the confidence that farmers have in using both city compost and INM principles by organising public field trials and increasing the possibility to receive guidance from extension officers.

When considering the vast number of programs and other incentives that were deployed during the green revolution in India to promote the adoption of mineral fertilisers and other agricultural technologies it seems reasonable that a similar effort might have to be made to increase the use of city compost to change the current status quo of fertility management in Maharashtra.

It should be possible to make a case for the necessity of such efforts since increased adoption of city compost and other organic fertilisers are necessary to grant long term food security. Furthermore, the increased adoption and extension of city compost projects across Maharashtra and other parts of India provide the opportunity to establish sustainable solutions for dealing with organic waste. Since fertility management and waste treatment are pressing issues not only in Maharashtra but also in other parts of India the development of solutions for how the city compost concept can be developed and brought to scale should be explored further. In theory the potential of using city compost to change fertility management practices and supporting sustainable development carries great relevance. Hence future research and development projects should focus on finding ways to harness the theoretical potential to integrate it into a practical reality.

Popular science summary

In nature the process of composting breaks down fallen leaves and other organic materials to nutrient rich soil necessary for plants to grow. Composting is an important mechanism in nature that makes it possible to recycle nutrients from dead materials so that they become available to the ecosystem. With the development of agriculture humans started to use composting as a way of recycling manures, straw and other organic materials by turning them into fertilisers. Throughout the development of modern agricultural practices and the possibility to use mineral fertilisers the use of compost by farmers became more and more uncommon.

In India the introduction of mineral fertilisers made it possible to increase the production of food. This was an important step since India has struggled with famines in the past. Despite the positive short term effects the use of mineral fertilisers has been shown to also cause several long term effects that have negative impacts on food production. The long term problems of using mineral fertilisers can be explained by comparing modern agricultural fertility management to the natural processes mentioned above. Mineral fertilisers only add nutrients back to the soil that are important for plant growth whilst the natural nutrient cycle also adds carbon and other important nutrients that are important for the overall health of the soil. If a farmer only uses mineral fertilisers the soil health declines since it is not getting the nutrients it would get if the process was oriented on the natural cycle. This decrease of soil fertility also causes decreases in agricultural production since plant growth is not only dependent on the supply of nutrients but also needs a healthy soil.

One possible solution for the problem is the reintroduction of compost since it can provide the soil with the nutrients that are necessary to maintain both plant growth and soil fertility. One project that is focusing on the use of compost is the Urban rural nutritional carbon cycle (URNCC project). The project composts organic urban waste that can be used as compost which in turn can be used as a soil fertility promoting fertiliser. Currently the project is trying to expand the use of compost in various project regions in Maharashtra. One of the major challenges in expanding the project is increasing the number of farmers that are using compost. To convince more farmers it is necessary to understand what arguments speak for and against using compost from the farmers perspective. This question provided the basis for my thesis research and provided me with the opportunity to go to India to investigate what barriers and opportunities there are to increase the use of compost from the farmers perspective. The results of my study show that the main barriers preventing farmers from using compost are lacking political support, the influence of fertiliser companies and the low availability of high quality compost. Furthermore, my results showed that the promotion of integrated nutrient management, organic farming, and soil testing could provide opportunities for increasing the use of compost amongst farmers. In conclusion my study showed that farmers are in need of more information and guidance when it comes to starting to use compost. Since the use of compost was forgotten for a while it will take some time and effort to reintroduce it to Indian farmers.

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Figure 3: Rogers E. M. (1962) *Diffusion of innovations.* 1st edition New York: Free Press of Glencoe.

Figure 4: Akenroye T. O., Dora M., Kumar M., Elbaz J., Kah S. & Jebli F. (2021) A taxonomy of barriers to the adoption of sustainable practices in the coffee farming process. Journal of Cleaner Production Volume 312, 20 August 2021

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Figure 5: Akenroye T. O., Dora M., Kumar M., Elbaz J., Kah S. & Jebli F. (2021) A taxonomy of barriers to the adoption of sustainable practices in the coffee farming process. Journal of Cleaner Production Volume 312, 20 August 2021

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Appendix

Could Organic waste be a solution for food security in India?

By Felix Möhlendick, felix.mohlendick@gmail.com

Releases 2023

Promoting Soil Health by using City Compost

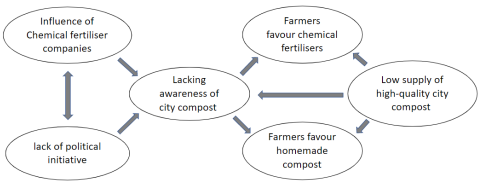
To sustain Indian agriculture, it's crucial to adopt new fertilization strategies. One effective approach is to increase the use of organic fertilizers like compost and animal manure, which enrich the soil with organic matter, improving both biological and physical soil functions (Indoria et al. 2018). To make compost a practical solution for India's declining soil fertility, efficient value chains must be established to ensure farmers have access to high-quality compost in sufficient quantities (Harper et al. 2004). Additionally, effective coordination among various government levels, extension agents, researchers, and the private sector is crucial to facilitate widespread compost adoption among farmers. The Indian government has initiated multiple projects and incentives in multiple states to promote compost usage and support the development of compost value chains. The goal of the nation wide initiative is part of India's goal to restore 23 million hectares of degraded land by 2030. As part of the nationwide efforts the URNCC project was launched in Maharashtra in 2015. The Project addresses land degradation by recycling urban organic waste into city compost. However, low adoption rates by farmers in Maharashtra hinder its success. To better understand farmers' perceptions and to find ways to promote city compost adoption, my thesis research aimed to generate a better understanding of the factors influencing farmers adoption of city compost.

Using a Qualitative approach to map the compost adoption system

The district of Pune located in the central west of Maharashtra, was the URNCC project district where the research for my master thesis was conducted.
The data to answer the thesis hypothesis was collected by using semi structured interviews. Participants for the interviews were selected purposefully, targeting individuals with relevant knowledge and experience. The study aimed for a minimum of 10 farmer interviews without setting a specific target for stakeholder interviews. Both compost-using and non-using farmers were interviewed to understand compost adoption factors, while regional stakeholders were included for their perspective on the compost value chain's development.
Thematic analysis was used to structure and interpret the collected data. To verify the validity of the collected data, inductive coding was used. By comparing the data with findings from other researchers it was possible to identify emerging themes that could be used to further analyse compost adoption in Pune.

Results

Based on the interview findings, the adoption of city compost in Pune appears to be stuck in the early adopters stage of Rogers' diffusion curve (Rogers 1962). Three primary barriers hindering increased adoption rates are identified.
City compost adoption in Maharashtra faces multiple challenges. A lack of political initiative in the Indian agricultural sector limits opportunities for its adoption. Furthermore, the significant influence of fertilizer companies shapes farmers' perceptions of city compost. Inadequate availability of high-quality city compost also impedes adoption rates. These issues collectively result in a lack of awareness among farmers regarding the availability and benefits of city compost, acting as barriers to its integration into their fertilization practices.

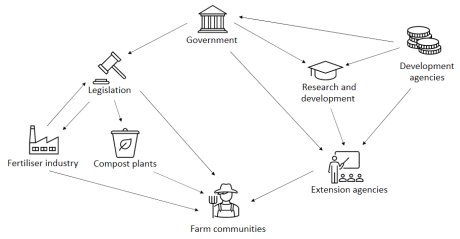


These issues collectively result in a lack of awareness among farmers regarding the availability and benefits of city compost, acting as barriers to its integration into their fertilization practices. To make compost a practical solution for India's declining soil fertility, efficient value chains must be established to ensure farmers have access to high-quality compost in sufficient quantities (Harper et al. 2004). Different opportunities that could increase farmers' adoption of city compost were also identified during the interviews. The main opportunity to increase the use of city compost might be the fact that all farmers that were interviewed had positive opinions about compost. Other identified opportunities were the promotion of Organic farming, INM and the use of Biostimulants. Furthermore, the growing awareness amongst farmers of the negative effects and increasing costs of mineral fertilisers could also boost the adoption of city compost.

Main Takeaways

According to my study, the trialability and observability of city compost's effects pose the most significant challenges to adoption. To overcome this, engaging various stakeholders, including governmental agencies, private companies, NGOs, and farmer unions, is essential to conduct field trials and provide convincing documentation.

Viewing the adoption of city compost as an Agricultural Innovation System (AIS) allows us to identify roles for different actors. Governmental bodies can enact legislation and allocate funds, following research emphasising effective communication methods from scientists and extension agents to farmers. Involving farmers in the research and development process is vital. Private sector entities and international donors and development agencies can also contribute to increased adoption.



My research highlights barriers to city compost adoption in Maharashtra, including a lack of political initiative, influence from fertilizer companies, and farmer preferences for other compost products. To address these challenges, integrating Integrated Nutrient Management (INM) principles and promoting city compost is essential. Government institutions and development agencies can lead these efforts, focusing on improved communication and education for farmers. Increasing confidence in city compost and INM through public trials and extension officer support is crucial. Given the urgency of these issues, similar efforts to those used in the green revolution are necessary to promote city compost adoption, ensuring long-term food security and sustainable waste management solutions. Future research should focus on practical implementation of these concepts.

References

Harper M., Pervez A., Rouse J., Drescher S., Zurbrugg C. (2004) Sustainable Composting Case studies and guidelines for developing countries. Water, Engineering and Development Centre Loughborough University 2004

The interview guide presented below was used for all farmer interviews that were done for this study.

Demographic profile
Gender:
Age:
Education:
Farm size:
Owns/hires land:
Crops grown:
Is the land irrigated:
Member of farmers group:

General opening questions about the farm and the farming conditions
How big is your farm and what crops do you grow?
How long have you been farming?
Have you noticed any changes positive changes in yields or other factors impacting your farm? Have you noticed any negative changes during the time you have been responsible for the farm? (Reduction in yields, less rain)
Can you describe the soils on your farm? Are they nutrient rich? Do they dry out quickly?
In which ways do you add nutrients to the soil?
Are you using compost to fertilise your fields?

Middle section when compost is used
How long have you been using compost?
What motivated you to start using compost?
What expectations did you have on the effects of compost?
Have you noticed any positive effects after you started to use compost?
Have you noticed any negative effects since starting to use compost?
Would you recommend your neighbours to start using compost?

Middle section if compost is not used
Do you use any organic fertilisers?
Have you ever thought about using compost?
What positive effects would you associate with compost?
Are there any negative effects that you would expect when using compost?
Have you heard of negative experiences from other farmers?
Is there anything that needs to change for you to consider using compost in the future?

Concluding section

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