°CICERO

Report 2024:04

The Burning Issues of Punjab

Exploring the Different Futures on Offer when Managing Residue in Punjab's Rice-Wheat Cropping System

Anders Delebekk

CICERO Senter for klimaforskning

Tittel	The Burning Issues of Punjab: Exploring the Different Futures on Offer when Managing Residue in Punjab's Rice-Wheat Cropping System
Forfattere	Anders Delebekk
Abstract	The annual rotation from rice to wheat across Punjab leaves millions of tons of straw residue. The preferred method for handling residue has been incineration. This contributes to the winter smog that covers the mega-city of New Delhi. In 2019, the Supreme Court deemed stubble burning illegal. This brought forth alternative means to handle residue. This thesis is based on fieldwork conducted in Punjab and uses a Science and Technology Studies (STS) lens to explore how the ways of handling residue affect the local and global environment and how more-than-human actors are excluded or included, depending on how performing actors frame and understand the problems and solutions. Farmers that burn residue do this due to time constraints and to avoid fungal outbreaks. The fungus is a friend if the farmers use the in-situ methods where residue is decomposed in the soil that strengthens. The ex-situ methods, which handle the residue outside of the field, make the residue into a monetized resource that can be utilized to produce renewable energy. This method increases the extraction of the soil's resources and amplifies many of the existing agricultural problems in Punjab. This thesis argues for a more inclusive future with a recognition of our co-species and asks humans to look beyond their initial issue when solving problems in the Anthropocene.
Quality manager	Solveig Aamodt
Utgiver	CICERO
Sted og dato	Oslo,20.08.2024
Finansieringskilde	CICERO, UIO:Energi and the TIK-center
Oppdragsgiver	CICERO
Prosjekt	INDGREEN
Prosjektleder	Solveig Aamodt
Forsidebilde	Anders Delebekk

Content

Summary

This report is a result of ethnographic fieldwork conducted in autumn of 2023 in Punjab in India. Every year during the crop rotation from paddy (rice) to wheat, millions of tonnes of residue are incinerated as a residue management method that damages the soil and its surroundings. Other residue management options that handle the residue either inside (in-situ) or outside (ex-situ) of the field have been gaining traction. These three options affect the surroundings in different ways, sometimes even without the promoters of the management options' knowledge. This report uses an Actor-Network Theory inspired lens to explore the three different futures that are on offer, and Callons' (1984) notion of framing and overflow in order to understand how the promoters of the different options understand the problems, but also if they recognise the consequences of their implementations.

The report has found that all of the actors have good intensions, but at times their actions lead to bad outcomes due to actors' limited frames. The incinerating farmers care for the next harvest, where a time-strained cropping system and fear of fungal outbreak pushes the farmers towards burning. Ex-situ looks outwards towards the global climate crises and seeks to monetize the crop by turning it into renewable energy. Ex-situ handles the burning, but fails to recognise, and hence amplifies many of the other problems that Punjab's agriculture suffers under. Ex-situ increases water usage, energy consumption and greenhouse gas emissions related to agriculture in Punjab, with the potential to eat up the gains of the energy production. In-situ is developed by local agricultural experts and keeps the focus on the local soil. By incorporating the residue back into the soil, microbial activity gets activated. This increases soil organic carbon and matter, which leads to increased yield while the usage of groundwater, fertilizer, and energy decreases. This results in reduced greenhouse gas emissions in total.
This report advocates for a more inclusive future where we recognise the benefit of taking care of our co-species and always finding holistic solutions when solving human made problems in the Anthropocene.

Preface

First, I would like to thank my sponsors: the TIK-centre and UiO: Energi for making my travels to Punjab, India financially possible.

I would also like to thank everyone at CICERO, especially Solveig Aamodt and Karina Standal for your feedback and for allowing me to participate in the research project INDGREEN. Gratitude is in order for everyone else that has been part of the INDGREEN project as well, with special attention deserved by Ayushi Saharan for welcoming me to the scientific community of TERI, New Delhi.

Filippa and Wouter Braarud, thank you for opening up your house to me in New Delhi, what a hospitality! Erlend Simensen at TIK needs a shoutout for introducing me to the Minhas family constituting of Tejesvi, Tanya, Aarin and Maninder who I extend my heartfelt gratitude to. Thank you for making me part of the family during my time with you. Also, the effort put in by Mr. Hareram Mukhiya while I was part of the Minhas household is worthy of a book of its own, thank you!
My Bathinda-Boys who showed me the ropes during my initial time in Punjab will all have a special place in my heart. Thank you for valuable discussions, friendship and for sharing your families with me. All of my informants, thank you for giving me insights to your thought, ideas, frustrations and hopes so that I could make more sense of a confusing topic.

Thank you to Vilde for your valuable feedback, "pirking" and patience. Thanks to proof-readers and classmates, parents, and friends.
Bård Lahn, my supervisor, thank you for steady guidance and insightful comments throughout this process.

Also, as a sociologist of associations, I want to bring out maybe the most important non-human actor in the writing process, the YouTube-video: "Ultimate 80's Synthwave Playlist - Undercover in Paradise // Royalty Free Copyright Safe Music", created by Karl Casey. Thank you for bringing just the right beats to ensure my attention holds throughout the day.

All mistakes are mine and mine alone.
Anders Delebekk
Oslo
05.05.2024

1. Introduction

I had spent one month with the farmers of Punjab, India when the fields, that just one week prior had been spurring with life, started to burn. The blue skies turned gradually grayer as November grew old and the scent of bonfires filled the air. The winds carried the smoke to New Delhi – and I followed. I had left what had been a vibrant city a month prior. The sun that had been so present was now covered by a thick grey gloom, which encapsulated the grounds, at times making it hard to see what was right in front of me. The conversations with my friends had turned from topics of food to air quality. The air quality was also the first thing I would check when waking up in the morning, just to find out if it was more poisonous than the day before - it always was[1]. The smells that had earlier been vibrant and interesting were now dominated by the strong aroma of what reminded me of burned rubber. Before I left for Punjab, most of our common meals were enjoyed on my friend's balcony. Attempting this in mid-November would bring about headache, cough, and discomfort. This would be the reality for 30 million people for another three months.

When the paddy is harvested at the end of the kharif-season in Punjab, 20-30 cm of paddy residue is left covering the soil, amounting to millions of tonnes. All this residue needs to be managed in just 20 days to sow the rabi-crop, wheat, on the same soil[2] (Gupta, 2019; Dutta et al, 2022). This agricultural system that dominates Punjab is called the rice-wheat cropping system (RWS), and the preferred method for residue management has for a long time been incineration (Gupta, 2004). The burning leads to high emissions of greenhouse gases (GHG) and dangerously poor air quality in the neighbouring megacity of New Delhi (Kumar & Joshi, 2023; Abdurrahman, Chaki & Sani, 2020). The people of New Delhi suffer from this and live with increased risk of respiratory diseases and premature deaths (Gupta, Agarwal & Mittal, 2016). In 2019, the Supreme Court ruled the practice of residue burning illegal (Liu, Sanyal & Singh, 2021), paving the way for an array of new solutions. These new solutions can broadly be put into two camps: in-situ, where the residue is handled inside of the field (Singh et al, 2020) and ex-

---

[1] See pictures in Appendix A. I would also recommend that you started with a peek on the pictures, in order to get more vivid images, from Delhi's air pollution, but also from the fieldwork I conducted in Punjab
[2] Paddy means rice, this is the preferred word in Punjab. Kharif is autumn crop while rabi is spring crop.

situ, which relies on the extraction and handling of residue outside of the field (Lohan et al, 2018). The burning fields are not the only problem the RWS enacts: The agricultural regime that dominates the soils of Punjab also brings with it the depletion of soil organic matter (SOM), soil organic carbon (SOC) and groundwater – to mention a few (Rodell, Velicogna & Famiglietti, 2009; Benbi et al, 2015; Yadav, Idhu & Thaman, 2016; Buttar et al, 2023). The combinations of these factors have the potential to lead to the eventual collapse of the agricultural system of Punjab (Shiva, 2015), a soil that ensures the food safety for millions of people, inside and outside India (Jodhka, 2006a; Goel, 2011; Kumar, 2019).

This report is based on qualitative data collected from my own ethnographic fieldwork in Punjab during the harvest and burning season and complemented with document work. The report seeks to explore how the three distinct alternatives to residue management address the broader sustainability challenges posed by the RWS, offering varied futures for the soils of Punjab. It aims to understand the workings and impacts of these solutions and seeks insight into the perspectives of the human actors involved. Specifically, it examines their understanding of the benefits and how their choices influence the outcomes.

1.1 Theoretical Inspiration and Research Question

Of the three solutions for residue management, one of them is already established and is widespread across Punjab, namely residue burning. The two other solutions, in-situ and ex-situ, seek to establish themselves as more sustainable options for residue management. In such periods, when several alternative possibilities seem possible and no option has become hegemonic, controversies are rife. Later, when the dust settles, the roads not taken may be forgotten.

This report is built upon the theoretical discipline of Science and Technology Studies (STS). STS scholars direct our attention towards the possibilities that once were present but have been eclipsed by the black boxing of what has become a hegemonic technology. Black boxing refers to how the inner workings of objects or concepts are obscured when their use becomes an established practice. When something becomes black-boxed, the side effects are that rationales are taken for granted and certain facts created. Things stand still (Latour, 2007; Sisimondo, 2011). Actor-network theory (ANT) is a theoretical branch within STS, developed amongst others by Bruno Latour (2007). It explains how knowledges and friction found in the establishing phase of new technologies, knowledges etc create links and trails through their movements that can be followed. Right now, there is a lot of movement to be followed in Punjab.

By exploring and describing the different possibilities in an early, pre-establishment phase, one of my academic contributions is to map and explain the different actors, understood as more-than-human actors, that create and are affected by the different alternatives for how residue is managed in Punjab. More importantly, I will draw attention towards those actors that are forgotten when people are seeking solutions to limited problems. To cite Bowker and Star (1999:291): "People often cannot see what they take for granted until they encounter someone who does not take it for granted". This report is thus advocating for the need for a holistic approach when seeking solutions to problems, such as residue management, in the era of Anthropocene. This means that the report seeks an alternative to a human-centric approach that does not recognise the agency and possibilities that exist within the non-human living actors we share our planet with – and which comes with the danger that other problems within the RWS are amplified. In our time, the boundaries between human and nature have become established distinctions (Latour, 1993; Tsing; 2004; Haraway, 2008). This report seeks to illuminate the links that exist between all the entities within the different solutions, and how the treatment of our co-species can influence the overall sustainability of the RWS in both negative and positive ways.

ANT is a useful framework to illuminate the different actors that are a direct part of the work and the performance of the thing which is studied. A critique of ANT is that it does not recognise the working of that which is not set into motion (Bellacasa, 2017). I will supplement ANT with its theoretical offspring "care studies" to draw attention towards the more-than-human invisible actors that often fail to get recognised within a standard ANT analysis, where too much of the spotlight is given to what is already in motion. Care will also supplement ANT on an analytical level when looking at the constant performing of care that needs to be conducted within the different assemblages (Mol, 2008). This entails that I will describe a detailed empirical work where I seek to tease out the different consequences of the chosen method to handle residue that are unaccounted for. By doing this, we can better understand the rationale of care that is utilised by the different actors, and where care is located. Because, as we will see, care is not always good, and care can be in tension (Mol, Moser & Pols, 2010). The concept of care in tension will also contribute to demonstrate how good intensions can lead to bad outcomes. This is a story with no villains, only reckless behaviour.

To complement this, I will give an overview of how soil can be understood as a living organism in need of care, or a medium for extraction (Bellacasa, 2015). This will both be used in order to explain which hegemonic thought that prevails within the actors that are promoting and performing the different solutions towards residue, but also to explain that this report understands soil as a multispecies world rife with potentially missed opportunities (Bellacasa, 2013; Krzywoszynska, 2021).

The final theoretical concept that this report will draw on is framings and overflows, developed by Callon (1998). This concept will be used together with the other frameworks to better understand how the key human actors, presented in the following section, understand their role and recognise or do not recognise the wider consequences of their doing, depending on how they frame the problem and the solution

I have now outlined the theoretical framework that underpins this study. This sets the stage to explore the main focus of the report: examining how three different residue management methods address the sustainability challenges presented by the RWS, and their potential impacts on the soils of Punjab and beyond. The report aims to understand the processes and effects of these methods, and to gather insights into the perspectives of the actors involved. Specifically, it delves into their understanding of the benefits of the different methods and how their choices influence outcomes. To do this, I have composed three linked research questions that will guide me in this endeavour.

The first research question is to unveil the actors, human and non-human, that are part of the different solutions. Answering it will offer insights related to the different solutions so that research question 2 and 3 can be answered. The first research question is:

Which human and non-human actors are part of the respective solutions to the problems of residue?

This research question is part of teasing out of the consequences of the different solutions, by following the actors. For the second research question I have looked to care studies for ethical inspiration towards neglected actors (Bellacasa, 2017). I also seek to give honour towards the positive side effects that can come with the different solutions to the problems of RWS. This leads me to my second research question which is:

What futures do the different solutions offer, based on how they impact the overall sustainability of the RWS?

When this second question has been answered, we will have a clear understanding of the different futures that are offered for the soil and the RWS, depending on which solution is chosen, the third research question can be sought answered. During my fieldwork, the performing human actors gave clear indications of their interests and what they valued, but also how they perceived soil. The third research question aims to understand how the consequences are "allowed" to happen, but also how the frames of the solutions create different allies.

How does the way the actors frame their solutions impact which actors are not recognised and which ones are enrolled in their assemblage?

1.2 Presenting the performers

I will now offer a few lines in order to introduce the main promoters and performers of the different solutions to RWS. This will give an overview of the situation in Punjab before I move on to the theoretical and methodological chapters. It is the actors presented in this section that will be central to answering research question 3. What they keep inside and outside of their frame of interest is central to understanding what is recognised and emphasised in the different solutions and how this can lead to detrimental or positive results for the RWS.

The first actor, or performer, are the farmers that are using incineration in order to manage the residue. For a long time, this burning practice was the standard. This has, as explained above, created problems that now have been enacted as an issue that needs to be solved. To address this problem, in-situ and ex-situ has been gaining prominence. These competing solutions will be the main focus of the report, even though incineration will also have a prominent role as a possible solution. Showing and explaining this will work as a way of measuring the impact the two other solutions have. Incineration is also novel in its own right because its external influences are leading to profound changes within the solution and the farmers performing the incineration. These farmers, who will represent the burning solution, belong to the Jat-community, and have deep historical and cultural roots to farming in Punjab (Jodhka, 2023).

The main promoter of the in-situ solution is Punjab Agricultural University (PAU). PAU was established as a result of the green revolution, a technological revolution that drastically transformed agriculture in Punjab. Since then, PAU has been a key actor in Punjab's agricultural sectors through its knowledge production (Kumar, 2007; Sandhu, 2014). It was the place where the high-yield variety seeds (HYV), which now dominates Punjab's soil, was developed (Wolf, 1986). They have been developing and researching the in-situ method for many years. The method is based on mulching down the residue, incorporating in the soil, letting it decompose and then finally turning into a manure (Singh et al, 2013).

Ex-situ is not a uniform solution like in-situ but works as an umbrella for a variety of solutions. During my fieldwork I encountered cardboard-companies, mushroom cultivators and energy companies – to name a few[3]. Where they have different outputs, their input is the same: Residue from the paddy harvest is extracted from the fields. I have decided to focus on one company named SAEL. SAEL has attracted an investment of 600 million Norwegian kroners from the government sponsored Norwegian investment fund Norfund, and a significant loan from the Asian Development Bank (ADB) (Norfund, 2023; Asian Development Bank 2023A).

SAEL is an Indian company involved in solar energy, storing of agricultural harvest, processing of paddy for export, and waste to energy power plants. This means that it is a stakeholder across the supply chain of the RWS in Punjab, where it has the highest proportion of its business (SAEL, 2022). The focus of this report will be on SAEL's waste to energy segment. They handle the residue by transporting it to one of their four power plants in Punjab where it is incinerated. This process turned the residue into instantly utilised electricity (SAEL, 2024) This method is classified as a renewable energy source because the carbon it emits is reintegrated into the carbon cycle; the carbon captured during vegetation growth is sequestered when the biomass is harvested and regrows, thereby storing an equivalent amount of carbon. (Schlamadinger & Marland, 1996; Herbert & Krishan, 2016).

Their international financial sponsors make SAEL an interesting representative of ex-situ. But by focusing on SEAL, the report also seeks to contribute to the ever-pressing nature–renewable energy conflict (Jackson, 2011; Aslaksen, 2021).
My interest in the case

My attention towards India happened in tandem with the increased recognition the country has been getting in the last couple of years. India has been identified as a key player in a spectre of different issues that are set to form the 21st century, like security, economics, and climate change (Vidyarthi, 2013; The Economist, 2023; Sanders, 2023). In Norway, my home country, the government has also expressed an amplified interest in India and has recently increased its efforts to strengthen the bilateral cooperation[4] (Stortinget, 2023). My main academic interest prior to my master report was renewable energy. India has to establish a stronger renewable infrastructure to achieve its goal of net zero by 2070, while still keeping up the pace of its economic growth (Bhattacharyya et al, 2022; Li & Haneklaus, 2022). Norway has been involved in the renewable energy sector in India for a long time (Statkraft, 2016). What allured my interest towards Punjab's RWS was the Norfund investment in the SAEL, which practiced ex-situ with the promise of cleaning up the air while producing renewable energy (Norfund, 2023).

Upon my arrival in Punjab, I was exposed to the two other solutions presented in this report – incineration and in-situ. At the same time, I witnessed and was told about the sustainability issues that the RWS was facing and how it was slowly moving towards collapse (Shiva, 2015). There are substantial political, economic and technical resources revolving around the intensive cropping of rice and wheat (Singh, 2017a), something Unruh (2000) describes as a form of lock-in where the technological trajectory is hard to break. The Delhi government attempted to break the RWS lock-in in 2020 but failed because of persistent mobilisation from the farmers (Jodhka, 2021; Gill, 2022). At the moment, the potential other futures that measures such as crop diversification could have offered (Pujara & Shadid, 2016) will not yet materialise on an institutional level. The best way of facing the problems of the RWS today is thus from within, even though

[3] Dutta et al (2022) offers a good overview of the different ex-situ options that exists in Punjab
[4] This culminated with the free trade deal signed in March 2024: https://www.norway.no/en/india/norway-india/news-and-events/norway-enters-into-historic-trade-deal-with-india/

directing more investments in another component of the RWS will probably strengthen the lock-in of the RWS.

I found the three different options to residue management to also handle and understand the problems of the RWS in different manners, sometimes with potential dire consequences. With these new insights, I moved away from the initial design of the report where SAEL was the main case, to this one – where the spotlight is shared with the incineration and in-situ.

1.3 Report overview

Chapter 2 will introduce the theoretical concepts that will work as the foundation for this report. I will start by briefly presenting the history of STS, and how the interplay between technology and society became part of academia. This will lay the foundation for presenting terms found within ANT, inspired by Bruno Latour (2007), which will help explain and identify different phenomena that will be encountered in this report. Subsequently, care studies will be explained and used to advocate for a more attentive attention towards the neglected actors affected by the different solutions (Haraway, 2016). After that I will explain the Framings and overflows approach, developed by Callon (1998), that will be used to frame the interests of the different actors to understand what becomes an overflow. The theoretical chapter will end with an overview of how soil health can be understood differently by different actors depending on which scientific discipline they rely on. Simultaneously, I explain how soil health will be understood within this report, an understanding built on biology and ecology and sees soils as constituting millions of essential microbes that need to be taken care for if humans want to thrive (Bellacasa, 2015).

The third chapter will be dedicated to methodology. Here I will describe the research process. I will detail how I conducted my fieldwork, faced challenges and encountered both gatekeepers and informants. I will also explain ethical considerations and how I handled the data collected.

The fourth chapter is the background chapter. I will explain the history of the green revolution, the RWS and how the problem with residue is a human-made problem. The chapter will also offer insights into other sustainable issues that the RWS faces today, and that will be impacted differently by the different ways of managing residue.
The fifth chapter is the first to present empirical findings. The findings presented here will not be linked to a specific solution like the subsequent three chapters. Instead, it will show the importance of farming in Punjab, and how farming shapes their culture, but also how the issue of residue burning materializes and is understood by Punjab's farmers.

Chapter six, seven and eight will each present the data collected in relation to one of the solutions of residue management: incineration, in-situ and ex-situ. Here the different human and non-human actors that are part of and affected by the solution will be illuminated for the first time. Each of these chapter will end with a summary that also answers research question 1 for the respective solution in focus.

Chapter 9 will answer research question 2. Here I will reassemble the neglected aspects that were found in the findings section and discuss them up against each other to understand their positive and negative consequences in different segments of the RWS.
Chapter 10 is set out to answer research question 3. I will use the Framings and

Overflows approach, and the concept of care in tension to show how the different actors work with, and understands what they do, and make do within the RWS.

Chapter 11 will bring forth a conclusion that will present the essence of the report.

2. Theoretical framework

In this chapter I will present the conceptual framework I see as most suitable for exploring and analysing the consequences of the different solutions to biomass management within the RWS in Punjab. I will first start by giving a brief introduction to the broader, and relatively short history of STS, and how this has helped to contribute towards the development of ANT. This report will use ANT in order to map and understand the different entities that appeared during my fieldwork, and that I found to be significant for unveiling how the different solutions to RWS residue management work. Through this I will unveil the unforeseen actors and occurrences these assemblages make work and set in motion. I will supplement this with care-theory to draw attention to the unforeseen actors that have been neglected by the respective assemblages: burning, in-situ and ex-situ.

ANT and Care will complement each other in order to utilise the framing and overflows framework that will be presented next. I introduce the framing and overflows framework from Callon (1984) to understand how the external consequences are allowed to work, and how externalities is taken into account and valued by the different actors that I see as the most active propagators of their respective solutions: incinerating farmers, SAEL, and Punjab Agricultural University and other farmers that relies on in-situ.

I will then present a text by Lien (2017) which has been a source of inspiration for me to draw my attention towards the catalysing problems and opportunities that can occur when new constitutions of actors create new realities. Finally, I will present a short history of how soils have been perceived and how soils have been started to be understood as anthropogenic soils, constructed by humans. Here we will see how soils can be understood by the different actors, but also by me.

2.1 STS:

STS is an interdisciplinary space which has been utilised to shed light on a variety of different topics with a particular focus on the synergically doings of humans and non-human living organisms, things and objects. All these entities are playing a pivotal role in my report, meaning the discipline's heritage makes it a suitable match. Hess and Sovacool (2020) claim that there are two different ways of practicing STS. The first being to use a variety of different disciplines and analytical tools found within the humanities and social science field to evaluate and study material objects and technologies without the distinct need to make any connection to political or societal occurrences. The other, being more of a discipline in itself, studies how knowledge production and technological artifacts are constructed through different assemblages. These assemblages constitute and alter themselves in different ways, in different times, and in different places in a dynamic synergically process with society and nature. This holistic view has criticised the boundaries that have been constructed between the different entities that exists on our planet (Latour, 1993; Haraway, 2008). This has pushed certain parts of the STS-field to move towards a more-than-human approach, which Bellacasa (2017, P.1) has defined as a term that *"speaks in one breath of nonhumans and other than humans such as things, objects, other animals, living beings, organisms, physical forces, spiritual entities and humans".* The interdependent relationality between society, materiality, nature etc., entails that there is no deterministic linear process in the evolvement of technologies (Jasanoff, 2015).

A good example of an important early instalment into the STS'verse is Bijker and Pinch (1987). Through their study of the safety bike, they showed that technologies are not created through a spur of ingenuity where the technologies' final design are determined solely by the inventors but evolve in a social interplay where the agency of development is dispersed across society. Their work gave agency to the social in the construction of technologies. Winner (1980) contributed through identifying technologies' role in shaping the social when he studied how the measurement of bridges excluded the poor, bus-depending people from reaching the beaches on the outskirts of New York.

These two works stand today as classical contributions to the early instalment of the STS literature. The consequence if both lines of thought are true, is that that we are living in an interplay of more-than-human interaction that are all having varying forms of agency. This is a relevant notion for my report, where I am examining what I have found to be human-centric assemblages, that rely on and catalyse the motion of more-than-human actors. This interest in *technoscience*, meaning the interplay between science, technology, and society, was further "radicalized" by thinkers such as John Law and Bruno Latour through the development of *Actor-Network Theory* (Sismondo, 2010).

2.1.1 Actor-Network Theory

ANT is one of many terms used when one is acting as what Latour (2007) would call a *sociologist of associations.* Latour's proposition of becoming 'sociologists of associations' challenges conventional sociological methodologies by advocating for a detailed exploration of the networks that bind actors—human and non-human alike—thus foregrounding the dynamic and constructed nature of social relations. This perspective necessitates a shift from traditional analysis that focus on societal structures, to a nuanced mapping of associations, revealing the intricate web of interactions that makes up the social fabric. This entails that agency is distributed across the more-than-human assemblages that one studies. This point is pivotal for being accepted under the umbrella of the sociologist of associations.

Apart from that, ANT and all its offspring under the umbrella is a dynamic and abstract framework still under development. I explain this because of the plurality of ways to use ANT can influence the connotation of terms in unpredictable ways, depending on the readers predisposed understanding of the terms (Michael, 2017). This means what I will present here is *my* theoretical framework, and the terms defined will only come with the baggage that I put on their shoulders in the following section.

2.1.2 Sociology of Associations

I will first start by presenting key elements that Latour (2007) defined when he constructed the distinctions between mainstream sociologists and a sociologist of associations. The goal is to show the rationale of ANT's contribution to social science according to ANT. The lack of clear power structures within ANT is a common criticism. Hence, a subgoal in the following section is to explain how one can unveil power within ANT (Michael, 2017).

According to Latour (2007), a mainstream sociologist would start out by systematically putting people into homogeneous categories based on their gender, ethnicity, socioeconomic background, educational level etc. These categories are constructed and deployed, meaning, they are performed by humans. Utilizing them will assume power-relations that might not be there and will not be sufficient to give an honest representation of the study of inquiry, being a short-cut when conducting social science (Knorr, 1988). A second consequence of this, according to Latour (2007), is that you are starting in the wrong end of what should be your inquiry. These categories are representing a ready set society, meaning you are starting with the social in order to explain a thing. You are also depriving agency from the actors of the story, being the victims of a third dimension out of their grasp. Still, an important distinction here is that groups, categories, do exist, but they are formed, they are constructed, performed through an array of its assemblage and in order to do them just, one needs to follow their traces. To do this, one should work with a flat ontology where the local circumstances are always taken into consideration. This entails that an actor with a lot of agency in Norway might not have the same agency in Punjab. How they perform is depending on the other actors around them, and a sociologist of associations would follow the traces the actors create in order to construct the reality. A side effect of this is that by following the traces, you will eventually understand *how* something works. I find this best explained by Latour himself in the form of a fictional dialogue between a professor and a student (2007, p143):

> *"P:[...]being connected, being interconnected, or being heterogeneous is not enough. It all depends on the sort of action that is flowing from one to the other, hence the words 'net' and 'work'. Really, we should say 'work net' instead of 'network'. It's the work, and the movement, and the flow, and the changes that should be stressed. But now we are stuck with 'network' and everyone thinks we mean the World Wide Web or something like that.*
>
> *S: Do you mean to say that once I have shown that my actors are related in the shape of a network, I have not yet done an ANT-study?*
>
> *P: That's exactly what I mean...."*[5]

[5] Due to Latour's critic of the word network throughout his work in "Reassembling the social" is also why I have chosen to go for the term assemblage instead of the more classical network.

This approach will be beneficial for my research inquires. I seek to understand how something becomes created as an unrecognised reality. Outcomes do not spur out by a sole actor in the ANT-understanding of the world but is constituted by how different actors influence each other. In order for me to be able to say that this unrecognised outcome is a result of these actors' action, an understanding of how different actors influence each other and create new local realities is needed. Hence, I will through the following of actors be able to explain how something is made work. The clearest example in this report will be how the microbes in the soil will have radically different behaviour, depending on the other actors that constitute the microbe’s surroundings.

2.1.3 The Local

The importance of local is a pivotal point made my scholars of ANT. ANT is not suitable to describe, for example, global warming in its entirety, capitalism, or other grand world assemblages, that would be too vast of a project. The local time and place are always a unique setting. This does not mean that the local cannot be bound up with another local. Anna Tsing (2015) followed the traces of the Matsutake mushroom to explain how realities were shaped and reshaped across continents, but still bound up in different locales.

It is in these settings ANT, or its offsprings, is most suitable and has been used to explain a lot of peculiar cases, often seen as outside the realm of social science, like the laboratory, scallops, forest, agriculture, or soils etc (Latour & Woolgart, 1986; Callon, 1984; Star, 1999; Doganova, 2018; Watts & Scales, 2015, Bellacasa, 2017), and will now be used to understand residue management in Punjab.

2.1.4 Terms and relevancy of ANT for my report

In this section I will go more explicit into why ANT is relevant for my report. While I do this, I will use the empirical background of my case. Simultaneously, I will take breaks in order to explain terms within ANT as they appear. I chose this approach because it is hard to talk about ANT without using the proper terms, and I wanted to avoid the usage of a glossary list at the beginning. Also, by holding the theory and the empirical work closely together from the beginning, the hope is that you, the reader, will become more familiar with the case early on. This does not mean I have started my analysis; I am just giving examples of how one can think of actors within the RWS through the vocabulary of ANT.

Instead of the word Network, I will use the term assemblage that is Latour’s preferred word in his 2007 book. Assemblage is defined as a cluster of actors that are performing a task. The RWS can be understood as an assemblage. These actors, who can be human and non-humans (more-than-human), are bound together through associations. If the RWS is working optimally (from a certain point of view[6]), all the associations are correctly performing their task without causing friction, the actor is working as an intermediary, an actor that is faithfully part of performing, constructing, and maintaining the RWS (Latour, 2007; Michael, 2017).

One of these performances has been to burn the residue after harvest in order to quickly prepare the field for the next harvest (Dutta et al, 2022). Then, a new actor appeared, a court ruling from the supreme court that deems the burning of residue to be illegal (Liu, Sanyal & Singh, 2021). This law causes friction within the established assemblage. Now,

[6] I will explain this better as we go, but by this i mean that different actors can have different understandings of what is a successful assemblage. For example, reindeer herders vs. a company that produces wind energy.

the residue that earlier was disposed of in a predictable manner is flooding the fields. It has been turned into one example of a mediator, where the message or the performance of that actor complicates other aspects of the assemblage (Michael, 2017). Latour (2007, p.39) explains the distinction between them in this way:

> *"For all practical purposes, an intermediary can be taken not only as a black box, but also as a black box counting for one, even if it is internally made of many parts. Mediators, on the other hand, cannot be counted as just one; they might count for one, for nothing, for several, or for infinity. Their input is never a good predictor of their output; their specificity has to be taken into account every time."*

Latour continues by emphasising the need to always understand the alluring roles mediators have, which is a pivotal point in ANT:

> *"As we will slowly discover, it is this constant uncertainty over the intimate nature of entities—are they behaving as intermediaries or as mediators? –that is the source of all the other uncertainties we have decided to follow."*

An actor can work as a mediator or intermediary at the same time, within different assemblages, meaning, actors can have different identities, all depending on which assemblage they are identified as part of. For some assemblages, the law is the mediator for example, while for other assemblages, the law at least has the possibility to be an intermediary. In order for the RWS to again be stabilised, an array of novel solutions has emerged that tries to stabilise their own assemblages. These solutions have the potential to work as intermediaries within the greater RWS assemblage, this means that the solutions for residue management of incineration, in-situ and ex-situ will from now be referred to as assemblages.

A keyword for why ANT is relevant for my report is novelty. The notion of black-boxed is important here. Conventional thinking concerning black boxing where what matters is the input and the output, and what happens between is taken for granted (Michael, 2017). This I feel the need to complement with Star's (1999) thinking concerning infrastructures, and its relationality. Through this she explains how certain things have different connotations depending on your relation to the object. So, a taken for granted entity for the general public, like the RWS, would probably not be that for the farmer who is the one that is constantly involved with the doings of the soil. Another key takeaway from her work is how infrastructures become visible upon breakdown, meaning the associations that constituted the taken for granted entity are illuminated.

Latour (2007) touches upon the same thing, but he also includes creation within his framework. When something new occurs, like the establishment of a new technology, or the introduction of one in a new setting, it means that new associations have been or are being created. This occurs either by the construction of new actors, or the reshuffling of pre-existing actors. When something becomes black-boxed, taken for granted, associations do not move, they stand in their place, and hence, they are hard to spot. It is upon movement one can spot and trace these associations that ANT is intrigued with, and as I showed prior in this section, there is a lot of movement in Punjab, both within the RWS as it stands, but also through and due to the emerging assemblages hoping to become standard solutions to what has become an issue in Punjab, namely residue burning.

2.1.5 Enrolling Assemblages

In the previous section I presented the terms assemblage, actor, associations, mediator and intermediary. These are all terms that can be used for describing something that is already out there in the world, with its effects. This report is primarily focused on the emerging assemblages and will now present terms developed within ANT that explores these aspects.

When I set out to discover the case, I felt that I needed a term to easily distinguish between actors that are being moved, by an array of different reasons, and the actors (who are just as influenced by their associations as other actors) that are seeking to construct certain futures. Within classical ANT, actor-networks, or assemblages which is my preferred term, were often held together through the workings of a "primary actor" (Michael, 2017). This term, and its history, comes with a connotation of a sizeable amount of agency. I instead created the term *future-makers* to speak of the actors that primarily set out to construct a certain assemblage for managing the residue. The reason why I am interested in their future-making abilities is due to what I believe to be lasting consequences, realities, that the future needs to live with, if in-situ or ex-situ becomes the standard way of managing the residue in the RWS. In this report, SAEL and PAU will go under the umbrella of future-makers, representing respectively ex-situ and in-situ. This term speaks more to their aspirations than to their actual agency and is a temporary role, meaning you can cease to be a future-maker without ceasing to exist, and you can also change through the array of different actors in your assemblage from an intermediary to a future-maker.

There is no promise that the future-makers' aspirations become standards. See them more as caterpillars. Even though they have the potential to turn into butterflies (or moths), most caterpillars never reach adulthood (Herman et al, 2019). If the future-makers do reach adulthood, they can still be an unsignificant actor, an intermediary in a larger assemblage. Still, in this report they will play an important role where we will understand the consequences of their potential success.

So, why do they aspire to become future-makers? Here I will introduce the term *interest* that do not deviate too much from the standard definition of interest. It is an outcome of any sort that an actor sees as beneficial. More important for this term within my report is the understanding that interest is not static but can be altered with new actors or concerns becoming emergent within the assemblage they are constituting (Michael, 2017).

In order for these interests to be transferred three terms are important. The first is *enrolment*, which is described by Michael (2017) as the process of successfully aligning various actors' interests and actions towards a common goal or project. This means that the term speaks of the process of placing an actor within a new form of assemblage. This is done through *translation* of an actor's interests, meaning to redefine one's interests. These interests can be altered at random due to actors rearing themselves, or through an active process by future-makers, but then the term *interessement* is more suitable. In this report we will see how problems that are enacted as issues attract attention from aspiring future-makers, they will further try to enrol actors in order to make their interest a reality and it is in this performance I will use the term interessement (Michael, 2017). Callon (1984) in his work on scallops defined interessement as to interest others to your cause. He goes back to the etymology of the word interested; inter-esse, meaning to be interposed between positions to justify his word. In his example he talks about building devices between the actors that I will refer to as future-makers and the actors they see as essential to convince in order to create a stable assemblage. He uses what we typically define as material objects as examples, but in essence it is about creating strong associations between actors, and in this report, we will see how other living organisms can be used in order to impose interessement.

2.2 Care and neglected actors

While ANT is constructive when examining acknowledged actors, it can be criticised for not bringing sufficient attention towards that which is not acknowledged and stays outside of the assemblages. Donna Haraway's (2006; 2016) work has highlighted the critical importance of recognizing and integrating the roles of often overlooked actors—be it species, ecosystems, or non-living elements—in maintaining ecological balance and ensuring collective survival. By focusing on the interconnectedness of all entities in the web of life, her work advocates for a deeper understanding of the complex interdependencies that sustain our planet. This approach underscores the necessity of extending attention and care to these unrecognised actors, as their contributions are essential for fostering a sustainable and inclusive future. Since research question 2 seeks to understand how the assemblages make actors create unrecognised results, I am particularly looking for those actors that are neglected, those actors that are not put into the assemblage with intentions, hence, ANT would be inadequate. This prompted me towards being *inspired* by a feminist approach in relation to my research, building on what I understand as an offspring of ANT, namely care-studies. Care, as theory, and practice, just like it's STS relative ANT, does not exist as a static entity but needs to be adjusted to its local situation (Mol, Moser & Pols, 2010). Care will also be applied in order to draw attention towards the complex work and the different interests that exist within the different assemblages I will study.

This report is highly influenced by the work of Bellacasa on *Matters of Care*.

In her 2011 article and following book from 2017, she advocates for an attention towards the "matters of care" within technoscience. Here she extends on Latour's "*matters of concern*" to reassemble and bring attention to neglected *things* within scientific and technological discourses. Latour's concept seeks to underscore the complexity and networked nature of objects, advocating for an understanding that goes beyond traditional subject-object divides and highlights how objects become central to significant debates. Bellacasa takes this further by arguing that this networked understanding should inherently include an ethical dimension of care, one that acknowledges and addresses the relationships we have with both human and non-human entities.

Bellacasa's emphasis on care will serves as a method, or motivation, to reassemble neglected things that through their precarious, marginalised position is at risk of harm within respective assemblages. Her framework is suitable in order to bring ethical consideration and active engagement with these entities. This, she argues, is crucial for a more inclusive and comprehensive approach to technoscience. She posits that through the practice of care, previously overlooked or marginalized actors can be recognised and valued, fostering more equitable and sustainable scientific and technological practices. This reassembling through care not only enriches the discussion around matters of concern but also promotes a more responsible and ethically aware engagement with the world, ensuring that the contributions and well-being of all actors, especially the most neglected, are considered. She asserts that recognizing and caring for the soil's properties, that she claims and values is mutually beneficial for all, as our interdependent existence necessitates ensuring the soil's ability to sustain us, thereby facilitating a sustainable co-existence. I found this approach to be suitable for my research, especially research question 2 where I aim to understand the different futures that are on offer, depending on the assemblage. By following the actors, and seeing what something makes work (Latour, 2007) the consequences of the assemblages will be unveiled, but it is the thinking of Bellacasa (2017) that draws the consequences into the centre of attention.

It is also suitable to contribute to answering research question 3 and unveil how the understanding and recognition of soil and its constitution of more-than-human actors is connected to action and consequences. Consequences beyond soil, due to the ecosystem functions that healthy soil contributes with, like water retention and carbon storage. By neglecting soil, one might also be at risk of neglecting the cascading consequences of turning important intermediaries for the RWS into mediators.

2.2.1 Care in tension

This brings me to my second notion of care, when observing neglected things, one will be introduced to tension that occurs when performing care. Annemarie Mol (2008) introduced complexities within care. In my report this will refer to the conflicting interests that could be bound in the different actor's rationale of good care. Care practices can have different connotations depending on your situated knowledge (Druglitrø, 2018; Haraway, 1988), just like a mediator can be an intermediary and vice-versa depending on the unique assemblage. Krzywoszynska (2021) introduces frames when talking about soil care to explain this, although with a slightly different connotation than Callon that will be presented in section 2.3. Different actors have different needs, to give order to their reality and identify needs, frames get established from different perspectives. These frames can co-exist and be in tension, since their meaning of care, or good care can imply different things acted upon on the same actor. In my report this will be used in order to draw attention to the different interresements that are deployed by the future-makers and other essential actors searching for solutions to the burning issues of Punjab. I will use this concept together with Callon's concept of framings and overflows that I have yet to present in order to understand the different motivations that exists to do good, and how these good intentions can lead to harm in other parts of the RWS.

2.2.2 Care as performance

The third notion is that care is a performed relational activity. Care within STS is also about the practices, tinkering, that needs to be conducted for something to function. Mol, Moser & Pols (2010) explain how care can be about the different activities that are performed in order for care to materialise. For something to happen, one would need constant tinkering, performative actions that will be understood as the construction of an assemblage of care. The more comprehensive performances without tangible returns, the harder it was to impose interessement on the farmers. Within my report, this set of thinking will be used to draw attention towards the performance that needs to be conducted in order for a solution, what we will later understand as assemblage, to function. It will emphasis a care towards the farmers, and how their choices are bound by different sets of capacities at times, where it overworks, overcapitalization, or knowledge.

2.2.3 Summary care

I have now presented ANT and Care-studies. Where ANT will be used to understand what and how something works, care will be used to draw attention to that which the assemblages make work which are not initially recognised. Care will also be used in close collaboration with the third theoretical branch that I will present in the following section, framings and overflows in order to understand externalities. Care will also be used in order to understand what is understood as a good and sustainable outcome for the different actors that are performing their respective assemblages, and to see that the different connotations of care can be in conflict, care in tension.

2.3 Framing and overflows

I have now introduced the framework that will help me to lure out the actors and their effects. The result of this will be processed through another addition to ANT, that of framings and overflows, originally developed by Callon (1984). This will help me to understand how different future-makers can “allow” certain externalities to occur. Externalities refers to unexpected realities as a result of the assemblage, good or bad.

Framing, as Callon (1984) articulates, serves to simplify and stabilise complex socio-technical interactions by establishing boundaries that delineate the assemblage. This process inherently involves choices about what to include within the frame and what to exclude, decisions that are as much political as they are technical. The act of framing, therefore, not only structures the network but also enacts a form of recognition or non-recognition towards certain elements and externalities. Those elements that are placed outside of the frame are often deprived of visibility and influence within the network, leading to a lack of recognition of their potential contributions or detrimental impacts.

The concept of overflows emerges as a critical counterpoint to framing, highlighting the consequences of what is left outside the established boundaries. Overflows embody the unanticipated, often undesirable effects that result from the network's operational processes, effects that were not accounted for in the initial framing. This includes a wide range of externalities, from environmental damage to social inequities, that remain unrecognised and unaddressed within the confines of the frame (Callon, 1998). The challenge of overflows is not merely one of containment or control but of recognition and accountability. It underscores the need for assemblages to be responsive and adaptable, to reconsider and renegotiate what is included within the frame and to acknowledge the full spectrum of externalities their operations engender.

The interplay between framing and overflows, especially in the context of unrecognised externalities, reveals the inherently contested nature of socio-technical assemblages (Latour, 2007). It highlights the political dimensions of technological and economic systems, showing how decisions about inclusion and exclusion can shape societal outcomes and environmental impacts. The negotiation of what is within the frame and what is left out is a continuous process, reflecting shifts in power, knowledge, and values within the assemblage (Law, 1992)[7].

[7] Law (1992) is not using the terms framing and overflows but are building an argument where *material heterogeneity* are influencing how we understand the world, which again trickles into power relations-simply put.

Through this lens, the report aims to deepen the understanding of how future-makers decide what is recognised through their interest and not. Callon's concepts of framing and overflows will serve as an analytical tool for examining the dynamics of inclusion and exclusion and will help me to argue for a more holistic approach when doing technoscience in the Anthropocene.

2.3.1 The possibilities of overflows

One text that has examined how solving one problem can lead to other, unaccounted for problems, is the text by Marianne Lien (2017): *Unruly Appetities: Salmon Domestication "all the way down".* This text I believe has been of great importance in opening up my thinking towards the more-than-human actors we (humans) surround us with. More importantly for this report, she explores humans' at times limited ability, or maybe ability, to solve one problem at the time, constantly moving forward with the goal of never going backwards. I see a lot of similarities between this text and my own case. As the salmons became domesticated by Norwegian fish farms, an avalanche of unsustainable externalities followed (Sætre & Østli, 2021). Lien (2017) looks at the externalities when tackling externalities. In order to handle the problem of sea lice within the net-pens, the species wrasse becomes domesticated on an industrial scale due to their lice-eating abilities. Not only does this new actor require the fish-farmer to adjust his behaviour and the material surroundings of the net-pens to accommodate the new actor, but it also comes with a set of their own problems. The wrasse was overfished, having to be carried with trucks over vast distances, wrasse eventually became the second most farmed fish in Norway. In order to feed the wrasse in its infant stage shrimp had to be sourced from across the globe which again created new relationships, and so it went, with new, unexpected, relationships and consequences being created at every turn.

What does Norwegian salmon and Indian paddy residue have in common? In my report, you will see from early on that the green revolution has been a human centric approach that came with what has become an unwanted externality, namely the residue. The process we are in now, where the future-makers are enrolling their assemblage in order to fix this, can be seen as the wrasse attempt to solve the problem of lice in the net-ponds. The consequences of the wrasse introduction, that is what is the scope of this report to unveil.

2.4 Conceptualising soil

During my interaction with the different assemblages, I was increasingly made aware of how soils can be enrolled to perform, or not perform, different tasks depending on which assemblage that the specific soil had been enrolled in to manage its residue. Through this interest I was also made aware of the importance of not neglecting soils. My interest was at first driven more of curiosity, then an actual motivation for including it in my report. It was only through the readings of the historical oversight of soil science by Granjou and Meulemans (2023) I was opened up towards the many role's soils have performed throughout history. Bellacasa (2015) showed me the modernist human habit of neglecting soils. This section will show how I conceptualise soils, and the different legitimate manners that soil can be conceptualised by other actors. These insights concerning soil will be used in the discussion regarding research question 2 and 3 in order to understand which regimes of thought the different soils exists under in the respective regimes. This is pivotal in order to render the power structures that produces and reproduces the soils off Punjab, and to understand how certain unsustainable performances and associations are allowed to exist.

First, for soils to become a point of interest for social science, it had to be rendered visible through the workings of other disciplines. Jenny (1941) introduced five factors that shape soil formation. Together with Anderson (1991) they introduced humans' role as a naturalised element with the ability to influence the five factors in different ways. Effland and Pouyat (1997) saw this as insufficient, claiming that human influence is significant enough by itself culminating in Dudal (2004) introducing humans as the sixth influence on soil formation. Historian Winiwarter (2014) make the case that agriculture has been changed with the development of chemical supplements like fertilizers and pesticides. Especially the development of the former has made *Liebig's law of the minimum* a possible reality that has become the hegemonic agricultural regime. This law reduces soil to a medium between the input and the output, where the yield is dependent on always having more nutrients than what is set as the bottom limit. The consequences existed in the land of unknown, since we had not yet mapped and understood the soils biota.

According to Granjou and Meulemans (2023), who are leaning on Paul and Frey's (2023) explanation of soil microbiology, ecology and biochemistry, this fields has recently developed devices capable of counting and understanding the roles of the previously obscured microbes. Through the readings made in the laboratory, soils have been enacted as something more than a one –dimensional source for extraction of resources for human consumption. This also opened up soils to be understood from the more-than-human approach developed by Haraway (1985). In Haraway's 2008 book *When species meet,* we get introduced to the complex entanglement of lives that constitute every living being, be it human or not. Through this she challenges the boundaries of what anything is, since nothing exists on its own, and everything is affected by anything.

Bellacasa (2015) makes the claim that ecology and biology has allied themselves with the result of becoming a voice of authority in a field previously dominated by physics and chemistry. This turn has brought the importance of the biotas in the soil to the forefront. She refers to Coleman et al (2004) who sees the soil as constituting all its living organisms. This is because any soil's properties would be different with a different assemblage within the biotas. This result in soil being alive through the interplay of its microbes, that should be seen as the soil and vice-versa. This is important for my report, because as we will see later, the microbes living under the soil are acting as the victim, the villain and the hero dependent on the framing and the actors that constitute its assemblage.

Soil can also change its meaning through purpose-altering. When soil is owned, it is land, or field as will be the preferred term in this report. Li (2014) uses ANT to explain how cash crops, fences, legal frameworks and the promise of prosperity changed communal land used to feed the local into capitalist entities rigged for global trade. Bellacasa (2015) would probably explain this as a change in hegemonic ideas so to say, towards *productivism,* a human centric approach. When soils have been colonised by productivism, what matters is the potential profit that can be extracted from the soil. Soil becomes industrialised, like a factory, where inputs-fertilizers, creates outputs-yields[8]. The multispecies world that constitutes the soil, either becomes invisible, without representation, or gets enrolled in a human centric yield enhancing scheme (ibid). This invisibility made Bellacasa (2013) conceptualise soil as a form of infrastructure, inspired

[8] She makes no direct mentioning of the law of the minimum, but from my understanding she is here explaining how the laws are still being performed and perceived as the most rationale way of farming.

by Star (1999) and Star and Ruhledger (1996)[9], which only becomes visible upon breakdown.

2.5 Summary theoretical chapter

I have now loaded the report with its theoretical tools that *have* been and *will* be utilised throughout the report. By *will*, I mean, that ANT and its terms will be actively used from the background chapter when it is relevant to bring forward a more-than-human actor that is relevant for the different assemblages. In the finding's chapters, ANT will be used to follow the actors methodologically through their doings. I will through this thinking explain the network and how it makes some things work. Care will emphasis a need for attention towards those mal side-effects that harms that which is not recognised, which will be understood through how care can be in tension and more concretely Callon's framework of framings and overflows where what is not accounted for initially becomes side-effects, good or bad. Soil science will be used throughout to complement our understanding of the rationale the different assemblages build on.

By *has*, I am referring to the blurred lines between method and theory when relying on a theoretical framework like ANT. This means I have brought the theoretical luggage with me since before entering my ethnographic field site of Punjab. These experiences will be a focal point in the coming chapter, methods.

[9] One critic I got from my fellow STS students when I said I wanted to include infrastructures within my theoretical framework was that Star's infrastructures is mainly referring to human made constructs. I said that might be so, before I reminded them of their modernistic boundaries and asked them, as I will ask you, to read my backgrounds chapter. There is nothing solely natural with the soils off Punjab.

3. Methods

The aim of this report is to understand the broader sustainability challenges that will be impacted in different directions, depending on which residue management assemblage that is performed. The other aim is to understand how the future-makers understand the consequences of their assemblage and draw attention towards the actors that are not recognised by the future-makers. To do this I needed to interact with the actors, and in the spirit of Latour (2007) allow them to guide me into the world, so that I could construct it through their own voices, and not filtered through other constructions of reality.

To do this just I conducted an ethnographical field trip to Punjab and New Delhi, India in the autumn of 2023 in order to get direct contact with the case, the people and the other actors that I was studying. Through my informants' guiding I have followed their statements into the documents. This has made documents an extension of my field site, where I have been able to dig deeper into that which was right in front of me.

My data collection resulted in 31 formal interviews, an extensive number of informal group discussions and interviews. Through participation and observation, I have lived side by side with my informants, working the fields and getting tangible insights into the problems that residue poses in today's Punjab.

In the following chapter I will explain how I have worked, from the humble beginnings in Oslo in January 2023, to the last phase of handling and analysing the data the field trip extracted, but also how I have handled ethical concerns.

Preparation phase 1:

In this section I will explain how I went by in order to identify an interesting topic for my master report, and the reflections I made concerning my approach to research questions and theory. This will include a reflection over how I have let ANT guide my inquires and focus while in the field.

3.1 Finding Case

Finding this report point of interest, the problems related to the RWS and more specifically how it manages its residue was not a linear process where an interesting case magically appeared in front of me to be studied. My *initial* interest was India, renewable energy and Norwegian development policies.

To find a relevant case for my report, I employed two methods. Initially, I searched online using keywords like "Norway," "India," "Renewable Energy," and "investment" to identify potential topics. Subsequently, I reached out via email to Norwegian institutions engaged in expanding renewable energy in India, which led me to the Norfund-SAEL investment, which triggered my interest towards the residue management problems in Punjab. The correspondence also connected me with CICERO, a Norwegian research institute, and their research project INDGREEN, focusing on India's climate negotiation roles and low-carbon development. Intrigued by my proposed case study "New associations in Punjab due to Norwegian investments," I joined the project. I then contacted Norfund to express my interest in studying their SAEL investment. A preliminary inquiry with a person involved in the investment helped refine my data collection strategy and define a viable case study (Yin, 2018).

3.2 Initial literature review and inductive approach towards research questions

I started with a loosely defined research question where I was to study the new associations that are formed on my field site in Punjab. When conducting research, one of the most essential components is to define your research question. In order to broaden my understanding of the topic, I did a literature review which I hoped would help me develop and define my research question (Yin, 2018). I used google and google scholar and searched for documents and prior research on the problem of residue handling. SAEL had prior to the Norfund investment applied for a loan from the Asian Development Bank and this process had produced a range of documents that I read to get an overview and understanding of the technology SAEL offered[10]. There had also been some public hearings related to their project[11]. Apart from that, I read news and scientific articles related to residue burning in Punjab, but also other energy projects in the global south where Norway had been involved. Keep in mind the SAEL-Norfund connection had just been announced, hence, there was a lack of documents related to the case, meaning there was an obvious research gap. Social scientist had also neglected the study of the relationship between energy infrastructure and residue management in Punjab. The closest I got was an article by Pandy and Sharma (2021) who relied on STS scholar Jasanoff's framework of sociotechnical imaginaries. They examined how public participation influenced the green transition in India and used a bioethanol plant that relied on paddy residue in Punjab as one of their case studies, but this was outside of my interest.

From my reading it was clear that I had the potential to close a research gap, but I was not able to shape a research question. This, combined with the uncertainty concerning what sort of access I would get in Punjab, I chose to have an inductive approach towards my research question, where I should let the data, I gathered shape my research inquiry (Azungah, 2018). This offered more freedom to discard previous ideas if they were proven irrelevant and follow new trails. Also, with a pre-determined research question, I would have to force my data through its filter in order for it to be answerable, this I found to be in conflict with Latour's (2007) sociology of associations method, where I should let the actors lead the way. O'Reilly (2005, p.98) said:

---

[10]https://www.adb.org/projects/56276-001/main
[11] One example: https://ppcb.punjab.gov.in/sites/default/files/documents/PHSukhbirAgroFZR(Eng)18.10.2018.pdf

"...ethnographic research is iterative-inductive, moving back and forth between foreshadowed problems and theory grounded in data, and does not usually decide exactly what the focus of research is until near the end".

I found the flexibility that an inductive approach gave me to be one of the most influential choices taken in the preparation phase. As you probably have understood by my introduction and theoretical framework, major changes have occurred since the pre-set. The SAEL-Norfund investment, which was supposed to be the key actors in the story have to share the spotlight with other future-makers, while the renewable energy aspect has been reduced to being one of several actors within the ex-situ assemblage.
Still, I cannot claim full inductiveness. ANT had early on appeared as a relevant theory. In ANT the boundaries between theory and methods are blurry (Michael, 2017). ANT requires a special attentiveness to the more-than-human actors that constitutes the assemblages of interest (Latour, 2007). To apply it justifiably theoretically after fieldwork, I needed to include ANT thinking from the get-go. This has shaped my inquires, as you will see in my empirical findings section, I have been keenly interested in the empirical workings of all the actors, living and non-living that constitute the fields in a way I probably would not have been had I not been under the influence of ANT.
This has created a classical chicken and the egg paradox. I have let my data shape the research inquiry, but my data is no doubt shaped by the influence ANT has had over the way I have conducted my research. As Fortun (2009, p. 168) said: *Form dictates content.*

3.3 Choosing method

Method and research question is usually tightly connected, and some methods are more suitable for certain research questions than others. Since I am, as I show in the previous section, examining a case in the making with little theoretical or empirical material to lean on, a case study became an obvious entrance to the field for me. In a case study, one aims to make in-depth meaning of what one studies. The interrogative word you put in front of what you are inquiring, like w*hat*, *who and which*, could be an indicator of the method that is most appropriate. I have since the beginning leaned towards an explorative overarching "what", where I seek to understand the consequences of the implementation of the three different assemblages. With this explorative approach, any sort of method is applicable, and one should lean on an array of them in order to get the in-depth understanding one seeks in a case study (Yin, 2018).

There were two methods that stood out as most relevant for examining the new associations that were being enrolled in and from Punjab following the attention residue management had been gaining. The first being ethnography, and an array of tools that comes with this approach, so that I could be able to extract data that was not available for me to access any other way (Hammersley & Atkinson, 2007). The second method is documents analyses to draw from already existing knowledges and claims. I find them to be complementary. Through fieldwork I met the people and the more-than-human actors constituting the RWS, they showed me their perspectives, and opened up for new information and epistemologies I was not aware existed. By following their claims through documents, documents became an extension of the field site, that allowed me to understand better how, for example, the soil that I had been standing on functioned.

3.4 Document work

In this section I will present how I worked with documents, and the different difficulties I encountered during my work with documents. These difficulties are also arguments for why I had to travel to India. I will then present how I used documents as an extension of my fieldwork.

When preparing for my fieldwork, I tried to have a practice-oriented mindset towards the documents. With this approach one tries to follow the work of the documents, to see how a document is worked with, and which realities it helps to create. It is another offspring of ANT, where non-living things, in this case documents, is ascribed agency (Asdal & Reinertsen, 2022). One problem I have encountered with too much reliance on documents was the lack of relevant documents that has been produced and distributed concerning the different assemblages that exist in Punjab. When it comes to this report initial scope, the Norfund-SAEL investment, the documents are limited to a few public press releases and was not sufficient for an interesting and relevant master report[12]. Also, I have found the art of seeking out public documents to be at times a frustrating and impossible task in India. With often non-existing, overwhelming, and contracting, or poor-quality data documents circulating[13].

Another point against solely utilizing documents as method is that my research is concerning the actors that are not recognised, hence, the belief would be that they have little textual representation. I have later found that most of the aspects I have been introduced to have had some sort of textual heritage, but in order for me to find them, I would have had to be all-knowing, with the world's knowledge in front of me for the picking. During my fieldwork I have found that the knowledge one person holds concerning the different issues in the RWS and future-making processes are very much bound up to their situation knowledge, with little extension across epistemologies.

By engaging with and letting these actors guide me, I was introduced to and sought out this textual heritage. I have tried to visualize the *documents as sites*, as envisioned by Asdal and Reinertsen (2022). I believe in ways the documents, by describing concretely what the soil consists of helped me to visit that which was formerly invisible, in ways giving me a livelier experience with certain sites that I was not trained to see prior.

A second tool I have brought with me from Asdal and Reinertsen (2022) is that of *document works*. I have used it when reading the few documents that are produced regarding SAEL, and how different numbers gets places and how they are presented. For example, in section 8.6 I will discuss how water extraction gets presented as a question of permits and how standards within the report form force SAEL to address this issue, which they do in a “smooth” manner. I have also focused on the practical work that are behind different scientific claims within the documents. The result of science is in many ways defined by practices (Latour & Woolgart, 1986). For example, within soil science what one measures when defining healthy soil is connected to your academic background (Bellacasa, 2015). This insight I have tried to use when being sceptical of articles. I cannot claim to have enough natural scientific insight to deem which methods are valid or not, but what I aspired to is to understand the background of the authors, both academically, but also which institutions they represent. Through this I have been

[12] https://www.norfund.no/investment/sael/

[13] This is one example of the quality of public documents you might encounter. The mw generated by each energy source by far exceeds the grand total.
https://cea.nic.in/wp-content/uploads/installed/2024/01/IC_Jan_2024_allocation_wise-1.pdf

better equipped at unveiling their situated knowledge, and also to understand the reasoning of my informants.

Documents helped me extend and enrich my fieldwork; Documents have been a medium which has helped me broaden the information I interacted with. This has been essential for my deeper understanding of the different aspects, and especially to understand the potentially detrimental consequences of the different assemblages.

3.5 Doing Ethnography

In the section that follows I will explain how I went by to conduct the fieldwork, and how I was able to get access to the different fields. I will put structure over chronological order. My reasoning is that I have been at multiple sites, and relying on multiple gatekeepers, informants and other sources of data gathering and trying to present this in a chronological order would take space and lead me into repetitions. Also, relying on such a vast array of data points have brought me into just as many situations where I have had to take active choices on how to overcome the different obstacles and opportunities I have faced. Hammersley and Atkinson (2007) notes that ethnography is an active process in where there are also active choices regarding what to include and what to observe, much more shaped by me and this process will be given transparency in the following chapter. Traditional ethnographic ethos would ideally present the data speaking through the conceived perspective of the informants with whom you have shared your time. Contemporary ethnographers, where I include myself, recognise that it is hard to free yourself completely from your predisposed biases and that the knowledge I have acquired has been processed and moulded by my situated knowledge (Haraway, 1988; Barone, 2020). This has allowed me to experience things for the first time, before things become familiar (O'Reilly, 2005).

3.5.1 Preparation phase 2: Finding location and aspiring access

The second phase of preparation, after finding the case, was related to more practical aspects of conducting fieldwork. Where, when, who and how to gain access. I had the notion that the phenomena I wanted to study, the loosely defined, ethnocentric research question "*relationships that emerges in the wake of Norway's investments into SAEL",* needed me to visit multiple sites that would be relevant for my study (Skilbrei, 2021). I landed in New Delhi on the 20th of September with a flight back the 13th of December, a perfect timing for experiencing the burning season that starts in October (Gupta, 2019). This might not be sufficient time in order to "become part of the background" and get the native view (O'Reilly, 2005; Russel, 2011) which meant I had to be efficient and focused on scheduling my time in India.

3.5.2 Planning my fieldwork

The first thing I did was to find the locations where SAEL had waste to energy operations. Through google maps I acceded the reviews that were written about the power plant. This I did in order to attempt an online ethnographic study, to get a better overview of the public opinions and controversies regarding the field site (Fielding, Lee & Blank, 2017).

I tried contacting SAEL through writing e-mails to people I found on LinkedIn[14], google, and an informant that showed me a print screen of an e-mail with the e-mail addresses of several people working at SAEL. I also wrote to two Indian professors connected to

[14] A social medium focused on professional relationships.

INDGREEN, who had mentioned the prospect of setting me up with an interpreter. Furthermore, I tried to contact two NGOs that I encountered through my reading of Indian newspaper articles regarding stubble burning. No one answered.

3.5.3 Going to the fields

After arriving in Delhi, I took the train to the city I had identified as suitable for the scope of my research at the time: Bathinda, a city/district in Punjab with a SAEL power plant in near proximity (SAEL, 2024). Bathinda district had more than 1.3 million inhabitants and 313 villages connected to it in 2011 (Government of Punjab-Bathinda,2024).
My hotel in Bathinda was located at the outskirts of the city in what is referred to as a market, a parking lot surrounded by commercial buildings[15]. Here I got to experience an in-medias-res beginning of the perils and opportunities that can appear during fieldwork. Short story shorter, two minutes after my arrival to Bathinda I came across three friendly, and one angry intoxicated person. The angry person tried to attack me, while his friends restrained him. This got the attention of some boys that were running two hotels and restaurants next door. I joined one of them into the hotel while the situation settled. This interaction turned into the friendly sort. The following day we had a dinner party in one of their restaurants. They all belonged to the Jat-community, the main landowners and farmers in Punjab (Jodhka, 2023). They had all been raised on farms which made them ideal for my research. They decided, or probably the famous Sikh-hospitality doctrine where the guest should be treated as a higher being (Chidanandjee, 2009), to help me attain the information I was seeking. For me, it felt like I had been bestowed upon by what Rock (2014) called a "fairy god mother", that was willing to use their time and resources to aid me in my research.

3.5.3.1 Gaining access and gatekeepers

While all of them provided me with interesting conversations, one of them took a more active role as a gatekeeper. A gatekeeper is a person that can help you to gain access and acceptance among a group of people you believe is interesting to acquire information from to investigate your topic of interest. They can be important figures in their own community, but they could also be people with a specific interest and curiosity in the topic (O'Reilly, 2005). During my time in Punjab, I mainly relied on four people that were vital for me to get access to the field and that worked as gatekeepers. Doing qualitative research, you let a smaller representative of people talk for the wider community or section of society they represent (Hay & Cope, 2021). A possible pitfall of being too reliant on gatekeepers is that you are certain to be influenced, or limited by the network that you are presented to, being "mislead" to believe that this is the only truth that exists (Hammersley & Atkinson, 2007). My gatekeepers, as you will see came from different backgrounds, brought with them different perspectives, and also introduced me to different sets of informants. This plurality in opinions I believe to be one of the greatest's strengths of this report.

The previously mentioned gatekeeper was a farmer's son from the Jat-community. He mainly introduced to me to other Jat-farmers and their families and friends. In order to maintain this relationship, I had to pose for a lot of family pictures, and it demanded a lot of social energy. Both in our day-to-day relationship, but also during interviews where there was often four or five family members present at all times. As O'Reilly (2005) states,

[15] Different western inspired restaurants and hotels that I would find later was mainly frequented by unmarried couples and "couples".

access is not something you get once and then you are in but demands constant maintenance. During every interaction I aimed for presenting myself in a manner that would not make people refrain from introducing me to their wider network.

The second influential gatekeeper was the headmaster of a local IELTS-School I volunteered at[16]. He was a well-connected person in the community. I was introduced to him through conversing with the students outside of the school. This relationship was a trade-off between me providing my time and English speaking skills for teaching a couple of lessons a day in a subject called "spoken English" in exchange for him introducing me to different farmers in the evenings. He introduced me to progressive farmers that were seeking an array of solutions to handle the paddy residue in order to avoid burning.

The third gatekeeper, I only interacted with digitally. I was introduced to him through an associate that worked for a company representing a significant portion of India's paddy export. The gatekeeper was the Chief of sustainability in this company. I had one interview with him before he would introduce me to farmers that were doing a mix between in-situ and ex-situ and a scientist that had worked on developing a decomposer to active the fungus in relation to the in-situ assemblage.

The fourth gatekeeper was living in Jalandhar. I was introduced to him through Erlend Simensen, my seminar leader in a subject related to renewable energy at UiO. The gatekeeper had a deep interest in agriculture and everything sustainable and his motivation for aiding me was to make the world one step closer to find a solution to the residue burning practice, according to himself. He was equipped with a righteous entitlement towards the public sector due to his role as a taxpayer. This meant that he was maybe not that much of a gatekeeper, but more of a gentle battering ram. He would arrange meetings and stage interviews through contacting several of the branches at Punjab Agricultural University, and Jalandhar agricultural department. He also introduced me to a progressive farmer (informant 11). Through this introduction the snowball effect came into play, where one informant leads to another (Hay, 2021). He introduced me to the farmers that had taught him how to handle his residue, but also people that were working the land and hence had a closer day-to-day relationship with the soil and the residue.

I eventually got access to SAEL and two people representing an investor. This was done through persistent e-mailing and was helpful to both get descriptions of how SAELs ex-situ assemblage worked, but also to understand their interests and see what falls inside and outside of their frame.

3.5.4 Interviews

In order to systematically capture data concerning the RWS and residue management while I was in the fields, I conducted a total of 31 interviews. I have included a list over the informants in Appendix B. I will use their assigned number to identify them when presenting my empirical material[17]. Every interview started with me introducing myself and topic of research. I then informed the informant(s) that if they chose to participate it would be anonymous, only being identified with their position and relation towards the

[16] This is English schools named after the International English Language Testin System (IELTS). The sole purpose is to give the students sufficient skills to pass the test so that it can help them migrate, preferably to Canada. They are everywhere in Punjab.

[17] I change between referring to it as" interview 5" meaning there was several people present at the interview and "Informant 11", meaning there was only one person present in the findings section.

RWS and the future-makers assemblages. I then made them aware if they at any point would wish to withdraw their statement, they could contact the gatekeeper that had made the introduction. I would conclude the introductory pitch by asking for permission to record the conversation.

There are mainly three forms of interviews when doing qualitative research, as explained by Thagaard (2018) which I will rely on in this section. The most rigid one is called *structured interviews*, where one follows in orderly fashion a list of prepared questions. This method can be useful if the researcher is sure of the topic of inquiry and gives the researcher the possibility of comparing the different answers that are given. Due to the variety in backgrounds, uncertainties regarding what I was actually researching at times, and as I also would find out, the control I at times would lose in interview settings due to interpreters with a will of their own, made this approach unsuitable for me. Instead, my report is based mainly on the *semi-structed interview* approach, but also a few interviews that for a variety of reasons are *unstructured interviews*.

In unstructured interviews, one is talking about an overarching theme, in my case residue management and the RWS. There were four interviews that ended up like this. Interview 2, the first farmer I interviewed was intentionally done in this manner so that he could speak freely, working as a preliminary inquiry that could introduce me to aspects, I was not yet aware off. Interviews 4, 27 and 28 were also unstructured, due to it being ad-hoc opportunities with new types of actors.

The remaining interviews were done with the semi-structured approach. Here I had prepared some questions or themes that I wanted to touch upon throughout the interview. The order they appeared would be more fluid, depending on which way the interview went. With this approach, informants could bring up topics that stayed outside of my frame, which I could chose to pursuit if they seemed of interest. This approach was suitable for me as it showed me things outside of my initial frame while I was still able to hold it relevant towards the RWS.

3.5.5 Informal and group Interviews

It was not a rare incidence that I conducted informal interviews. They became a daily activity inside the cafeteria in Bathinda since there was always people coming and going. What they all had in common was that they belonged to the Jat-caste and had been raised on farms before seeking urban happiness. Skillbrei (2019) sees this as an opportunity to understand the dynamic of meaning production and knowledge distribution. The Jat-sons often had homogenous opinions but every now and then someone would stand their ground advocating for a more sustainable future.

Skillbrei (2019) also explains how your role during group interview settings changes from an interviewer to a moderator. This was sometimes challenging in these settings, but I had more luck as a moderator when I came with the pre-defined role as teacher at the IELTS-schools. The purpose of the classes was to practice spoken English, and I was free to choose the topics. We would often find ourselves discussing different aspects of sustainability, and since most came from farming backgrounds, there was a lot of knowledge to tap into here. Due to ethical concerns, I did not take notes, and it has not been used actively in this report, but as Hammersley & Atkinson (2008) said, your experiences become part of your tacit knowledge, and I am sure these discussions have contributed to shape my report.

3.5.6 Working with interpreters

Russel (2011) states that it is beneficial to learn the language while in the field. I aspired to do this with limited success. My glossaries helped present me as a charming young man that I am sure eased people up to me, but I would still be reliant on an interpreter to conduct the interviews. A problem I faced here was that especially gatekeeper 1 and 4 at times would lead or display questions in certain manners that would influence the informant. Thagaard (2018) emphasises the need to ask open questions. One reason is that by not asking open questions the interview would be framed by the researcher, guiding the questions and not encourage the informant to bring new information forth. I aspired to live close to this creed and was able to do so in the interviews where I was not reliant on an interpreter. I talked with gatekeeper 1 and 4 in order to change their way, and gatekeeper 4 was able to adapt, with only occasional backlashes to his former sins. Gatekeeper 1 was living inside an echo chamber with the informants he was introducing me to, hence, I am not sure it would have made much difference if he nudged them or not.

Another problem I faced with gatekeeper 1 and 4 is how they would sometimes be reluctant to ask questions that I asked them to ask, with the reply "This we already know". Being faced with this I had to have a conversation that we were not in the business of findings truths, but rather opinions, and opinions can divert.

A third problem I faced, especially with gatekeeper 4 was how the answers would at times be coated with his own opinions or be given back to me with examples that had not initially been conveyed by the informant. We had spent enough time for me to know his talking points and I would filter out his opinions during the transcription of the interviews. This behaviour he had no problem adjusting after I brought it up and told him I could not use the data from the specific situations.

3.6 Participation and observation

In addition to formal interviews and more informal group interviews, a vital part of the data I collected during my fieldwork was based on participant observation in the daily lives of my interlocutors. A lot of the adaptations I have mentioned earlier is just as vital for this segment of my data collection, hence they are valid. According to O'Reilly (2005) the goal here is to partake in the daily lives, doing what they are doing. I attended the parties, family dinners, the "gerries" which means meaningless driving from cafeteria to cafeteria, hanging around doing nothing, but also working the fields, driving tractors, combines, burning residue etc. This will not be so present in my empirical findings but was important to gain the access to the informants, and especially the farmwork I did have given me a more tangible insight into the things the farmers addressed during the interviews, seeing but also doing the performative process of two assemblages, incinerating and in-situ [18].

3.6.1 Taking notes

Fieldnotes is the connection the researcher creates between the field site and his or her future self. It is important to write in a way that enables you to identify the place, concern and people that are pivotal to be involved according to Hammersley & Atkinson (2007). On page 142 they emphasise the need for good field notes:

---

[18] See appendix A for pictures.

"A research project can be as well organized and as theoretically sophisticated as you like, but with inadequate note-taking the exercise could be like using an expensive camera with poor quality film. In both cases, the resolution will prove unsatisfactory, and the results will be poor. Only foggy pictures result".

With this in mind, I tried writing holistic and inclusive notes on my phone and sometimes as voice or video recordings. In the beginning, with the uncertainty around my research topic, I had a hard time limiting myself and wrote extensively. During my first week there I re-read O'Reilly (2005) who testified to this symptom of uncertainty and reassured me that as the fieldwork progress and my knowledge and focus gets sharpened, so to would my fieldnotes. Rightly so, and I could see me moving away from the surface, down into how the soil would react during different regimes for example.

Blinkman, Kvale and Flick (2018) emphasise the importance of taking notes during and right after interviews to capture the non-verbal communication that would not be prominent in the transcription of the interview. I tried to do this as soon as I could after interviews in order to capture my initial impressions of the interview.

3.7 Working with the data

Of the 31 interviews, 24 interviews have been recorded with an average run time of 57 minutes. Out of these 24 I chose to transcribe 18. Six interviews were not transcribed because the information that was conveyed was not of interest to my research.
In the seven interviews that were not recorded, notes were taken. In two incidents the reason there was not made a recording was due to technical limitations with the interview being conducted through the social media app WhatsApp, while I was in noisy environments, meaning having them on speaker would not be feasible. In the remaining interviews recording was not made to respect the wishes of my informants.

3.7.1 Data handling

I have concluded that the data material that I work with is classified as yellow, meaning somewhat restricted in accordance with the guidelines provided by UIOs guidelines for data classification (2023). Due to this classification, I had to avoid storing the data on my personal devices for too long. I have stored the collected data on UiOs OneDrive service provided by Microsoft which is in accordance with UiOs data storage guidelines (2023). I have used UiOs Autotekst, powered by the program Whisper, provided by OpenAI to transcribe the interviews[19]. The transcriptions upon completion have been uploaded to OneDrive. From here I would go through the transcriptions, sorting the text in accordance with voices, only identified with pre-determined letters in order to ensure anonymity.

3.7.2 Processing the material

Processing my collected data has been a continuous process. When the scope of my research altered, or new perspectives entered my frame, so did the need to revisit and re-code my material, meaning it was a dynamic process. I am working with qualitative data. This method produces heaps of raw unstructured text (Basit, 2003). For the data to

[19] https://autotekst.uio.no/nb

yield meaning, I needed to systematically work with the material, extracting the pieces of opinion and information, putting it into themes to construct a pattern of sense and coherency (Bogdan & Biklen, 1997; Dey, 2003; Patton, 2005).

I had to revisit my raw data on several occasions, reading through the text, and in line with Latour's (2007) thinking, allow the actors to continuously speak for themselves and guide me. This process made me attentive to new aspects of my data material and opened up for nuances that were not recognised on my first or second read through. On several occasions I found the data to surprise me long after I had visited it the first time.

I started the initial coding at the first readthrough performed in the wake of getting the transcription of the interview from Autotekst. I would use the marker-function in word to prescribe their statements into different themes like money, sustainability etc. I would also leave comments where I would write down similarities or conflicts with other interviews, but also try to apply theory, writing which theory I found this to be applicable for with a short justification. Through this I got to see my data from more angels.

3.8 Ethics

My first ethical consideration started in the preparation phase when dealing with documents and articles. Said (2003) explains how the western lore of the "the east" is constantly being reproduced through an academic tradition that stands on the shoulders of the same giants. He explains the perils for a western researcher when having the first encounter with a location one is bound to visit through literature, where one can be blind to the nuances that exist on the field site and tries to confirm what the researcher already knows. In my case, focusing on farming and Punjab, the recent literature is "dominated" by farmers' suicide and economic distress (Kumar & Sharma, 1998; Gill, 2005; Kaur, Sharma & Garg, 2016; Ramakumar, 2023). I am not denying that this is a reality that many faces, but I would not deem it the most characteristic traits of Punjab either. Coming from Development studies, the direct descendent of the orientalism Said strongly criticises, I was keen on avoiding this mistake. I read multiple sources, but also by immersing myself in their culture through watching Punjabi movies and listening to their music, I was able to get a more nuanced picture of the proud history and culture of Punjab. Also, in the backgrounds chapter, I will explain different segments of the RWS and its consequences through literature. This literature is there mainly for giving me ethos and reliability, but it is all based on qualitative experiences. All the literature and documents I have included in the findings chapter is a result of the informants guiding me. This means, I did not use empirical observations to confirm literature, but rather literature to confirm empirical observations.

3.8.1 Ethics in the field

Before going to the field, I applied for an approval to collect data through qualitative interviews with SIKT, the Norwegian government's organ for handling applications concerning data storage and research (SIKT, 2023). SIKT approved my research. When in the fields I have kept the guidelines from the National Committee for Research Ethics in Social Sciences and the Humanities (2023) close at heart. I have already mentioned how permission was sought and how information was conveyed in section 3.5.4. At times, again the usual suspect gatekeeper 1 and 4 would be reluctant to ask for permission. Gatekeeper 1 would feel awkward at times, due to the power relation when interviewing his elders in the family. The two times he did not want to ask for permission, the interview situation instead turned into casual conversations. Gatekeeper 4 had more a nonchalant approach towards asking for permission, claiming it would hamper our possibility of gaining access, but he would always ask, and permission was always given.

Another place I had doubts about permission was when observing. I did not have the capacity, nor the language skills, to ask permission from everyone at times. This was especially prevalent when I was taking notes of people working the fields, they usually belong to the scheduled castes[20] and did not speak English. I would always interact and socialise and make myself known, but I am not sure if my motivations were adequately conveyed. When writing up my report, I have not found any need to include these interactions in the final product, hence, I believe my ethics are still in order. How I stored data as shown in section 3.6.1 is also part of the ethical considerations made during this research process.

3.9 Self-reflection

Since I conducted research in an unfamiliar place, I also need to recognise that I was exotic in some ways in rural Punjab, and that influenced the access I gained. Russel (2011) writes on access in relation to gender, and how male and female researcher will be able to access different sets of informants. This was true for me. In Punjab, my experience was that girls were overtly shy, and were often absent from public space[21]. The only females I interacted with were the mothers of my friends, which were seen as not suitable to interview, and a few of my students which I of ethical concerns was not comfortable interviewing. This means, there is a lack of female perspectives within this report. This I do not think influences the research in a significant way. Farming in Punjab is a very male dominant occupation, and the scope of my report is related towards the residue management assemblages, performed by male farmers. This means, the perspectives I was seeking existed mainly within male farmers.

I also believe that in some ways my skin colour can have contributed to the access I gained. As mentioned earlier, Punjabis' hospitality is famous (Chidanandjee, 2009), but I still believe I was treated differently, especially in Bathinda. I was introduced to the extended families, when we visited their home villages we would drive from house to house, making me at time feel like a prop, but this process was key to introduce me to new farmers. When it came to the government offices I visited in Jalandhar through gatekeeper 4, I do not believe we would have gained that access if he had not introduced me as a researcher from Europe.

Russel (2011) also writes on how age can determine access, and I believe the friendship I developed with the "Bathinda-boys" would not have materialised if I was 10 years older. Even though we did not share many interests (apart from farming in Punjab), we found community in our shared youth (and probably gender).

3.10 Summary

Through this chapter I have shown how I have aspired through all my choices to ensure that the data I produce is not only "pure", but also ethical. The data collection was conducted in Punjab in autumn, with a combination of ethnographic research and document works. The focus has been on farmers and other actors that work with different assemblages that try to solve the residue problem of the RWS. The data collected has been handled correctly

[20] Scheduled castes refer to the castes that are seen as the lowest castes in Indian society (Dushkin, 1967).
[21] Women's participation in the workforce is 9.2% below the national average, with 17.9% of women working in rural Punjab, with 15.4% in urban Punjab (IWWAGE, 2023

4. Background

In this section, I will outline the recent history that led up to the situation RWS is in today. Demarcation in time and scope is challenging in this chapter but being influenced by the sociology of associations (Latour, 2007), I will begin by explaining some lines I have drawn.

Punjab has for a long time been an agricultural state. The caste Jats, who are the main landowners in Punjab (Javid, 2011), will have a significant place in this report. Their introduction to Punjab in the late medieval ages (Nijjar, 2008) could be a relevant historical starting point, but I considered it sufficient to inform about their tight historical and cultural connection with the land (Javid, 2011). The partition of India and Pakistan 1947 and its aftermath are also relevant points of departure, violently splitting the historical Punjab into three different parts between two countries had big demographic consequences[22] (Hill et al, 2008).

The Sikhs, who is the main religious identity of the Jats in Punjab, were always a minority in Punjab (Krishan, 2004) and their hope of being a political entity was scattered. It became clear from my interaction with the Punjabis that this was a historical trauma that shaped contemporary Punjab, but the scope of this report would leave it to inform you of its occurrence without going into detail.

I have chosen the historical starting point to be right before the green revolution. In this historical moment, radical changes introduced an array of new actors that are still dominant today. And here comes my second demarcation – that of width. All these actors are entangled in an array of different actors, assemblages of their own before being black boxed as a nod within the RWS. Some of the actors will remain black-boxed. I will still introduce them, but the focus will be on those actors that are impacted and will be further impacted depending on the biomass solution applied.

I will start by introducing the human made choices and reasoning that preluded and solidified the RWS from its early days. I will quickly explain the motivation and climate

[22] Haryana, another state in India, had earlier been part of Punjab, and through my research I met many people that had families going back for decades in Haryana, but would still identify as Punjabis, and spoke Punjabi.

that the green revolution spurred out from, and how this shaped the relationships between the farmers and their soil. These perceptions and ideas still exist today among Punjab' farmers. Through this historical walkthrough of the green revolution that will lead up to the supreme court ruling of 2019 where incineration was outlawed, we will get an understanding of the sustainability issues that the RWS faces today. The initial focus will be on explaining and showing the different technologies and human choices that lead to the massive amount of paddy residue. The same associations are also responsible for many of the other problems the RWS faces that will also be highlighted. This includes fertilizer usage, GHG emissions, soil and water depletion and the energy situation in Punjab. All aspects that will be impacted in different ways depending on which assemblage that are managing the residue. Through exploring these aspects, the foundation will be laid in order to understand what is at stake in Punjab and discuss how the different assemblages deal with the wider problems of the RWS.

4.1 The Green Revolution

In the wake of independence in 1947, the Indian population found itself using the same traditional farming equipment that was used at the time of colonization. With decreasing crop yields the first years after independence, agricultural development was the focus of India's first five-year plan from 1951-1956. With positive results, potentially due to external factors created by generous monsoon seasons, the next five-year plan saw its focus directed towards industrialization, hence neglecting agriculture. With a growing population and stagnating agriculture, the country was on the brink of famine in the early 1960's. One big contribution to India avoiding famine was significant shipments of cereal from the USA. India sought to free itself from its dependency on foreign aid and become self-sufficient (Parayil, 1992 This need came simultaneously with the American doctor named Borlaug, deemed the father of the green revolution, ground-breaking research and development of the HYV-seeds in Mexico in cooperation with the Rockefeller Foundation (Sandhu, 2014). This knowledge was disbursed from the lab to around the world with the help of the Ford Foundation (Patel, 2012). The Ford Foundation can be said to have been key actor in the establishment of the RWS and as I will now show, a future-maker. The first trace I have found of the Ford Foundation interacting with the agricultural sector was in 1952 when they, in cooperation with the national government, launched the failed *Community Development Project* were fertilizer production sites and other essential components in modern agriculture were going to be developed in symbioses with heavy industries, framed as "temples of modern India". This project was not seen as viable for scale and was discontinued in 1959 (Frankel, 1971).

In 1961 the Ford Foundation sat up the *Intensive Agricultural Development Program* which came with a variety of incentives for increasing yield through new technological adaptations. Fertilizers and seeds were given at subsidised prices to farmers. To introduce more machinery, the Ford Foundation co-operated with commercial banks to provide cheap credit to farmers. The Ford Foundation continued and intensified the process of domesticating the water into an efficient irrigation infrastructure[23]. The Ford Foundation also encouraged the government to set up a functional marketplace, where the farmers could sell their crops at a predictable price, which culminated in the mandis system, which was the spatial location to acquire the Minimum Support Price. The Minimum Support Price is a state backed minimum price on certain crops that creates a safety net for the farmers, meaning that they do not have to negotiate with larger

[23] As I will show later in section 4.6, human water infrastructures have a long history in Punjab.

enterprises alone. The benefit for the farmer is that they get instant cash, due to the institutional backing from government (Ramakumar, 2022). The farmer would here have a stable income where profit came on top, after calculating all expenses (Jodhka, 2023).

This being in the 60's, a time when science and scientists were held in high regard and the optimists concerning their potential was significant and there was a common belief science could solve all human made problems (Sisimondo, 2010). This paradigm was clear also in this case, with the establishment of a scientific community. In 1962, what I would claim is one of the most important mediators today within the RWS in Punjab was established, the Punjab Agricultural University, the future-maker that represents the in-situ assemblage in this report, in Ludhiana. Here, Borlaug and his team perfected the HVY-seeds brough from Mexico, making them more suitable for Punjab. At the same time, other departments at PAU produced and distributed farm equipment compatible with the HYV and suitable for Punjabi conditions (Sandhu, 2014). How much vital, widespread technology that was produced in-house at PAU was a surprise during my own data-collection.

Punjab was early on identified as an ideal location for increased crop yields according to Randhawa (1977). The reasons he mentions is the level of technological adaptation due to the human capital, potential to exploit the ground water, and farms being on average bigger than in the rest of India. The latter claim was verified by Singh et al (2017b), who found that bigger farms were more able to adapt to and utilise new technology, with the result of more efficient area use[24]. Technologies were rolled out in the fields of Punjab, with dramatic changes to the local and the global. First, the support for HYV helped eradicate traditional crops (Wolf, 1986; Nelson, Ravichandran & Antony, 2019). Shiva (1991) writes critically on the green revolution and how HYV seeds replaced traditional seeds. Traditional seeds were cultivated for generations, specialised for the soils of Punjab and had a more complex gene structure than its lab-constructed replacements. Traditional crops had been produced and distributed among farmers without the exchange of money, with the development and experimentation happening inside the farms. The support from private and institutional backers like the World Bank and the FF, made HYV become more attractive.

Another way the future-makers translated the farmers' interests to enrol them into the assemblage was through framing the HYV as something modern, in comparison to what was[25] referred to as traditional crops, that sounded more primitive. Shiva (1991) makes the claim that there was not really any difference between traditional and HVY's yield giving qualities. At the same time, it is important to remember that the yield increased drastically in the years after the introduction of the HYV (Corsi, 2006). However, modern seeds, like the HYV, do not necessarily produce higher yield, but they are more responsive to chemical inputs like fertilizers and pesticides compared to the traditional seeds (Bowonder, 1979; Winiwarter, 2014; Han et al, 2016). This meant that for the RWS to successfully stabilise influxes of chemicals was enrolled to its assemblage.

4.2 Fertilizer usage

Punjab is one of only two states in India that still increase the annual use of fertilizers and represents 6.7% of all fertilizer used in India (The Fertilizer association of India, 2023). I

[24] I found during my own data collection this to be not only because bigger farms had more money, meaning they could easier afford new technologies. Another factor that became clear, and makes sense, is that it gets exponentially more rationale to use technology the bigger farm you have.
[25] And still is I experienced during my fieldwork.

have found conflicting numbers regarding how much fertilizer is actually applied in Punjab. A report by the department of Agriculture, Punjab (2014) claimed 91.06 kg of chemical fertilizer is used per acre. This deviates from my other sources, another document by the same department (2012) recommends a total fertilizer usage of 296-206 kg per acre. This is close to the numbers I have been told by my informants where it varies between 4-5 bags of DAP and 1-2 bags of Urea, meaning its between 250-340 kg of fertilizer applied per acre (Interview 2, 11, 14, 29). This number is important because one of the assemblages we will examine, in-situ, puts a lot of emphasis on the fertilizer-saving aspect. The negative effects of the extensive fertilizer usage radiate in all directions. One way is down in the groundwater (covered in section 4.6), but it also brought with it high GHG emissions (Kharjuria, 2016). Menegat, Ledo and Tirado (2022) calculated the emissions for the whole supply chain of nitrogen fertilizers, where India is the world's 3rd biggest producer, and found it to represent 2.1% of all GHG emissions on the planet. Phosphorate and potassium are two other prevalent fertilizers that all come with their own sustainability issues.

4.3 Intensive Agriculture

The introduction of fertilizers meant that the relation between crop and soil fertility was altered, and Liebig's *Law of the minimum* could always be upheld through the input of chemical fertilizers (Winiwarter, 2014). I understand this as a move towards productivism, where the soil was altered to become a medium between input and output (Bellacasa, 2019). This thinking and technology opened the opportunity for an intensive cropping pattern that covers 83% of the geographical land of Punjab, or 5.20 million hectares (Department of Agriculture Punjab, 2011). This is divided into two seasons, where the RWS is the dominant cropping system[26]. The kharif-season, meaning autumn, is dedicated to paddy, while the rabi-season, spring, is reserved for wheat (Gupta et al, 2003). In 1960, on the eve of the GR, paddy was cultivated on 4.79% of all agricultural land in Punjab. In 2012 this number had increased to 35.62%. In the same timeframe wheat rose from 29.58% to 44.59% (Kumar, Kumar & Joshi, 2015). This has had several implications. The Indian Government reported in 2004 that the state of Punjab, that covers 1.5% of all Indian land, produced 22% off all its wheat, and 9% of all its paddy (In Jodhka, 2006).

Through the adoption of technologies and mechanisms inherent in globalism, such as trade deals and the increased mobility of goods and ideas (Shadlen, 2008; Castells, 2009), India has transitioned the RWS from traditional agricultural practices focused primarily on local sustenance to an agricultural model that leverages new technologies, capital, and regulations. This shift has not only aimed at feeding the nation (Dutta, 2012; Prasad, 2005), but has also positioned paddy as a significant cash crop for India, catering to a global market with a share of 24% (Kumar, 2019). This evolution reflects a broader movement away from solely local sustenance towards a strategy focused on maximizing national food security and extending India's influence on the global food market. This movement has positioned the soil of Punjab as a key actor that is doing its intermediating job at securing global food security[27].

[26] The remaining % of cultivated land is divided on Maize, barley, oil seeds, sugarcane according to the department of agriculture in Punjab (2011). My own observations would put potatoes as an important crop, but this could have been shaped by my diet and the fact that one of my main informants owned several cold stores where potatoes was stored, sorted and distributed.
[27] Punjab alone do not represent 24% of all global paddy export, but as the key provider of Indian rice to the central pool, it is clear Punjab is essential for making this a reality. This means, the collapse of the soil of Punjab would be felt far outside of its geographical place.

One implication of the RWS is the short rest time that is allowed between kharif and rabi. Since soil fertility, the most essential component within soil under productivism, can be stabilised with an influx of fertilizer (Winiwarter, 2014), there is no need to let the soil rest. For the RWS to become a reality, active performances have to reproduce the system every year. These performances need to occur in a limited timeframe of 7-20 days for the wheat or rice to yield its full potential. In this time the field needs to be harvested, cleared of biomass and the new crop needs to be sowed (Dutta et al, 2022). This means time is a scarce resource within the RWS.

A consequence of this demand was the need for a substantial amount of labour within a constrained timeframe. Punjab lacked—and continues to lack—a workforce readily available for three weeks twice a year. This discrepancy resulted in a labour shortage, which in turn led to increased salaries. Consequently, mechanical technologies, which were subsidised by the government at the time, became more attractive. Tractors became ever more common, but a more interesting new actor for this report is the combine harvester (Combine). In 1971 there was a total of 18 combines in Punjab (Aggarwal & Mishra, 1973). In 2019, the number of combines had reached more than 8000 (Dutta et al, 2022). What is the significance of this? I will first describe the traditional method, which is still practiced by the smaller farmers in Punjab to this day (My own notes).

The straw is manually cut all the way down at the soil level. It is then brought to a wooden board tilted 45 degrees where it is struck across several times to shake the monetized seeds of the straw. The extra power you get swinging a longer straw makes it rational to cut it all the way down- hence giving value to the whole straw. When the bunch of straws has released all the rice corn, the residue is already in your hand and hence is easier to manage[28].

The combine, made for modern intensive agriculture focus on the upper part of the residue where the monetized part of the paddy straw is located, the seeds. This method instantly discards everything else as waste, leaving 20-30 cm long stubble[29] still standing in the ground (Sidhu et al, 1998; Dutta et al, 2022). This takes us to the next step that needs to be handled to sow the rabi-crop, the residue management.

4.4 Biomass incineration

The combine leaves the farmer on average 3.2 tonnes of residue per hectare that needs to be dealt with annually (Sidhu & Beri, 2008) or 1.295 tonnes per acre[30]. This adds up to 19.7 million tonnes of paddy residue across Punjab annually, whereas approximately 15.4 million tonnes get incinerated (Gupta, 2019). So, what sort of issues do this practice of burning residue come with?

In their 2004 study, Gupta and colleagues discovered that incinerating one ton of material results in the emission of 1460 kilograms of CO_2, 60 kilograms of carbon, and 3 kilograms of particulate matter (PM). CO_2 is a greenhouse gas contributing to climate change (IPCC, 2007), whereas PM is dispersed through the air.

The distribution of PMs is particularly influenced by mild north-western winds, as identified by Singh and Kaskaoutis in 2014, causing the smog to accumulate over New

[28] What they did with it, I am not sure.
[29] Stubble is residue that is still attached to the ground. I decided on the word residue because it is more inclusive (Lyles & Allison, 1976).
[30] One hectare equals 2.471 acres. This thesis operates with acres due to the influence of my informants who would always give their land size in acres. Hectares I have only interacted with in the literature.

Delhi—a densely populated megacity with more than 28 million residents. The Air Quality Index (AQI) in New Delhi reached a peak of 487 in 2019, according to Abdurrahman et al (2020). My own field observations, and my associates in Delhi would on several occasions between November 2023 and January 2024 observe AQI reach beyond 500. For perspective, London's AQI on the morning of January 4th was reported at 27 (IQAIR, 2024). Beig et al (2019) reported that as much as 58% of New Delhi's PM originated from burning residue. Conversely, NASA's more conservative estimate on November 1, 2022, marked the onset of the burning season, attributing 14% of New Delhi's PM to this source, which remains substantial. Such pollution exerts a severe impact on public health in the city, elevating the risks of respiratory conditions and premature mortality (Gupta, Agarwal, & Mittal, 2016). Research from the University of Chicago in 2021 highlighted the dire implications for longevity, indicating a potential 13-year reduction in life expectancy should current AQI levels persist.

Beyond atmospheric effects, residue burning also detrimentally affects the soil, elevating temperatures to as high as 42.2°C *in the upper layers* (Gupta et al., 2004), which undermines the survival of essential soil microbes and bacteria (Dinel et al., 1996; Kumar et al., 2019). Singh and Singh (2003) claim that burning also depletes vital nutrients such as carbon, phosphorus, and potassium from the soil and residue, further compromising the land's fertility. This will be further discussed in section 8.4, but spoiler, burning releases some of the nutrients from the residue, meaning, the only nutrient depletion related to carbon, phosphorus and potassium comes from the residue, not the soil (Bodi et al, 2014). Still, it is interesting because these sorts of statements have been enacted as truths for the future-makers of the ex-situ assemblage.

4.5 Soil

One issue I encountered during my reading on Punjabi-soil is that of contradictions within science. As I explained in the soil theory section, there has been a shift in hegemonic disciplines within soil science (Bellacasa, 2015). Different disciplines have different parameters on how to examine soil health (Hartemink et al, 2010). Another aspect, as I mentioned of in section 2.4, is the historical link between soil science and the agrobusiness (Sigl, Falkenberg & Fochler, 2023). Still, there has been numerous Cassandras[31] reporting on the declining soil quality in Punjab (Duxbury, 2001; Kaur et al, 2005; Rawal, Ghirmire & Chalise, 2017).

The metrics for assessing the health and quality of soil is a subject for debate. According to Singh and Benbi (2016), healthy soil is determined by the availability of nutrients, the same nutrients that are added with fertilizers. They found that the soil health of Punjab was improving, no wonder with the fertilizer usage in Punjab. Another interesting finding from their article, they found a correlation between adverse soil health and the socioeconomic background of farmers, indicating that wealthier farmers had healthier soil than their less affluent counterparts. Scientists who interpret soil health differently, have drawn other conclusions. Khan et al (2018) observed a drop in pH levels in Punjab, leading to acidification in the soil when the nitrogenous fertilizers were added. This resulted in poorer soil quality due to mineral toxicity and a deficit in important minerals essential for the soil’s functioning.

Leaning on our understanding of soil from Bellacasa (2015) there is no real distinction between soil and its biota of microbes. Within one tablespoon of soil, you can find

[31] A Cassandra refers to a person that predicts negative effects or events without the surroundings being able to believe or adjust their behaviour (Ferguson, 2021)

billions of different bacteria, fungus and other microbes essential for the soil's functioning (Bellacasa, 2019). These are functions that can be beneficial for the farmers also. It regulates water and nutrient access to the plant and enhances the water retention ability of the soil (Srivastava, Sarkar & Nasre, 2015). Some microbes do not respond well to fertilizers. Sarathchandra et al (2001) surveyed a field that had been threaded with different sorts of fertilizers for years. Their study suggest that soil threated with urea, a nitrogenous fertilizer, had approximately the same total microbial level, but the complexity, or diversity, of the microbial community had decreased.

SOC is another indication for soil health. The disruption of modern agricultural techniques in uncultivated soil has been proven to negatively impact the soil structure due to the exploitation of the soils organic matter, which has detrimental consequences for SOC (Davidson & Ackerman, 1993; Paustian, Collins & Paul, 1997; Murty et al, 2002). The more intense agriculture, the heavier toll on SOC (Nieder & Benbi, 2008). Benbi et al (2015) found cultivated soil in Punjab to contain between 21-36% less carbon than uncultivated soil. The actual % of SOC in Punjab's agricultural soil is a conflicting topic but are usually in the lower tier range. A survey by Yadav, Sidhu & Thaman (2016) found SOC-level in the top layer of Punjabi to average a little under 0.5%. Sharma et al (2019) found 32% of SOC in Punjab to be lower than 0.4% and 57% to be in the range of 0.4-0.75%. Dhaliwal et al (2020) on the other hand found SOC to be as low as 0.27% in soil under a RWS regime. In comparison, Maryol & Lin (2015) did a survey in Fezzan, an area in the Sahara Desert(!) and found the carbon level to be around 0.7%. While FAO (2017) reported that the Sahara as a whole usually has less than 0.6% SOC in its soil[32]. King, Bradley & Harrison wrote in 2005 of the unsustainable state of SOC in British agriculture. The numbers are still high above what one would expect to see in Punjab with SOC ranging between 1.3-4%, depending on soil type. Put all this together, and it paints a picture of alarmingly low SOC levels in Punjab.

In general, most of the soil in Punjab is seeing a gradual degradation of its quality materialized through the insufficient levels of nutrients and microbial complexities, essential components for a functional soil (Sharma et al, 2016; Sarathchandra et al, 2001) and at this rate could lead to an agricultural collapse (Shiva, 1991, 2015). The intensive human activity of the soil has consequences for other vital actors needed in Punjab.

4.6 Water

According to Sonmez and Sonmez (2007), maximum 50% of the nitrogenous fertilizer introduced by humans was able to attach itself to the plant. Oenema et al (2005) did a study on excessive usage of fertilizers and found a significant portion to leak through the soil, into the groundwater. This process can degrade the quality of the water, with potential spill overs to surface water (Wang et al, 2015; Bachman, Krantz & Böhlke, 2002).

Water sustainability issues are not only tied to contamination from fertilizers, but also through overexploitation. Water is a key actor within the RWS-assemblage and its exploitation is seen as essential under today's regime. Traditional irrigation was to a larger degree reliant on weather, meaning its connection to suitable weather made it an unreliable actor (Sengupta, 1985). To make water reliable for the foreseeable future, water became domesticated. The first canal irrigation system in Punjab begun in the 16th

[32] In the map that are presented on the last page in this report: https://www.fao.org/3/I8195EN/i8195en.pdf things are put into perspective. Punjab is found in the north-western corner of India and the colour clearly deviates from its surroundings.

century by the Mughals, and was vastly expanded by the British (Singh, 1985). Today there are seven canal systems, with a total length of 14500 km, providing Punjab's agriculture with water (Department of Water Resources, 2024). With the introduction of the water demanding HYV, water usage heavily increased and the existing canal system is on average short of 28.8% for covering the water consumption in Punjab. Too ensure stable and sufficient water access, they looked down (Singh & Bhangoo, 2013).

Rodell, Velicogna & Famiglietti (2009) conducted a six-year survey ending in 2008 concerning the groundwater depletion of Punjab, Haryana and Rajastan. They reported on normal rainfall in the period, meaning conditions was optimal for creating valid results. The study found a net loss of 109 square kilometres of groundwater, or 109 billion litres. This is extracted through water infrastructure, but there is another essential actor enrolled here. To pump the water, energy is needed. Electricity used on farms in Punjab are free of cost (Gupta, 2023). Fishman et al (2016) said that up to 20% of India's electricity could be used for groundwater exploitation. This entails, water is being exploited in an alarming rate, which could lead to an agricultural collapse (Singh, 2011a; Kashyap & Agarwal, 2021). Dhillon, Kaur & Aggarwal (2016) examined the energy usage and carbon emissions related to pumping groundwater in Punjab and found that the energy usage had increased with 90% between 1998-2013. GHG emissions with 30% in the same timeframe. In numbers this is 4,845,100 megawatt hours (MWh), bringing energy usage up to 5,383,444 MWh[33], carbon emissions went up 984,100 tonnes CO_2-equivalent (CO_2-eq) to 5,383,444 CO_2-eq[34].

Water stayed out of my frame for a long time, but I found traces of it throughout my data. The father in interview 9 told me, nonchalantly, that they pumped the ground water from a depth of 450 feet, and that every ten years they would have to go down 10-20 feet. The government officials in interview 13 would reiterate this, with a little bit more care "*The water level is going down every year. Every year like 8-10 inches, up to one feet…*". Interview 10 expressed great pessimism regarding the exploitation of water, claiming it would eventually lead to the end of agriculture in Punjab, and that this was the reason people chose to migrate. Wang et al (2012) found that every 5 meters of depth would on average add another 10% of GHG emissions due to the increased need for energy to pump it up.

The challenge of water resource management extends beyond local scope. Due to the perceived abundance of water, the growing pattern has gradually shifted towards one where flooded irrigation is the standard, leaving the crops constantly under water (Hundal et al, 2013). Flooded fields are one of the main drivers of high methane emissions in agriculture (Le Mer & Rogers, 2001). Khosa, Sidhu & Benbi (2010) researched the methane emissions under different flood conditions in Punjab and found that monthly emissions varied between 1656-6504kg per acre[35]. The lower number being under ideal conditions and is not a number one would expect to find in Punjab.

As you will see in the coming findings and discussion chapters, water is one of the key actors that are affected differently depending on the residue management assemblage, so to get an understanding of its dire state is crucial to understand the potentially different futures that are on offer.

[33] My own calculations.
[34] My own calculations.
[35] They presented their numbers in mg per meter per hour. I converted it to kilos per acre per month with an average month representing 30.44 days.

4.7 Enacting residue as an issue

We have now looked at different problematic aspects of the RWS that will be relevant in the coming findings and analyses chapters. The fact that they are problems do not necessarily mean that they will be handled, or even gain attention. One aspect of the RWS that has gained increasing negative attention in India's public, is the burning of residue. It is this attention that has brought the two "novel" assemblages, in-situ and ex-situ, to the forefront as a way of finding sustainable alternatives to the widespread practice. There will be no surprise for scholars of STS that problems often need to be enacted as issues in order to gain the public and political attention needed to mobilize the correct tools to deal with what is in focus (Hermansen, 2016). In this process problems get framed which can have implications for how an issue gets solved or handled (Sismondo, 2010; Asdal; 2011).

The enactment of the residue burning issue is the last historical point I will look into in direct relation to the RWS. We will from this understand how contemporary the enactment is, and through its framing understand how there is more an emphasises on solving the burning, not how to solve it. I will in this section rely on both documents, but also the lived experiences of the informants I met on the ground for understanding to what extent the documents produced through the supreme court ruling had actual effects on the ground.

If one looks at the literature, there is scientific literature that makes the connections between the annual burning of residue in Punjab and the air pollution in Delhi dating back years (Kumar & Kumar, 2010; Singh, 2018; Grover & Chaudhry, 2019). The state government of Punjab banned the practice through their pollution control board in 2005, but the law has not been enforced. In 2019 the AQI in Delhi reached record levels as mentioned earlier (Abdurrahman, Chaki & Saini, 2020). Jethva et al (2018) used ground level measurement tools and historical satellite pictures provided by NASA to connect the increased AQI-score with the annual burning of paddy residue in Punjab.

With the AQI peak in 2019, the public was getting increasingly concerned, this resulted in the supreme court deeming the action of open burning of agricultural residue illegal (Liu et al 2021). Many of my informants emphasised this as the turning point where the attention towards finding alternatives to residue burning gained proper attention. I met Informant 9, who belonged to the Gujjara community, a nomadic cow-herding community in Punjab. While he was collecting residue[36] he told me through an interpreter:

> *"The stubble burning was banned in 2019. So that time people were more willing to give them money for Ex-situ. So, they were giving them more money. Like 3000, 4000, 5000 INR per acre to take care of it. But now what is happening is that now people are also burning stubble, but the government is not so serious. So now people are not giving them money to take this stubble away."*[37]

[36] Using paddy straw as cow fodder is not recommended due to its high silica content, which negatively affects milk quality (Reddy et al, 2019), however, wheat residue is a common cow fodder in Punjab (Sidhu et al, 1998). Due to wheat residue already having an economic value within the Punjabi agricultural system, there is no problems related to residue burning between the kharif-rabi season.

[37] In this quote he also speaks of how the issue has faded in attention. I will discuss this further in chapter 5 and 6, with how the empowerment of the farmer projects itself through residue burning.

A professor at PAU, informant 19, who had worked on residue management for several years would also testify to the changing atmosphere in the wake of the supreme court ruling: "*The government comes with requirement for all solutions. They require we fix the stubble burning quickly, and for that they started providing more money*".
Reading the verdict from the supreme court, it is stated that the problem of residue burning is more widespread in Punjab compared to other states that are under the RWS like Haryana and Western U.P. It is also clear that this is in general framed as an air pollution problem, with the problem not being confined to a locked geographical area. Another interesting notion from an STS perspective found in the following sentence is how satellite pictures are what binds the residue burning to the air pollution (Supreme Court of India, 2020, p. 2):

> *"It is apparent from the satellite images which have been produced before us for the period 30.10.2019 to 04.11.2019. The satellite image clearly indicates that in Punjab there is widespread stubble burning which has taken place as compared to Haryana, in which only in four districts it has taken place. There is some burning in Western U.P. also. It could not have taken place even in a singular district or gram panchayat area as we live in a civilized country in which such kind of activities which create such menacing pollution not only in the area concerned but to the neighboring States also, by ill-effects of that people cannot be left to die or to suffer various ailments."*

Through further reading of the court ruling one can also see that all options are valid in order to solve what they see as the biggest issue regarding the RWS in Punjab, burning of residue (ibid, p, 37): "*…to find all possible solutions like in-situ, ex-situ, diversification from paddy to other crops as well as increased use of paddy straw in power generation and other allied industries*".

Through this we have seen how the problems of the RWS are enacted as a polluting problem that needs to be fixed with all available tools. We have also seen how this court ruling has created new associations on the ground, with fire becoming a mediator that is seen as a problem within the RWS, these associations will be the case of study in the following findings chapters.

4.8 Punjab's emissions connected to electricity production

Before leaving the background section I will quickly explain the energy mix of Punjab. This is done to give a reference point, especially when discussing the ex-situ assemblage, which are building their assemblage around production of renewable energy.

Today Punjab's electricity consumption mix is 40.34% thermal, 8.24% hydro, and 12,23% renewable energy, while 31.15% is imported from out of state[38]. The carbon emissions of Punjab's total energy use [39] were 100 million tonnes and was expecting to rise to 211.6

---

[38] India energy mix is mainly fossil fuels, meaning what excess that would be imported from a different state would most likely come from a fossil fuel source (IEA, 2021).
[39] Not able to find for electricity by itself, so important to note here is that transport represents 49% of all energy consumption in India (PWC, 2020).

million tonnes by 2040. This is driven mainly by economic growth and continues pollutions like residue burning (PWC, 2020)[40]. This shows that there is a clear need for cleaner energy sources, if India is to reach their goal of net zero by 2070 (Bhattacharyya et al, 2022; Li & Haneklaus, 2022).

4.9 Background summary

In this chapter I have explained the historical background that has preluded today's residue problems. I have shown how the residue is a human made problem, born out of the practices that dominates the RWS. This has led to detrimental air quality, especially in the mega-city New Delhi.

The RWS has also brough about other problems, problems that will all be impacted differently depending on which assemblage handles the residue. Soils microbes, soils organic carbon (SOC) and soils organic matter (SOM) depletes. The high usage of fertilizer brings with it heaps of negative effects, including high GHG emissions. The water, especially the ground water is being stressed, which trickles over to high energy consumption and GHG emissions.

[40] Produces on behalf of an Indo-German relations organisation and the state government of Punjab.

5. Findings 1: Into the Fields

In the first findings chapter I will focus on things that are important aspects of the RWS in general but that are not directly linked to a specific residue solution. What I bring up here will be relevant for understanding the magnitude of farming in Punjab, and how farmers understand their own role when it comes to the consequences of the RWS, as a force for good and bad. I will first present observations related to the material aspects of the RWS, and how nature has been altered in such a radical fashion to the point of naturalization among the people living there now. I will then move over to talk about how the Punjabi-Jat culture[41] impacts their worldview. These insights will be important for understanding the obstacles that the different assemblages can face and will also talk about the associations that exist between the farmers and their livelihood.

5.1 Road-side observations

Taking the train from Delhi to Punjab, the surroundings gradually changed from one filled with human habitation made of concrete and buildings, to one covered with agricultural fields. In every direction there are fields filled with paddy or occasional cotton if the soil is not suitable for paddy. The trees found around highways cut as straight lines through the fields between the urban centres. Some trees are also found thinly spread out in the field, often in a cluster with a small shack to keep tools, a water pump and charpais[42]. It is in these clusters most of my field interviews would be conducted. Through observing and interacting with the water pump I gained valuable insight into the distance the farmers had towards their impact on their surroundings. They were all drinking from the water pump connected to the groundwater. It is a contributing factor that poverty, and in general the hassle of bringing water to the fields, could be a reason for not having different water sources available, but through my notes, I have written on two occasions that I have been told that this is the purest water you can drink. One time was in a conversation with gatekeeper 1 and his father, while the other was said in the prelude to interview 9. These individuals were not poor, but large landholders. The water, lying under one of the most chemical soils in the world with low

[41] The Jat-culture and then also religion depends on its geographical location and local influences (Aloysius, 2000; Malhotra, 2014).

[42] A charpai is a traditional, knitted bed found everywhere in rural Punjab (Azhar, 1962).

absorption ability, it has been clear to me (retrospectively) that this might have been one of the most chemical sips of water I ever have consumed.

Another example of the distance put between the farmers and their impact was when we talked about the landscape's historical alteration. In between the urban centres there is a web of dirt roads connecting the villages that exists as human oases that elevates above the flat fields of Punjab. The fields end only when they reach the feet of the Himalayas in the north. From where nutritious water, suitable for agriculture, runs down to the plains (Gosal, 2014) where it is domesticated into human-made distributaries that irrigates the land (Jain & Kumar, 2007) creating new straight lines through the fields. One afternoon, I was talking to five small elder landowners about the alteration of the landscape. The younger generations had told me that the landscape was a static entity, but now the elder told me, to the disbelief of gatekeeper 1 that the landscape had been filled with small hills and what was translated as jungle. Their fathers had been the ones that had levelled the fields too increase crop yield, to easier cultivate land and made Punjab into the flat, almost treeless, landscape we see today in the wake of the GR. Still, nature was present, or at least it had found new ways to both benefit and beneficial for the RWS. Egret is one species of bird that has created a tight connection with the land. Especially during the harvest, you can see this tall, white birds following the combine, eating seeds it leaves in its path. Gatekeeper 1, who was the son of a Jat landowner told me that they value the birds due to their bug eating abilities, giving an example of how more-than-human actors can be working in an alliance with the farmers.

Some of the smaller land plots did not have access to mechanical modern tools and was harvesting paddy the old way through manual labour. These jobs were occupied by people from scheduled castes that had migrated for seasonal work. Alongside these small plots of land small communities of tentlike house built of plastic and residue popped up. Since their work was done manually, their technique would avoid the problem of stubble remaining in the field that has become prevalent with the combine harvester. They still relied on the traditional method, as explained in section 4.4. They cut the straw all the way down at the soil, they would then bring a bundle of straws to a wooden board, tilted in a 45 degrees angle, and hit the board to make the rice fall off. The rice would gather in a pile on a tarp that was put on the ground. The longer the straws, the easier it would be to get enough power behind each stroke; hence, the problem of stubble did not materialize in a traditional agricultural system. The straws were then gathered in piles along the road, re-branded as residue while they waited for someone to find value in it.

5.2 Enacting residue burning in different locations

An interesting observation I did was how residue burning materialized in signs and public awareness depending on which end, geographically, you were located in relation to residue burning. In Delhi this materialised through billboards that were spread out around the city, constantly conveying the AQI in real time. Within the Norwegian Embassy every apartment had an AQI device, and two big, one-metre-tall air filters. Smalltalk concerning AQI was not rare, and most people had the AQI-index on their phone as a widget, the same way I would have a weather widget easily accessible for me on my phone. Along the roads there would also be digital billboards with real time update of the AQI-levels. All this was part of enacting the awareness around AQI, keeping it as an issue, in case the grey skies and limited sight were not enough.

In Punjab the perspective was different. Here the focus was more on conduct and awareness. The radio would everyday talk about the issue of residue burning and emphasis that there were alternatives, like in-situ and ex-situ, for burning the residue. The news would everyday convey messages about number of fire incidents, clearly reflecting that they are in the other end of the problem. In Delhi, AQI, in Punjab, number of fires. There would be messages from the government concerning different sorts of punishment, one being that your gun license would not be renewed if you incinerated your residue[43]. There was wall painting that warned of the problems that could come from the practice of burning, and there were information centres regarding residue burning spread out around Punjab. These centres I visited, and the data collected, will be presented in section 7.1.1.

5.3 Farming as Culture.

It was not only the landscape that gave an indication of the importance of farming in Punjab. In this section I will outline the cultural importance of farming, especially among the Jats in Punjab. I do this in order to bring out an important perceptive that will broaden the understanding and complement the findings that are presented further down that are more directly relevant to the specific solutions to residue handling.

Punjabi Sikh culture is not static and is undergoing changes. The belated hip-hop phenomena Sidhu Moose Wala[44] was seen as the ramification of Sikh-identity and was constantly being played and talked about around Punjab. In his music he brings attention to many themes I found to be relevant in the cultural identity, something especially the incinerating Jats conveyed; farmers' pride, violence, and bravery with an us-vs-them mentality (Gangahar & Kapil, 2023). Bravery was particularly relevant when we talked about the Delhi protests. The protests were mentioned extensively through my casual conversations, but also in Interview 2, 7, 11, 13, 22, 25 and 28.

The Delhi protests, by some considered a cultural conflict, involved thousands of farmers, primarily from Punjab, congregating in the outskirts of New Delhi. The protests severely limited road access to the city for eight months. Among other things, keeping the RWS as it is and trying to preserve the minimum support price on rice and wheat was some of their main rallying causes (Jodhka, 2021). Punjabis talked about the protest with a sense of pride, even those that were not there. Similar to people sharing war-time stories of their heroic collective deeds. The protests had created resentment against the government, but also given the farmers an understanding of their strength in number. In interview 13, I was told by three local government officials how the farmers had increased their protest-activity after the Delhi-protest, and now they had to deal with protests on a regular basis.

Farmers also spoke of their sense of unity, frequently citing their collective strength and solidarity as means to resist or hinder the government's enforcement of laws related to residue burning. I was told that if the government tried to give them a fine, they would resist, and if they got arrested, they would all gather and protest. The following quote is from interview 2: "*You know in Punjabi, Dhaak. Dhaak*[45]*. Force of farmers is lord…*" Their unity and importance within the food system of India imposes on them a sense of

[43] See appendix A for picture.

[44] This music video is a great visual introduction towards rural Punjab, where he has brought attention towards many interest aspects of rural life: https://www.youtube.com/watch?v=twCHVhk8iMU&ab_channel=SidhuMooseWala

[45] The term Dhaak (धाक) speaks of physical strength, but also moral standing within the Punjabi culture, and how to stand firm when being challenged.

righteousness within their own culture and society to refuse the interessement attempts by government and other future-makers.

Their sense of unity was expressed as a positive force. Phrases like "*Who will feed them"*, "*the world needs the farmer",* etc. was not uncommon. These sentiments also materialised in stickers and paintings of slogans adorning cars and cityscape. One prominent slogan was "No farmer, no food"[46]. Through this they also saw themselves as the feeders of the nation, an important aspect in relation to research question 3, concerning framings and how different connotations of care can be in tension.

5.4 Summary

What I have tried to convey in this chapter are a few examples that speak of the farmers' relation to their role in society. Many of the farmers today are not aware of the historical impact that has been inflicted by their elders on their surroundings to make the soil an intermediary actor for the RWS. It is understandable with a collective memory loss as described by Sverdrup-Thygeson (2021), since most people alive today have grown up in this flat anthropological landscape that dominates Punjab, the changes to the environment have become so normalized and invisible it becomes taken for granted. Another indication of the distance put between the farmers' action and the outcome is how they believed the water under the chemical soil was pure.

The farmers showed a lot of resentment towards the government in the wake of the Delhi-protest, that might have complicated their willingness to follow the governments' heads for moving away from incinerating their soils. I will go more into detail on this in section 6.1. Final point to bring is how they understood their role as the feeders of the nation as an important responsibility.

[46] See picture in appendix A

6. Findings 2: The Incinerating Assemblage

As the research questions states, the purpose is to unveil the assemblages that constitute different practices of residue management and their impacts. I will start with the most controversial assemblage, the practice that has emerged as the most popular one in Punjab, attracting enough attention to be enacted as an issue, forcing the RWS assemblage to seek new solutions, namely residue burning.

I will first present different interactions I had with farmers and labourers that were either burning or were pro-burning. By presenting their claims and follow the actors I will lay the foundation for research question 2 and 3 to be answered, where I seek to find the consequences of the assemblage, but also how the consequences are understood by the farmers. There will be a focus on how the economy limits the farmers abilities to seek different alternative.

Throughout the chapter, and the two chapters looking into in-situ and ex-situ, I will show the different actors within the assemblage, both recognised and unrecognised actors. I will end this chapter with a summary that will also work to answer research question 1, where the assemblage of actors is explained.

6.1 In flames

I will start by taking you into the fields, to an interaction I encountered on my way back from another interview with a farmer. Here I witnessed the complexity of managing residue and how two assemblages complement each other to create a satisfying result for the farmers. The land which was incinerated in front of me was owned by one prominent member of parliament on state level. He belonged to the political party Congress, and ironically, according to my gatekeeper (4), been vocal in his resistance against residue burning. They had applied mitigating methods before resorting to residue burning, through temporally employing a group from a nomad-caste from the north-east (the community-name is not part of my notes) to cut and collect the stubble in a pile of hay that was on the edge between the two fields. The job the hired group had conducted was insufficient. To fix this the labourers would either need a stronger tractor than they already had to drag a machine they would have to rent or do it manually with their hands. With time of the essence due to the need to sow the next crop, this would not be suitable and hence, they found the only viable solution to burn the residue. In order to burn the residue, everything was collected into horizontal lines. The burner would then use a match to ignite the residue in one end. When there was sufficient fire, he would use a long stick to move the fire down the line to speed up the process. He had a long scarf to protect his respiratory system.

Another person I met (Informant 15), worked on what I believed to be a progressive farm. The worker did not get a daily wage, but instead got 15% of the profit[47]. The owner (informant 11), whose stand on residue burning and solutions will be presented in the in-situ section, had ordered a ban on residue for the last three years. The worker found this to be a point of annoyance, claiming it did not matter, for the sake of the climate or the pollution, what they did if everyone else was burning. The farm was practicing in-situ I had been told. Still, he told me that last year, two acres of land had been incinerated. The reason for this had been that water had been stagnant in the field for too long, meaning harvest of these two acres had been late. To prepare it for the next crop, the workers had set the field on fire, behind the back of the landowner. His stories of incineration were a more brutal one then the one I encountered before and resembled other stories I had heard of incineration. The difference was that while the first interaction only practiced partial incineration, with total incineration there was more residue. This meant fewer performative actions were required, and it was sufficient to create a proper fire and then the incinerator would observe, making sure that there was no unwanted fire propagation.

These two interactions show how burning is not necessarily the first choice, but occurs because intermediaries turn mediators, forcing the rest of the assemblage to act. Since keeping the RWS going is more important than ensuring the avoidance of incinerating, soil gets burned. They also showed that there are different methods for burning, but from my experience it is mainly the latter that is prominent in Punjab. Through these interactions the material actors needed for the incinerating assemblage to function have also been explained: fire and a stick. While the action of these farmers speaks more of unwanted side effects of mediators, most farmers in Punjab that are burning do it as a first choice, and these farmers that will be in focus from now in this chapter.

6.2 Burning with options

The first incinerating farmer I Interviewed (3) was on a farm on the outskirts of Bathinda, five minutes with a tractor from a SAEL powerplant. In this section, I will present why the farmers incinerate, even when there are other options available.

It was three brothers in their 60s and they together cultivated 36 acres of land filled with paddy. They were expecting to have heaves of residue to deal with in a matter of weeks. While conducting the interview, the white smoke of SAEL was constantly going up in the air. The interest of my inquiries at the time was more concerned with SAEL explicitly than the sustainable issues related to the array of different solutions, and this is mirrored through my questions. When asked a general question about SAEL, they themselves created the links to burning of residue and air pollution. They said that burning the residue only pollutes for one day, while SAEL pollute all year. *"There is no less pollution,*

[47] This is important because this should give him incentives for ensuring high yield, and since the position he held often is for lifetime (my own notes) there should be incentives for ensuring the longevity of the soil.

it is the same". This claim will be discussed in section 8.4.1. By this they showed that through their knowledge and logic, it was not wrong to burn, since they assumed pollution would be the result if the choice was between SAELs power plant and burning residue.

We then went over to talk about different solutions and here I heard an argument I had heard several times in my more casual group conversations with the farmer-sons at the cafe: *"It's the government's responsibility, if they want to fix this, they need to pay for it"*.

But what about legal consequences, haven't the government tried to nudge you into abolishing this through making this action illegal? To which I got the reply: *"In India nothing is bigger than farmer*". But will you not get a fine I asked? "*In Punjab, it is farmers Unity, farmers strength, they give fine, we don't pay*". This underscores the quotes concerning farmers unity presented in 5.2 in a context where the farmers feel untouchable. They would on several occasions claim that any alternative (in-situ or ex-situ) would have to be spearheaded by government support and that the government should bear the burden of the farmers potential adaptation. For them burning was an easy solution that demanded little manpower. Remember also in section 4.3 how labour was a scarce and expensive resource, meaning it was usually up to the farmers and maybe one or two workers to prepare the whole field in 20 days.

I had recently spent a lot of time reading up on the pernicious consequences of residue burning wanted some confessions to what I deemed as bad behaviour. But, what about the air pollution in Delhi I asked, do you have no consideration for them? This question was answered with a reference to the Delhi protest before once again repeating the mantra after making the connection with Delhi and asking the government to pay. They blamed the people in Delhi for blaming the farmers, witnessing of resentment towards the central government. Was this resentment new? It was clear that the Delhi-protests had definitely shaped some contemporary identities in Punjab. The farmers had established distinct categories, with an us versus them mentality[48]. The Punjabi-farmers that had been the heroes of the green revolution, had taken a popular turn for the worst in the 1980's when ecological and political problems had been rife in Punjab (Jodhka, 2006b). It was not uncommon for my informants to mention that the government was framing the farmers unfairly for the air pollution, and if they wanted to fix it, it should be their responsibility to pay for it. I will leave the question of government funding here and bring it up again in the section related to finances.

6.3 Soils

We then went back to talking about SAEL. They told me first that they did not pay enough to cover the cost of collecting and transporting the residue, even with their proximity to the plant. I then asked if they knew anyone that had sold residue to the plant? "*Yes, but only once, once you sell to SAEL, you will never sell to them again.*" But why is it so I asked? First, they mentioned fertility, that burning enhanced the soil. In section 8.4 an informant from SAEL raises a contradicting claim, and I will have a more thorough discussion there, but in general, biomass contains nutrients. Upon burning, this will be released back into the soil after being converted to ash (Giardina et al, 2000; Bodi

---

[48] I was handed a list over all residue burning incidents in the district of Jalandhar during interview 13. In this document (found in appendix C) you can clearly see how there was a spike in burning after 2019. I suspect this to be as a protest against government with the Delhi protests as a backdrop, the numbers recede to 2019 numbers in 2022 when the Delhi-protest has calmed down. It could also be because of increased government attention towards the issue after the 2019 supreme court ruling, an attention that might have faded. Because of the uncertainty I have chosen to not include it in the masters, but it's still an interesting notion.

et al, 2014). The ash will also increase the soils organic matter through being incorporated with the "original" soil (Gonzalez-Perez, 2004). This entails that some of the nutrients that exist within the residue will be released back into the soil.

The health of the land[49] was also an important factor for them when deciding to burn the residue. The lack of salinity within the soil and access to groundwater made this field suitable for paddy cultivation, a claim that is also scientifically proven (Hussain et al, 2018), but this combination also had greater issues with fungus compared to for example the saline soils where cotton is the main crop for cultivation. I would later visit a cotton farm and ask them about the claim concerning saline soils and fungus- they would reaffirm this by saying they did not have the same problems with fungus as paddy farmers (My notes). The farmers I interviewed (3) claimed the best way to deal with disease is to burn the land, hence burning was positive for the soil. This was a statement and understanding that was not uncommon among the farmers I was introduced to from gatekeeper 1, but also through my interaction with the students who were also from Bathinda and its surrounding areas. Apart from informant 10, none of my farming informants had any formal agricultural education. They lived inside echo champers of truths regarding soil and farming, where the knowledge gets passed down from generation to generation. Knowledge also needs to be seen as an actor within an ANT-assemblage (Latour, 2007).

I followed their statements regarding the fear they had of fungal outbreaks and if burning of residue was a valid solution into the literature, in order to see if these could be claims that spoke of sustainability. I found different ways that the fungus could be understood in relation to residue management, and as we will see in the next chapter, in-situ has a totally different understanding of the fungus and its possibilities. This fits well with an ANT analysis, where we understand that input reflects output, meaning the other actors that an assemblage is constituting depend on how one specific actor, in this case the fungus, acts. Since the topic in this chapter of my report is concerning incinerating farmers, I will only explain the output where fungus spoils the crops, the concern raised by the farmers I interacted with.

The soil contains a vast and dynamic array of different microbes like fungi and bacteria (Webster & Weber, 2012). Beri et al (1992) found that burned soil contained between 5 to 10 times fewer microorganisms and 1.5 to 11 times less fungi compared to soil where the residue was left in the field, the in-situ method. Dumontet et al (1996) used 11 years to survey a forest where parts of it had burned. They concluded that even after 11 years after incineration the microbial biomass had still not recovered, and that long term effect was particularly noticeable in fungi, compared to bacteria's. This means, burning does have a positive effect on the microbes if your aim is to get rid of them, but is there any point in getting rid of them?

Dodan, Ram & Sunder (1997) wrote about several instances where different strains of fungus had reduced the yield of the farmers in Haryana, the neighbouring state of Punjab, from the 1980s throughout the 1990's. According to Shukla et al (2022), 125 million tonnes of potential yield (all crops) was lost to fungi disease in 2012 and was identified as one of the greatest threats to increase yields. All the while, microbial diseases have a tendency to increase in places where water irrigation levels are high (Roudales et al, 2014). Another article by Summerell, Klein, and Burgess (1988) found that burning of residue in the previous crop was the most efficient way of avoiding

[49] Using the word land and not soil when talking about health is telling of their relation to the area they were cultivating, showing how it is a resource for extraction.

Pyrenophoro Tritici-repentis, or yellow spots in the coming wheat harvest, framing it as a rational option.

Summing the last insights up through an ANT-lens, we can see the humid environment, perfect for paddy cultivation, to be full of microbes, that could work as intermediaries. Occasionally the association between the more-than-human-actor and the humid environment would lead the microbe into becoming a mediator for the farmers through a fungal outbreak. In order to stabilize the RWS-assemblage, fire was introduced and the mediator would be subdued into intermediary. The intermediaries could stay this way until the link between the practice of residue burning and New Delhi's air pollution was enacted, making the fire the unstable mediator.

6.4 Finances

Despite the justification for residue burning being the presence of fungus, the farmers appeared open to other solutions, they just had to come with less financial risk. This was a mantra repeated to the point where I could have changed my methodology to quantitative if I had been systematically counting. So why were the farmers so concerned with demanding that the government should pay? Is it the farmers that are translating their will to the government in order to enrich themselves? As I described in the backgrounds chapter, subsidies have always been an important interessement within the RWS, especially in the prelude in order to get the farmers on board and acquire the correct technologies. If you asked my gatekeeper (4) living in Jalandhar City, he would say that farmers have too much power in Punjab, that they are spoiled and lazy. Keep in mind he is not a farmer and was feeling frustrated with what he saw as an unfair power balance between farmers and the broader society in Punjab. Additionally, the Delhi protests had resulted in severe logistical problems for him, both personally and professionally, which had increased his resentment. In general, the frequency of farmers protests was a point of frustration for him.

During my time in Punjab, I heard of two smaller farmers protests related to money. Looking back, as I elaborated on earlier, it is clear that there is a long history of money transfers from state coffers to farmers. Has the history made the farmer lazy and risk-averse? Let us first remember that the subsidies the farmers received was part of a vast network of actors being enrolled to ensure the food safety of India. The farmers had not been the future-makers within this assemblage. Their realities translated through the successful interessement of India's government, FF, and Borlaug's technoscience. They had been essential future-makers with their knowledge production, but there was more than knowledge that needed to be enrolled. HYV, the fertilizers, or the machines acting as tools for the purpose of the RWS also needed to be disbursed. What was the actor that bound them all together? What made the farmers able to afford and roll out machines? It was money, subsidies, that brought them onboard. But what else happened when these interessements successfully established the Assemblage? Well, a lot, but we will stay within the world of economics at the moment. As shown earlier, the HYV is not attracted for their natural high yield, but how they communicate with other actors like fertilizer and pesticides. The seed production had moved out from the farm, to become a commercial product. Machines were needed, and machines needs fuel. The move to productivism, agriculture focuses on profit through exploitation (Bellacasa, 2015), had made agriculture a money intensive business, where a constant cash flow was essential, also for the farmers, with or without subsidies. What is the result of all this?

Yes, the farmers income did increase steadily throughout the 1970's but has since stagnated with the soil reaching the limits of human exploitation (Satish, 2006) within the

RWS as we know it today. Stagnation of output does not mean stagnation of input (Mann & Chauhan, 2023). Input prices and consumption have increased, while the minimum support price has not followed to cover the increased costs (Gill, 2005). My informants would tell me how they would go straight from the mandis to the fertilizer shop, seed shop etc. to acquire the essential components for the next harvest, meaning, cash is an essential and ever more scarce resource in the RWS.

The GDP associated with agriculture has also dwindled. On a national level it has gone from 55% in the 1950's (before the green revolution, to 17.8% in 2019 (Shetty, 2023). I have not found as long historical lines for Punjab in particular, but in 2004 the agriculture represented 32.65% of Punjab's GDP, while in 2022-2023 it had gone down to 29% (Punjab Data, unknown year; PRS,2024). This is normal with urbanisation being the natural step in development one might think if one looks at the macroeconomics but let us look at the people. Jodhka does just that in his book from 2023. In 1951 there was 298 million people living in rural India. In 2011 this number had reached 833 million people.

Shetty (2023) shows in her study of historical agricultural investments in India how the number of farmers in India has gone up from 70.5 million in the 1970's to 146 million people in 2015. This has led to farm sized dwindling from 2.3 acres to 1.08 acres in the same time period. In a Marxist view, capitalism would lead to centralisation of both capital and agricultural land (Lianos, 2016), but what we see in India is the opposite. The sum of all this is financial distress that has led to widespread suicide in Punjab due to debt (Kaur & Mavi, 2016), a topic that was not uncommon to touch upon during conversations regarding farming.

Other phenomenon that I was told was related to the finances, and which I got to discover closely through my volunteering at the IELTS school, and through the general obsession with Canada was migration. The reason they migrated I was told, was the lack of opportunities in Punjab. If two siblings split the farm, the input would remain high with need of machines and so on while output would maybe not be sufficient for covering the expenses of two families[50]. This exodus had also resulted in vacant farms that were now on lease. An officer working on agriculture in Punjab told me that farmers usually own small plots of land. Due to the exodus of Punjabis to Canada, a lot of land was now on lease. Farmers that do not own the land have fewer incentives to think long-term regarding soil health, and an extra expense to cover due to the leasing cost.

Together this paints a picture of financial distress for the farmers in Punjab. Not only are they asked to increase their spendings to solve a problem they do not identify as theirs, but they are also asked to invest in something that can ruin their livelihood due to the lack of fungal control that fire offered.

6.5 Summary - Research question 1

Burning of residue is a process that requires little time, which is beneficial within the time strained RWS. In the first example, where burning was a way of solving the poor handling of an attempt on ex-situ management, the burning would also require more active performances from the actor. The other examples that were retold by my informants showed the incinerating assemblage as a solution that demanded little performance. In

[50] This is regular conduct all over the world, but what is special about Punjab is the high living standard of the farmers, while being in a developing economy with few options outside of farming. In other developing economies, the farms would usually also be smaller, meaning the socioeconomic status would not change. In developed countries, there are usually more lucrative opportunities outside of farming.

order to solve the problem that gets established through an interplay between the HYV, the combine and the intensive cropping pattern, as shown in the background chapters, one only needs to enrol fire and sufficient dry conditions in order for the fire to work as an important intermediary that prepares the land for the next crop. This makes it an easy and affordable solution for the farmers.

Still, this is only the visible material actors that are part of actual performance of incinerating the farm. Other things that need to be part of the assemblage is bound up in ideas concerning burning residue, or not burning residue, and what is of interest for the farmers. Through the following chapter we have seen how the assemblage that these farmers are part of, makes it rational to burn. Their knowledge binds the farmers to the idea that finding alternatives to burning residue is a risky business where their livelihood is on the line. Burning of residue is not only the easiest solution, but it is, for the farmers under this regime, a sustainable solution, where it ensures that the next harvest will not be spoiled by an uncontrolled fungal outbreak.

Also, the farmers see the efforts conducted by the central government as part of a narrative to make the burning farmers look bad, a view that is fuelled by the farmers' resentment towards the central government. This could make burning of residue into an act of protest against the centre.

Another reason for the farmers is concerning finances. We will see more of the different ways future-makers try to translate the interest of the farmers through financial means in the following chapters, but this does not change the perception the farmers have related to their financial situation. They find that the financial burden of changing something that they do not see as unsustainable should not be on their shoulders. This is related to the increasingly marginalised financial situation farmers are facing today, compared to the heydays of the 1980's.

7. Findings 3: The In-Situ Assemblage

With the controversies surrounding burning of residue within the RWS, other solutions were gaining traction. One of these solutions, in-situ, where you incorporate the residue into the soil, is the one that is preferred by the local agricultural experts at PAU (interview 13, 14, 17 and 18). In this chapter I will first explain the positive experiences of farmers performing in-situ. I will through this explain the different actors that are needed for the in-situ assemblage to work sufficiently. I will also discuss some problems that the farmers face when part of an in-situ assemblage before These insights will help me explore how the climate and the local environment is affected by in-situ.. Through this process I will show how the actors within the assemblage create associations with actors that initially were not part of the solution. These novel associations translate more aspects of the RWS than the residue and the burning. By following and exploring how the in-situ assemblages' impact other aspects of the RWS apart from burning I will be able to answer research questions 2 and 3, which seek to find the consequences of the different assemblages, but also how the solutions are framed.

I will end with a summary where I will show explicitly what is constituted within the in-situ assemblage, which will answer research question 1. As it aims to explain and illuminate the different actors that are enrolled in the in-situ assemblage in order to manage the residue of the RWS.

7.1 Incorporating

When in Bathinda most of my informants had been incinerating Jats[51]. In Jalandhar I encountered farmers, not belonging to the Jat-caste, that had been acquiring land through investments. One of my informants (11) that identified as a businessman would help me snowball into new perspectives and informants introduced me properly to the in-situ method that I previously only had heard rumours about. His main business was trading of potatoes. He had stored the surplus from the potato business in 40 acres of land. It had taken him ten years. This meant he was a self-taught farmer who had not been influenced by family members when acquiring the knowledge concerning farming, which was the case with the incinerating Jats I encountered in Bathinda. He had moved

[51] Apart from informant 3 who had performed ex-situ.

away from burning to incorporating the residue six years ago. What had convinced him of changing his way? Another farmer, which I also got to interview (informant 12), had started doing in-situ two years prior to informant 11, meaning informant 12 had been practicing it for a total of eight years now, and could speak of positive results. The following quote is passed through gatekeeper 4, when asked if he would consider going over to the competing assemblage ex-situ if the monetary value of his residue was increased:

> *"So, whatever money they are spending on it [performing in-situ]*, but the next crop is much better, so they make the money in that. So, chances are that they will still go with in-situ only. Because that is very, very good for them. He now saves fertilizer and has seen on average maybe 15% increase in crop productivity since he went away from burning."

Informant 11 had also seen the economic benefits of doing in-situ:

> *"It is [increase in yields] not for first year, maybe second year you will see...you dig it in, and it kind of softens, it becomes like a fertilizer."*

Informant 11 had started to save fertilizer after practicing in-situ for three years. I later asked him in a SMS-conversation how much fertilizer he saved after six years of in-situ, and he told me:

> *"In next crop. We Save. 1 Bag of potassium and 1 of dap [Di-ammonium Phosphate]and 2. of urea approx. cost per acre".*

One bag of urea had been reduced from 50 to 45 kg in 2021 in an attempt by the government to reduce the usage of fertilizers (Ghuman & Daliwal, 2022). This meant a 90 kg decrease of urea, 50 kg of potassium and 50 kg of phosphate. This I found to be extensive. I would ask him again two months later, after the wheat seeds had been sowed. This time I also asked him to be more specific with how much they applied in total per acre in order to make sure that we were talking about the same thing. He would then be more unsure about how much urea they saved, but he told me that where they previously had used between four and five bags of potassium and DAP, they had now reduced it to three and that total fertilizer usage had been reduced between 10-20% per acre.

The farmer in interview 28 would testify to saving fertilizer after handling the residue with in-situ. He only mentioned urea. He had only been practicing in-situ for two years, so according to the science I will present in section 7.1.2, he still had the greatest rewards in reduction of input ahead of him. He said:

> *"We were using three and a half urea bags, and now we are using three bags. It is 45 kg bags, now, 22 kg we are left with".*

That means a 12% reduction a number more in line with PAU's statement (Punjab Agricultural University, 2023). I will go more in detail on the key takeaways from this interaction in section 7.1.2, namely that the in-situ assemblage can reduce the high consumption of fertilizers that is associated with the RWS, while at the same time increase the yield.

7.1.1 Machines

Informant 11 then proceeded to talk about which technologies and methods that had to be introduced in order to successfully incorporate the residue into the soil. New machines are essential actors that need to be enrolled into the assemblage. They work as the association between the farmers and the soil in order to incorporate the residue into the soil where it can decompose. Another thing we will see in this section is how there are several machines that come with different consequences for the soil's sustainability.

PAU had a testing ground/model farm at the outskirts of Jalandhar. The facility was fittingly called "Promotion of Agricultural Mechanisation of In-situ Management of Crop Residue".[52] Here I met two informants. It was six machines they promoted with three being created at their facilities in Ludhiana. They were called Paddy straw chopper cum spreader, PAU Super SMS, Happy Seeder, Super Seeder, PAU smart Seeder and PAU Surface Seeder. All of them needed to be attached to a tractor of a certain size. This means, a suitable tractor is another component a farmer would have to acquire if he did not already have one. The machines all basically gave the same results when handling the residue. The differences are located in other parts of the technology, that are essential for its climate impact. I will focus on the two that I found to be most prevalent during my fieldwork. I will here offer a quick description taken from interview 14.

The Super Seeder is the one that could show highest adaptation rate among farmers (Buttar et al, 2023). This machine was also prevalent in my observations. It had a mulching mechanism in front meaning it had the opportunity to mulch the stubble, but it was normal to turn the stubble into residue first with the cum spreader due to lack of strength to handle the dense stubble formation. This was done by pulling the cum spreader across the field, mulching the stubble into loose straws. After that one would take the Super Seeder across the residue. The mulcher located in front would then turn it into even shorter straws, easier to decompose. The next technology that was combined in this actor was a rotavator that would till the land. At the far end there is a seed drill that would insert seeds into the tilled soil together with the mulched residue.

The Happy Seeder, another actor that I observed on numerous occasions, has basically the same functioning, except, it does not till the soil, but injects the seeds directly into the soil through a drilling machine. This means disturbance of the soil is left at a minimum and would enhance what is going to be the subject in the following section, SOM and SOC (Dhalwal, 2019).

7.1.2 Into the soil

In order to understand the invisible process that occurs underground, I needed to go to the location where the knowledge was being constructed, PAU Ludhiana, the main agricultural research facility in Punjab. Here I met a professor that had worked on in-situ and ex-situ for 13 years, aiming to fix the residue problem that came with paddy sowing. He told me that the first 8 years had been conducted without much attention until the air pollution in Delhi was enacted as an issue, bringing the attention of the national government towards the residue problem. This had resulted in an influx of capital from

[52] See pictures xxx

the government to conduct research and distribute knowledge. He first made the claim that government previously had been convinced that the best solution for residue was to turn it into an industrial resource, in order to promote industry. Their work had convinced the government that in-situ was the most suitable option saying:

> *"Government is moving towards in-situ because we have told the rest of the government that the residue is a gold".*

He elaborated:

> *"It is not a waste, it as an organic manure...if you take this also out of the field, then you know what will happen to the field. We have shown them all the data...All the nutrients are left in the soil".*

He would further explain that this was essential for the soil's health:

> *"You do a search, how nutrient requirement, how water requirement, sowing, seed rate, everything. The whole agronomy changes".*

The water would hold better in the soil, meaning you would not need to extract the same amount of water as earlier, this will be brought up again in section 7.3. The nutrients that were naturally in the residue would be incorporated back into the soil, and the carbon within the residue is stored in the soil he would claim. This all speaks of positive externalities when trying to solve the problem of residue. But what about the fungus I asked, cannot this increase the chance of spoiled crops?

> *"When the residue is there in the soil, it may be new pests, there may be new diseases, so we have to regularly monitor them. If you burn you kill all, everything. So many insects will be killed, but also other organism, if you do in-situ, you need to better monitor."*

In this quote he speaks of the need to monitor the soil better, in comparison to incinerating, which will kill everything, also organisms that you want in the soil. There is more risk of fungus without burning, not due to the increased residue that will decompose, but because of the absence of fire within the assemblage.

Gatekeeper 3, who is the informant in interview 27, worked as head of sustainability in a big agricultural company. He talked in great length about the benefits of in-situ. For five years now they had sought to find a solution to what he framed as "*heavy biomass in the field*", meaning residue. I asked him what would happen when the stubble decomposed, and he would give a comprehensive answer:

> *"So, when the organic carbon content increases, the crop yield will increase with the help of other fertilizers and other things. Otherwise, when the organic carbon content is limiting, you put whatever is there, it will stop at a limit. So organic carbon, that is becoming a critical point now in the agriculture... we found that the straw contains maximum potash. And potash is*

the main source, main fertilizer which is required. So, the other thing was silica, and the third thing was carbon. Right? In addition to nitrogen and other components which are there in the straw, mainly three components which we were focusing was potash, silica and carbon. Carbon, that was becoming a key factor because soil fertility was reducing because of decrease in the organic carbon content in the soil."

When we had turned to the differences between in-situ and ex-situ when it comes to soil health, he would first repeat the same claim that the professor had stated: That the soil gets deprived of its resources, it will lead to what he would call *"max exploitation of the nutrients in the soil"*. This was the reason for stagnant and decreasing yield he said, and he would visibly describe this:

"Yes. The difference in soil is definitely there, for sure there. Because those farmers who are using the in-situ, this one, decomposition of the soil, stubborn, in their case, the soil that is very soft, it is, you can feel the difference in the compaction of the soil."

I want to bring out one more quote to summarise the key points extracted from the conversation. Here he clearly speaks of the associations that are enrolled when having an in-situ approach towards residue handling.

"...So, what at our end, we prefer is, we prefer the straw which is rich in nutrients that should be retained in the field so that the nutrients, they are recycled. So, once they are recycled, carbon content increases, mineral content increases and the minerals which are insolubilized in the soil, they get mobilized..."

Informant 15 would testify to the altering quality of the soil in the wake of in-situ. He was not a fan of in-situ for reasons I will mention later, but he would say, through an interpreter:

"Like the soil, it really changes if you do in-situ. So, he said like here they did in-situ, here they did not. And he said the rice quality that they have from here and here is very different. The colour is also different."

To go more into details of these statements, and to better answer research question two where I uncover the sustainable consequences of the different assemblages, I will now turn towards the documents and explore the science behind the statements. Through this we will also see more concrete numbers that will be useful in the coming discussion.

Dobermann and Fairhurst (2002) had found paddy straw, the part I have called residue, to contain significant amounts of essential nutrients. Zhao et al (2019) found that incorporation of residue, in comparison to removal, would increase the presence of nitrogen, phosphorus and potassium in the top 20 cm with more than 15%. Organic carbon would also increase with 22%. This leads to increased crop yield (Reddy & Mehta, 2021). When it came to the claim concerning reduction in usage of fertilizer, Xia et al (2020) did a two-year survey into how incorporated biomass and reduction in nitrogenous fertilizer impacted yield within a rice-wheat system. Their test soil was not under an RWS regime so there could be factors that are drastically different here that I am not able to grasp. Their findings seem to suggest that a 20% reduction in nitrogenous done in tandem with straw incorporation would lead to a 4.6-6.7% yield increase, and an increase of organic carbon in the soil with 2.6-6.2%. With a reduction of 40% nitrogenous fertilizers however, the yield drastically sank. They concluded that nitrogenous had to be optimised. Finding the goldilocks of nitrogenous usage when incorporating straws is essential and required more care from the farmer then what had previously been the case (Yadvinder-Singh, Bijay-Singh & Timsina, 2005). Malik et al (2022) did field tests within the RWS in Punjab on different incorporation and fertilizers regimes. Their study suggests a 50% reduction of fertilizers while incorporating the residue would be optimal for increasing yield. Several other studies have also found biomass incorporation to have positive effects on reduction of fertilizer, yield, and overall soil health (Rasmussen et al, 1998; Misselbrook, Menzi & Cordovil, 2012; Rosegrant et al, 2014).

Through the last three sections we have seen how new actors within the in-situ assemblage, like the happy seeder and the super-seeder together with a tractor and the knowledge of the farmer are able to reduce the importance of another actor, fertilizer. These associations are vital for the assemblage to function, but this is only what is visible from the point of the farmer. It has been made clear that the interest of the farmers gets enrolled through the correlation between financial and environmental sustainability. The most vital actor, the one that does the translation process from residue to value, and from value to interessement is a more-than-human actor, one that thrives under this regime, but suffers under another, the fungus.

7.2 Fungus

How exactly is it that these nutrients get transferred from what has gone from straw, to soil, and then back again out into the straws?

In order to understand these new associations created in the wake of the in-situ assemblage, I once again let the science show new aspects of my field site that I was not able to observe with the naked eye. One interesting aspect here is that biology and ecology have recently started to emerge as the hegemonic voices in soil science, taking the spotlight from the academic disciplines chemistry and physics. Whereas these disciplines had focused on inputs and outputs, biology and ecology were advocating for a more holistic approach towards soil science where all the components that constitutes soil, and its doings where appreciated (Bellacasa, 2015). These components are referred to as microbes and include fungi, bacteria, actinomycetes and algae to mention a few. Microbes live in a dynamic synergically relationship with its surroundings (Garacha, Katyal & Sharma, 2016). Sharma, Singh, and Kumar (2020) found incorporation of straw to enhance microbial activity in the soil. When biomass gets incorporated into the soil, the different biomasses get activated. The fungus, the same fungus that was seen as the villain for the incinerating farmers, is an ally when decomposing the incorporated residue (Chang, Fan, Wen, 2012). The fungus breaks down the complex structures within the residue performing a vital intermediary role within the assemblage. This process releases the nutrients to the soil (Mäkelä, Donofrio & Vries, 2014) that again can get absorbed by the wheat (Rubio et al, 2014). This process also gradually increases the

SOM within the soil, which is positive for overall soils health (Duiker, 2018) but also comes with externalities of its own which will be the focus of the following section.

This section is an interesting contrast to the claims made in the previous chapter, where the fungus was the villain mediator that was solved with fire. This speaks of Latour's (2007) thinking of how the same actor can play different roles, depending on the assemblage which the actor is part of.

7.3 Water

Now we have seen how the different actors within the assemblage have been enrolled, from the knowledge the actors gain, to the machines, to the fungus, to strengthen the biomass in the soil with the result of increasing yield and saving fertilizer. All beneficial outcomes for a farmer. In the following section, we will look into how the water holding capacity of the soil gets translated through increased biomass in the soil, and how this affects water usage. This is a positive outcome in its own right, but through bringing these insights with us, we will see in section 7.4.2, how other aspects, related to GHG emissions change when the soil's water regime changes. I will rely on prior research on the topic to build my argument. I was nudged into researching the water saving capacity by Informant 19, the professor at PAU, who said: *"The soil improves in plenty of ways, it holds water better, nutrients stay within the soil..."*

A quantitative survey, conducted by Singh et al (2019) in Punjab found that 62.5% of the asked farmers that were all doing in-situ believe that it would help conserve soil moisture, which is a different way of saying less irrigation is needed. This is in line with views stated by informant 19 and 27. Informant 11 would claim that more water is needed, because as the soil becomes less sandy, the water does not stagnate in the fields. Interview 12, 14, 16, 18, 19, 22 also spoke of how soil's water needs changed with in-situ. I went towards the literature to get numbers to back up their claim. Hudson (1994) who has been cited by FAO[53] (2005), said that on average 1% increase in SOM would increase soils water holding capacity by 3.7%. Due to the increased SOM in the soil, water subtracts and stays within the soil. This removes surface water but is still available for the plant. In the process of removing surface water, water evaporation is also reduced, meaning more water is available for the plant at all times (Zeleke et al, 2004; Singh, Jalota & Singh, 2007 Bhatt et al, 2020). I later confronted informant 11 with this during a phone call, and he would admit that due to the invisibility of the water, he had just assumed he would need more since he had been taught that the paddy needs to stay drowned in water. Due to the free electricity on pumping ground water, he did not really have any relationship to the water he consumes, hence, he would pump up more to make sure the paddy had sufficient water. His mentor, informant 12, on the other hand, had identified the water altering effects that in-situ caused as positive. The interview is done through an interpreter:

> *"That's because of the benefits that I told you. These are the next crops; they are much better. The soil becomes porous. And water stagnation is less. Also, in the next year, when the soil from the bottom where you have buried the paddy comes up, it becomes into total manure. So, it is very beneficial for them. Because they are into agriculture for the long term. For*

[53] Food and Agricultural Organization- I have inserted this here to put ethos behind the claim.

them, they know the benefits of it now. And they cannot switch back to being ignorant farmers who don't care." [54]

How much water is saved in real numbers? This I have found hard to answer, most articles are concerning soil's water holding capacity, and do not mention how much water that is saved. The first conducted research on this topic in Punjab that I found was by Baldwinder-Singh et al, 2011. They looked at residue managed by happy seeders. The article found that the plant compensated by increasing transpiration, referring to the process of water being uptake by the plant, while at the same time reducing its efficiency, meaning water usage was the same. This article I find somewhat flawed, and premature, with the soil being exposed to the in-situ regime for a short time. As we will see further down in this, SOM builds up gradually and SOM and the soil's water holding capacity is relational, meaning increasing SOM increases water holding capacity (Hudson, 1994; Bot & Benites, 2005).

There is a qualitative survey by Singh et al (2019) that claims that the farmers had seen a 20% reduction in irrigation hours, which they stated would amount to a reduction of 296 m^3/296.230 litres of water per acre[55]. If we go to a wheat-maize system in China, Zou et al (2020) found reduction in water usage after incorporating residue to vary between 4% and 22%. Apart from this article I have found few articles that look at the direct correlation between amount of water reduced and SOM. At the same time there seems to be consensus regarding that increased water holding capacity within the soil decreases the need for water (Hudson, 1994; Reicosky et al, 1995; Bryant, 2015; Gould, 2015; Eldridge, 2018) but all articles look at what happens to the soil, meaning its water holding capacity, not actual water use reduction. This leads me to think that this research has primarily been conducted by soil scientists, where water saving is a positive externality. Due to this, I will rely on the lived experiences of the farmers from Singh et al. (2019), who said they had reduced their water with 20%.

As Hudson (1994) has proved, the water holding capacity increases as SOM increases. SOM takes time to build up, and through the proper methods will increase every year (Duiker, 2018). This means; by relying on 20% reduction, I will lose the catalysing effects that would come by persistent construction of SOM. Hence, the number might be higher, it might be lower, but when dealing with soil science, I have learned, and as you will see, keep on learning, that one cannot be spoiled by numbers of representative truths. In section 4.6 we saw how the canal system was short of on average 28.8% water that needed to be met with groundwater exploitation (Singh & Bhangoo, 2013). This means, a 20% reduction of water usage would go a long way in reducing the groundwater exploitation. Another externality of this would be reduced electricity usage due to less need to pump up groundwater.

In this assemblage, the interest of the farmers gets transferred to see the fungus as their ally, helping them to solve the problem of biomass and increase its yield with a reduction in cost. Through this process, other actors get impacted. Fertilizer reduction, a healthier soil (according to the biologists) and a drastic reduction in the exploitation of groundwater. This whole assemblage is depending on that the fungus works as a loyal intermediary. Could other actors push the fungus into mediator mode again?

---

[54] I included the whole quote because it is a great summary of the things that has been discussed earlier. Also, this quote speaks off the farmers motivation when doing in-situ in a great way: in it for the long-term.
[55] They found this number by extracting 20% of 3661 m^3 per hectare, a number produced by Kaur et al (2010). Kaur is a co-author on the Singh et al (2019) article, but the number is produced in a different setting.

7.3.1 Time

Time scarcity is already a concern that is one of the main drivers for the incinerating assemblage. Time scarcity was also perceived as one of the biggest obstacles in the in-situ assemblage, and was brought up in interviews10, 30 and 31. Also in several group conversations, all with incinerating farmers in Bathinda, in-situ was seen as a little reliable alternative to burning due to the fear that residue would not decompose in time and lead to spoiled wheat crops. I will now examine if there is any hold in these claims through an interplay between literature and conversations. This is relevant for my report in order to prove the potential that exists within the associations of residue, mulcher and microbes.

Singh and Sharma[56] (2020) conducted a seven-year experiment at four different soil plots in PAU Ludhiana. They simulated RWS, with harvesting and incorporation of residue in the 3rd week of October. In the second week of November the wheat was planted for the rabi-season. This resembles the timeframe I observed the farmers work with during my time in Punjab. Their nitrogenous dosage from each respective plot was 0, 90, 120, and 150 kg. They concluded that all the residue decomposed in all the plots. Another finding from their study backs up the claim made by my informants: all plots, regardless of fertilizer input, saw an increase in their yield when incorporating the residue.

The same quantitative survey that started the water section 7.3, conducted by Singh et al (2019) asked farmers if non-decomposition of straws was a problem in 2017-2018, meaning, these were the early adapters, building on little experience. They used a Happy Seeder that does not till the soil[57]. 25.71% of the farmers said it was a big problem that residue did not decompose. 65.71% said it was of medium concern. A potential weakness in their survey is that it is very general. The article does not say if the farmers are experiencing decomposition issues on their whole field, or on limited spots in the field. The questions and alternatives they are asked do not give place for nuances.

One farmer I interviewed (28) had experienced decomposition problems on small parts of his field. This is also the only time I heard any concerns regarding this from any of the farmers I interviewed that were conducting in-situ incorporation. "*The soil, it is not level, it is uneven. You will find that some parts of the soil are more compact so to say, than other parts"*. This did not impact his overall experience with in-situ and the conversation was in general a tribute to the benefits he had experienced after being enrolled in the in-situ assemblage.

Still, my data collected at the fields from farmers already performing in-situ, the ones that had lived experiences, did not raise any concerns regarding decomposition (informant 11, 12 & 15). If decomposing appeared a problem, the company that gatekeeper 3 worked for was at the moment working on a decomposer, made out of natural fungi and other microbes that would ensure absolute decomposing. They were giving it out free of charge. One kg of decomposer is enough to decompose 5 tonnes of residue. He also claimed that there were specific bacteria inside the decomposer that fight off unwanted fungi and thus ensure there was no crop-destroying fungal outbreak, which was the main concern for the incinerating farmers in chapter 6. This could be the actor that ensured that the organic actors within the in-situ assemblage never turned into a mediator. To

---

[56] Informant 19 had contributed indirectly on this article, so I am here following the actors, just that his claims are peer-reviewed.

[57] Super seeder, the other prominent in-situ machine in Punjab tills the soil, and there could be a different result with this machine.

summarise, my data indicate that time constrains is not a major issue for the in-situ assemblage in general, with stable decomposition and increased yields.

7.4 Greenhouse gases

In the previous sections, I have explained how new enrolment made the different actors associations within the in-situ assemblage act in a way that created benefits for the soil. We have seen how these benefits impacted water. In the following section, GHG emissions related to the in-situ assemblage will be discussed in order to answer research questions 2, that is exploring the consequences of the different assemblages, good or bad.

The first number I will examine is how the reduction of fertilizers contributes to reducing GHG emissions related to the RWS. When trying to find data on reduction of fertilizer and GHG emissions related to fertilizers I have found deviating numbers, both within my own data, and from the scientific articles. Due to this uncertainty, I decided to work with the lowest numbers possible, to avoid glamorising in-situ. This means, the actual numbers are probably higher than the ones that will be presented here.

First, I will present the amount of GHG that comes from the production of fertilizers. Here, I also encountered an array of numbers. Jain (2023) found the supply chain of nitrogenous fertilizers released 23 tonnes carbon and will be the first one I examine. Down to earth (2019), an Indian popular scientific magazine, wrote an article based on a CSE report I am not able to access[58]. In the report they examined emissions related to production on different sites across India. They found the best performing sites to range between 0.43 and 1.13 tonnes of CO_2 emitted per ton of urea produced, but would also state, as is "common" knowledge that the biggest GHG emissions related to urea is not from production, but from usage. Kusin (2015) presents numbers regarding the emissions through usage of nitrogenous fertilizer that I have broken down into kilos. According to these numbers, one kilo of nitrogenous would emit around 9.74 kg of CO_2-eq when applied to the fields. This would add up to 10.2 kg of CO_2-eq per kg. With a reduction of 22 kg of urea, as informant 28 claimed, this will lead to a reduction of 224.4 kg CO_2-eq per acre related to urea-fertilizer.

Another important fertilizer was DAP, which mainly adds phosphorus, but with an 18%nitrogenous content it is also applied for its nitrogenous attributes (KRIBHC, 2024). A Chinese article, meaning, Chinese supply chain, found DAP to contribute with 39.2kg of CO_2-eq to the atmosphere per kg produced (Gong et al, 2022). Fertilizer Europe (2014) claimed production would emit 2.03 CO_2-eq, while usage would bring the total up to 11.27 CO_2-eq. Goel, Kansal & Pfister (2021) did a survey where they examined different options for sourcing phosphorus fertilizers in India. They found that production of DAP would emit 8.32 CO_2-eq. Unfortunately, I have not been able to find value chain surveys for India, as for China and Europe, hence, the number is probably higher. DAP do come with emissions when applied on the fields (Hasler et al, 2015), and from my understanding there is no reason to believe this to be lower than the emissions found in Europe which saw an additional 9 kg of CO_2-eq reaching the atmosphere after production. In order to do this just, we would need a number. Hence, I have added 8.32 and 9 together which brings the total CO_2-eq per kg used to 17.32. It is probably not

[58] CSE stands for Centre for Science and Environment and is a public interest research organization based in Delhi. Down to Earth is their tool to communicate with the public, meaning it's based on a scientific report. Here is the link to the report: https://www.cseindia.org/release-of-grain-by-grain-cse-s-new-report-on-environmental-rating-9602.

correct, but the number is probably rather too high than too low, with India's transport sector being still overly reliant on older diesel trucks[59] (IEA, 2021) among other factors. Through observations I got acquainted with the Punjabi traffic, which is inefficient due to flawed roads and a chaotic traffic picture that makes it impossible to drive economically[60].

Informant 28 claimed as we saw in section 7.1 that he would reduce the usage of DAP with approximately 22 kg after two years. If we stay in the lower segment as promised in the interlude to this section, that will mean a reduction of CO_2-eq related to the RWS of 381.04 kg per acre.

Through this we have witnessed how the interessement that was transferred towards the farmer can lead to a direct reduction of GHG emissions due to certain actors like fertilizers becomes less significant within the new in-situ assemblage. The total reduction of GHG per acre just due to fertilizer-reduction is 605 kg of CO_2-eq. As we saw in section 7.2, essential nutrients became available to the plant due to the working of the strengthened diverse biomes that were able to thrive in the soil. In the process, positive climate externalities are created through the reduction of fertilizers.

7.4.1 GHG related to burning

We saw in section 4.2 that burning one ton of paddy residue would result in 1460 kg of CO_2. This was 398 kg of carbon before it was mixed with two oxygen atoms. If we add on the 60 kg that was also a biproduct, would mean that one ton of paddy equals 458 kg of carbon. As was mentioned in interview 19 and 27, carbon content in the soil does increase when adding biomass. This entails that the soil work as a carbon storage unit when biomass is incorporated into the soil. How much that will remain and stay in the soil is debatable and depends on soil type, and soil disturbance through till, no-till etc (Stockmann et al, 2013). Meaning, Super and Happy seeder will yield two different results. A report by NORSØK written by Serikstad, Pommeresche, McKinnon & Hansen (2018) claim that normally one third of the carbon that goes into the soil are stored. Barcena et al (2016) found that the soil's capacity to store carbon was at its greatest when carbon levels in soil is already low, which would indicate that Punjabis soil is perfect for capturing carbon, based on the detrimental numbers presented in section 4.5. But assuming that one third of 458 kg gets stored by one ton, that means 152 kg of carbon, that would lead to 557 kg of CO_2 if released into the atmosphere. At the same time, 1114 kg of CO_2 would be released in the process, but that is still a better number than 1621 kg of CO_2. By now, adding fertilizer reduction and the increased stored carbon, in-situ has reduced 1162 kg CO_2-eq per acre.

7.4.2 Changing water system changes methane emissions

In section 7.3 we saw how the increased biomass altered the soil so that the paddy did not have to be constantly flooded. Flooded paddy fields are the main reason for the high methane emissions that are associated with paddy cultivating. By moving away from the flooded field practice, the methane emissions are drastically reduced (Singh and Benbi, 2020; Singh, Jalota & Singh, 2007).

Ranguawal et al (2023) found methane emissions per acre in Punjabi rice-fields to emit 1631kg of CO_2-eq per acre due to the flooded fields. Sanchis et al (2012) claim that rice

---

[59] Heavy fright trucks represent 45% of all GHG emissions related to the transport sector in India (IEA, 2021).
[60] Highways are filled with cars, buses, rickshaws, pedestrians, cows, bikes etc that are all moving in their own preferred speed with no lanes being respected.

field methane emissions could be reduced by up to 90% by moving away from flooded fields. The same article would claim that incorporation of residue would lead to increase in methane emissions in the breakdown process, but it "fails" to account for the alternatives. Cordeiro et al (2024) surveyed the methane emissions in India under different residue management regimes and found incorporation to bring about the lowest emissions. Saptoka et al (2015) confirmed this, and claimed net emissions will be reduced during incorporation compared to other options. At the same time, it is important to note that the result will vary immensely, depending on if the field is treated with tillage or no-tillage (Kiel, D'souza & McDonald, 2015[61]. Jain et al (2000) found that by moving away from flooded fields in paddy cultivation in northern India, towards intermittent flooding of the fields[62], there was a reduction of between 6.47 kg and 16.19 kg of methane emissions, which means 161.86-404.69 kg of CO_2-eq per acre, or 28%.

7.5 Enrolling assemblages

One of the most important methods that were used to translate the interest of farmers was through knowledge-enhancement. Several of my sources that did not perform incineration would say the main reason for incineration was the lack of awareness in the farmer, but also lack of knowledge of the alternatives and what benefits could be gained through changing methods. Not only did they have to acquire new knowledge, but they also had to de-learn their old. How were they made aware? In this section I will show how different actors worked to spread the in-situ assemblage. This is relevant for answering research question 1, where I am tracking the different actors within the assemblage.

As mentioned earlier, there was an array of different technologies enrolled to impose the governments interessement, which is to lower the AQI in Delhi. There were advertisements of solutions and of warnings of consequences, but also messages guided farmers to information centres.

The PAU facility with the in-situ machines where I conducted interview 14 worked as one such information centre. Here farmers could come to learn new skills. The week before I came there, they had had a workshop with more than 200 farmers that had been informed about the benefits and getting instructions of how to incorporate the residue into the soil. They were instructed on how to use the different machines that were essential for in-situ to become a reality.

The company that gatekeeper 3 worked for had set up model farms to impose interessement for their solution on the farmers. This is the response to a question regarding how they would work in order to enrol farmers towards in-situ during interview 27:

> *"One thing is model farm. Our company holds a model farm of two and a half acres in the heart of the Basmati cultivation area, cultivating area, where whatever we are promoting to the farmers, we demonstrate it in our farm. So, whatever is happening, that we are promoting, we demonstrate, we experiment ourselves and then we dictate to the farmers. The*

[61] This is another aspect the in-situ assemblage could mitigate through the roll out of Happy Seeders, the no-till method could become more prevalent.

[62] This means short periods without standing water, so not the exact same thing, but the article can still give an indication.

other thing is we do step by step. Like we select the farmers who are progressive, who want to adopt new technologies. With those farmers, we select some area which we develop as a model farm."

Both these examples show institutional ways of performing interessement, but as we saw earlier with informant 11 and 12, they would also work actively to enroll other farmers into the in-situ assemblage. Informant 11 has two quotes that speak of their role, one is "*All the farmers that I know, personally, they do not burn, they now do in-situ, it is rationale"*. But also, when asked what he would do if he found out that one farmer in his circles would burn his residue as a solution he answered: "*We would scold him"*.

7.6 Obstacles for the assemblage

In this section I will bring up an example of how and why a farmer was tempted to leave the annual performances of the in-situ assemblage. While this is an interesting case by itself, I would advise you to have more focus on other pieces of information that come from this interaction. Through listening to his frustration, actors like money, diesel usage and carbon emissions get presented, important information in order to answer research questions 2.

The businessman farmer (informant 11), the one advocating for in-situ was having concerns around the fuel bill he had experienced after incorporating the residue. When I talked to him at the end of my trip he said *"Only diesel, fuel bill. For in-situ... Yes, three lakh (300.000). Three lakh"*. This was for 40 acres, meaning 7500 INR per acre. To put that in context, Jaswinder (2023) found the gross income per acre in Punjab to be 42.600 INR. This means, that the cost of in-situ represents 17.66% of the profit margin. He would use 30 litres per acre he told me. One litre of diesel emits approximately 2.7 kg of CO_2 (North, 2006), this means 30 litres would amount to 81 kg of CO_2 emissions per acre in order to stabilise the in-situ assemblage.

But why had my informant's interests started to be translated away from in-situ? This was a person I had on our prior meeting seen as more than an intermediary, but one actively working to enrol new farmers into the in-situ assemblage. A new actor had appeared within his assemblage, talking about the prospect of biogas. He had now changed his stand on in-situ, claiming it would be sufficient with occasional incorporation of residue. Informant 11 told me with his newly acquired knowledge:

"No need of in-situ. If you once done or once in a three years, once in a four years, it will be okay. But every year it is like so much hectic and needless."

What I witnessed here was different interests making him into a mediator, an unfaithful conveyer of the in-situ assemblage. He would claim that the soil would see the same benefits. But why, was it only money? No, he still claimed financially he was saving more on fertilizer then he used on diesel, it was mainly the workload. In-situ is a performative solution, where different tasks need to be performed in the correct order. His worker, the one I introduced earlier, testifying to increased soil health, was opposed to in-situ. The message was done through an interpreter, but I could see from the body language and the pitch of his voice that he was agitated saying that the work is too much.

"Different machines. Mulcher is a different machine. After mulching, rotavator is a different machine. After rotavator, the plow, that is a different machine. Then the disc is a different machine. And at the end of the tractor, you have to change the machine. And after that the leveler is a different machine. They are all different machines."[63]

This he said, is especially problematic if the farmer does not get time to harvest before mid-October. Then they will not have the time for all this preparation for the Rabi-season. There could be several reasons that could disturb and then postpone the harvest. The field we were conducting the interview on had delayed their harvest for five days due to an unexpected storm that had flooded the fields. To drain the water quickly, they had sacrificed a small plot of the land, creating a hole they would lead the water into[64]. Tinkering, but it also shows how even if you have all the machines and all the knowledge, an unexpected actor, in this case the weather, can come in and deprive the assemblage of their agency, forcing them to think in different ways from what previously would have been needed. During the regime of incineration some extra days would not have been a problem, but now it was the difference between incorporation and incineration. This shows how in-situ is a solution that demands a lot of care in order for all the actors to be intermediaries. It can also speak of why in-situ is not an attractive option for some farmers with heavy workload and financial expenses, which will be the topic of the coming section.

7.6.1 Finances

Here we will see both how money was an obstacle, but also how money was used as a way of performing interessement for the farmers towards in-situ. By this I will explore further how the in-situ assemblage gets enrolled. Simultaneously I will show the big threshold farmers need to be able to step over to perform in-situ and then why the alternatives, ex-situ or burning, can be a tempting option.

The local government's agricultural office I visited (Interview 13 and 18), worked with rolling out the seeders among farmers, using subsidies as a tool. The prices for a super seeder could vary between 150-250.000 INR[65] which government covered 50% of. They told me there was sufficient machinery for in-situ in the market now to cover the soil's demand, but the market demand was lacking. The subsidies did not apply for running charges like diesel, or if a bigger tractor was needed to pull the seeder.

As we saw earlier, the business-farmer (11) had used 300.000 INR to incorporate the residue, a big cost he would say, while at the same time stating he could afford it. Informant 11 also put out his thoughts of the problems of acquiring the different machines. Again, he would say, that for him, that had the financial means to think long term, and make the required investments, but would sympathise with the people that did not have the means to make the choices he had done:

[63] This quote talks about his feelings concerning in-situ and is not relevant for which machines to enrol. Many of these machines are now combined or exclude each other, like disc or rotavator- meaning I will not rely on this quote when discussing machine-enrollment in other segments of the thesis.
[64] See picture in appendix A
[65] Also confirmed in online store https://www.tractorjunction.com/tractor-implements/super-seeder/

"And it will take so much investment also. It will take a bigger tractor, 4x4, like, a minimum 10 lakh, 15 lakh investment in a tractor. And implement, so, 5 lakh or 4 lakh. It is very, very, very, very hard for the small farmer. It is very hard. So, it is like, for the small farmer, it is very difficult to practice. Okay, but nowadays, there are persons... All the people are doing, like, in the rent also. Like, you will give me 9,000, I will do it for you. India is a very diverse economy. The human resource is very cheap here. You know that. So, people come and plough for you, and things do for you also."

The latter part of the quote refers to farmers that do not have the means to acquire the tractors themselves would rent what was needed from bigger actors, effectively causing a trickle up effect. This solution would be problematic, since smaller farmers would have to wait until the bigger farmers were done and could potentially lead to forced burning due to time running out (notes from group conversation).

Informant 11 would further elaborate on the problems smaller farmers face regarding finances. Here he is drawing lines to what has been discussed previously in this chapter; how in-situ takes time to yield benefits. What he says here, regarding how an alternative is selling the residue, will be relevant in the following chapter where I discuss the third solution, ex-situ.

"My Indian farmer is more likely to capture short gains, short-term profits. They are not a long-term, they are not able to think long-term. Very less, like our people, very less, big farmers think long-term. Yeah, this will benefit next year. But small farmers have very small capital and small time to have gains. I will take, they will prefer short time practice, if someone offers them 4000, they will sell it [Residue] because they love to, love short-term profits. Not like us. We are having a lot of things to, like, a lot of business, another business also. We are not dependent on this. The people are dependent on this, like, five to six acres only. They will love to sell it, okay? They love to sell it because they can gain instantly. "

I am here allowing him to speak on behalf of more precarious farmers. I chose his quote due to the inclusion of details, but I will provide another quote uttered by a farmer's son (Informant 10) that held a degree in agriculture.

"The government of India do not provide us machines. If the machines are available, then they are very expensive for us. All small farmers, marginal farmers do not afford them. So, they have to burn it."

When we were discussing in-situ over ex-situ as an option for farmers, the professor at PAU (Informant 19) would also mention the problem of enrolling the farmers when the option of instant money could be more tempting for small farmers in distress[66].
It is hard to translate someone's will if they themselves need to carry the financial burden for an abstract potential return in the future. That is a luxury many farmers in Punjab do not have. For these farmers, the ex-situ assemblage, which is the focus of the next chapter, might be a better option, where residue is given an instant monetary value.

7.7 Summary - Research question 1

In this chapter the different actors that are part of the in-situ assemblage have been unveiled. We have seen what works, and what the in-situ assemblage makes work, and this summary is a suitable place to answer research question 1 which states: W*hich human and non-human actors are part of the respective solutions to the problems of residue?*

PAU, the future-maker within the in-situ assemblage, uses a variety of tools to impose interessement towards the farmers to enrol them in the in-situ assemblage. Some of these translating actors within the in-situ assemblage are also part of the consequences, since they are actively being promoted, like the reduction of fertilizer and the increase of yield. These consequences will be relevant to answer research question 2, which will be the topic of chapter 9.

PAU has for years now produced knowledge concerning how to best incorporate the residue into the soil for it to decompose. To enrol farmers in this assemblage, there has been both formal and eventual informant knowledge distribution. One way is the model farms and information centres that were established by both PAU and the international corporation that gatekeeper 3 worked for that was exporting paddy. They used a mix of public awareness campaigns, and workshops and machine training in order to enrol the farmers. The informal distribution of knowledge is between the farmers themselves, as we saw they shared the secret of their increased yield, which worked to impose interessement towards other farmers. The shame of burning that evolved in certain circles is also part of leading farmers towards the in-situ assemblage.

PAUs knowledge production has also spurred the development of the different seeders that are used to incorporate the residue into the ground. The government is trying to make the seeders more attractive through subsidies, but these are often not sufficient to get the interest of the smaller farmers, because the threshold is still seen as too high. The seeders need to work in tandem with a mulcher and a sufficiently sized tractor and the diesel required to run the operation. These associations together enrol the residue in a way that activates the more-than-human actors that live in the soil. This is when the actual translating process of the farmers' interest occurs. The microbes break down the nutrients within the residue and transform it back into the soil. This increases SOC and SOM and microbial diversity within the soil. Through enrolling the microbes as an ally, the farmers can empirically witness how their soil's attribute, appearance and yield changes. For the farmer, soil health is positive, but saving fertilizer and increasing yield are strong arguments for being enrolled in the in-situ assemblage.

In this chapter we have also covered the other actors that exist outside the residue handling framing, and that are more explicitly related to research question 2, which is

[66] This was said after I ended the recording and we were saying our goodbyes, so I do not have a direct quote.

how in-situ increase SOM and SOC, reduces carbon in the atmosphere and the groundwater depletion. At the same time, in-situ demands a lot of up-front cash, something that is not supposed to be a problem for the following assemblage: ex-situ.

8. Findings 4: Ex-Situ

In this chapter I will explore the last assemblage that I will bring up in this report; ex-situ, which means to handle the residue outside the fields (Kaur et al, 2022). There will also be a focus on the future-makers, the actors, and how their interests are imposing interessement and shape the actors that become part of the assemblage. There will be an understanding of how soil is perceived, and what consequences these perceptions have for the more-than-human actors that constitute the soil under Punjab's RWS. The summary will be used to answer research question 1.

8.1 SAEL and renewable energy

As mentioned earlier, there are many different ways of performing ex-situ, with different products being produced by the residue (Dutta et al, 2022). This report will focus on SAEL, an Indian company that has managed to get funding from international actors like the Norwegian government fund Norfund, and the Asian Development Bank (Norfund, 2023; Asian Development Bank, 2023A). During my fieldwork many of the other ex-situ options were very low-scale and focused on the locale. SAEL is scaling up and their link to global actors makes them an interesting case study due to their major growth potential. Another reason why SAEL is interesting is its branding as a renewable energy infrastructure, an infrastructure which often finds itself in conflict with nature (Gulbrandsen, Inderberg & Jevnaker, 2021).

The option SAEL offers is based on extracting the residue from the field and incinerate it in a power plant. Through this process it will be turned into what is defined as renewable energy (SAEL, 2024). The carbon that is emitted in the incinerating process is captured during the sequencing crop planted on the same fields, that will extract the same amount of carbon from the atmosphere, essentially making it a carbon neutral energy source (Schlamadinger & Marland, 1996; Herbert & Krishan, 2016).

8.2 From the soil to the atmosphere

In the following section we will become familiar with how SAEL's ex-situ assemblage works. I will also present some statements given by key informants that are involved with SAEL to unveil the interests that exit within the future-makers doings. I will in the following sub-section present findings from an interview I had with informant 1 that represented a sizeable investor in the company. From this interview I will first present why SAEL was seen as a sustainable investment. I will complement this with citations from other scholas to show how aspects of the investors' interests regarding sustainability are "common knowledge" regarding problems with renewable energy and the green transition in the global south. What I extract from this interaction will unveil points that will be used in the discussion in the following chapter up against Callon's "framings and overflows". Through the conversation I will also unveil the performative process that needs to be conducted for the residue to be turned into energy, an aspect that will be important to understand in order for the assemblage to be fully illuminated.

In my conversation with informant 1 I was told that the Global South encounters distinct challenges compared to the more robust economies of the North in expanding their green energy capacities. For instance, coal plants, while relatively inexpensive to establish, come with running operational costs over their lifespan due to the continuous need for coal to generate energy. Renewable energy infrastructure entails high initial investments but offer the advantage of lower operational costs. However, in countries classified as high-risk, these upfront costs act as a significant barrier to investors and financial institutions, leading to either a lack of investment or elevated interest rates. This scenario renders renewable energy projects less appealing to economies that are already under strain. This is also conventional thoughts about energy infrastructures within the literature and can be found in Pengels, 2010, Stram, 2016 and Sachs et al, 2019 to mention a few. According to informant 1, their investments seeks to address this issue by allocating funds to support the construction of renewable energy projects in the global south, thereby facilitating a transition towards sustainable energy solutions. The investors had identified India as a high-risk country for increased GHG emissions, and hence SAEL was a company that matched their profile, being an Indian renewable energy company.

Another issue highlighted by Informant 1, more intrinsic to renewable energy than to the global south, that makes SAEL a promising investment, was its approach towards addressing the inherent challenge of weather-dependent renewable energy sources' load stability, which renders them an unstable energy source. This problem is documented by Falchetta et al.(2019) and Ezhiljenekkha & Marsaline Beno (2020) for example. SAEL's power plants relies on biomass that operates like a coal power plant. This means, the energy demand could be ensured through the storage of residue, which is also documented in Kurinji and Kumar's (2021) report on using paddy residue as part of an energy infrastructure in Punjab.

Through this we can draw lines back to Tsing (2015) as elaborated on in section 2.1.1.1, and her idea of how the local, through certain actors, in this case SAEL, gets bound up in other locals. The investor is one such actor from a different locale, who brings in money that can work as tools for imposing interessement, through expanding the assemblage's operations. At the same time, the assemblage does not end here. The translating association within this assemblage is the knowledge that they are operating under. This knowledge, on the problems and solutions concerning renewable energy, especially in the global south, and how the world needs to produce more green energy is an insight that has been produced interdisciplinary globally in the last years. These processes and perspectives moulds how the actors act and see themselves and their surroundings within the ex-situ assemblage. A relevant notion for research question 3.

8.2.1 Handling residue

There are several steps that the farmers need to make to turn the residue into commodity for capitalisation. The process the farmers had to go through, as I was described by informant 1 and 30 is identical to the process that was explained by informant 3, a farmer that delivered the residue to a cardboard company. An essential difference between SAEL and the cardboard company is that for the cardboard company to collect your residue, informant 3 would have to pay the company for the process. SAEL are paying the farmers, but it comes with a bigger responsibility for collecting and transporting the residue for the farmers (Interview 1, 30 and 31).

Before transporting the residue to the power plant there were numerous performances that had to be conducted, I was told in interview 1 and 30. First was the obvious, paddy had to be harvested. Then, the remaining stubble would have to be mulched down. This is done with a similar mulcher as was used when doing in-situ. Now, all the stubble was loose residue covering the fields. After that, it was preferable that the residue would sun dry for some days. This is because of requirements from SAEL for maximum humidity level within the residue for the residue to burn properly. The residue would then be collected and shaped into standard sized by a bailer. After that, it would have to be taken with a tractor to a collection centre, where it again would be transported to the power plant. By this account, we can see that the performances conducted on the field require more steps compared to the in-situ assemblage we explored in the previous chapter: mulch, bail, collect, and then sowing would have to be done.

Informant 11 said three rounds over the fields resulted in 30 litres of diesel per acre, or 81 kg of CO_2 emissions. Adding another round would bring the number up to 40 litres of diesel or 108 kg of CO_2 emission per acre. After that comes the transportation of the residue out of the field which would come with new emissions. Kurinji and Kumar (2021) estimated that one tractor would be able to transport seven tonnes of residue with a big trailer connected to it, meaning one trip could cover the residue from approximately two acres. It has been hard to find the average travel distance that the residue is sourced from, but as I experienced in interview 2 when talking to the farmers next to the SAEL biopower plant:

> *"No one here sells to them, we sell once, we don't know anyone who gives them. You sell once, and never again. The pay is not enough to cover the charge of bringing, and also, we need to burn because of the mushroom".*

This could indicate long travel distances. I also at a point drove behind a tractor with residue dived up into standard sizes on the trailer[67]. One of the persons in the car I was in claimed that the tractor was going to SAEL[68]. This was around 40 km away from SAELs power plant outside of Bathinda. This distance with tractor and trailer would add approximately 20 kg of CO_2 per acre by relying on emission numbers found in

---

[67] See picture Appendix A.

[68] The highway would pass SAEL, and he was the son of the farmers that was interviewed in Interview 2 who lived right next to it. Also, we had a longer stop 20 km down the road. The tractor would surpass us, and we will catch up with it, this time 15 km away from SAEL.

Ramaschandra and Kashyap's 2009 article that looked into emissions related to the transport sector across India. This brings the total emissions per acre up to 128 Kg CO_2 related to the process of collecting and processing the residue before taking it to the power plant.

8.3 Energy production

The energy production is the final leg of the life of the residue. This is where it gets transformed into a valuable resource again. I will now follow the material actors within the assemblage located at the power plant. Through this I will unveil the efficiency rate in order to discuss how bioenergy can compete with coal, the most prevalent energy source in Punjab (PWC, 2020). We will also make acquaintance with an actor, the combusting engine, that, as we will see in section 8.6, demands a lot from its surroundings.

SAEL focuses on how their waste-to-energy solution could be a financially sound way of reducing the air pollution in New Delhi. The positive effects of this were said to be that farmers would earn money while at the same time renewable energy would be produced. I was told that one acre of residue would be sufficient for producing around one MWh of electricity. This was apparent through interview 30 and their website (SAEL, 2022). To confirm the electricity production ratio of residue, I have looked into documents produced in relation to plans for construction of new power plants by SAEL. I found a report by U.B Consultants[69]. They conducted a technoeconomic viability study for SAEL in 2018, regarding a proposed 18 mw power plant in Punjab. Here the number 1 kg of biomass for 1.2-kilowatt hour of electricity appears. This means, 1 ton creates 1.2 MWh. We know from before that one acre produce 1.295 tonnes of biomass (Sidhu & Beri, 2008). This means, even at half of full capacity, SAEL is able to process a large portion of the residue in Punjab today, but what about the efficiency of the technology?

The place where the transformation from residue to energy occurs is in a combusting engine called *Water cooled vibrating grade* (Asian Development Bank, 2023A). According to Luo and Zhou (2022) this is a rather efficient technology. Two documents produced by SAEL, for the ADB[70] (2023A, 2023B), expect an efficiency rate off 83%. Efficiency rate refers to how much energy one is able to get out of the potential energy that was there.

8.3.1 Friction for the farmers

Were there any problems here for the farmers? Since I have not been able to talk to any farmer that is linked to SAEL it is hard to pass a judgement, but SAEL does not provide the machinery, that needs to be acquired by the farmer. Machines needed are mulcher, bailers, trailer, and a strong enough tractor. Farmers that live in villages surrounding the Ferozepur power plant voiced concerns in a public hearing conducted by the governmental agency Punjab Pollution Control Board (2018). They are experiencing that they do not have access to the bailers that they would have to rent, the cost is 1500 INR, and that SAEL would source the residue from fields further away, meaning increased travel distance and carbon emissions related to the transportation.

When talking with other informants, they raised equal concerns when we talked about the prospects for ex-situ. Several of the informants (taken from notes) would say that they

[69] Full name of company: U.B. CONSULTANTS PRIVATE LIMITED PROJECT & MANAGEMENT CONSULTANTS
[70] The report is concerning Rajastan who uses the same technology as in Punjab, but not the same residue, hence, there might be deviating numbers.

had experienced or heard stories of people that would have to wait for the bailer machines, just like more precarious farmers doing in-situ that were forced to rent machinery. The bailers would first go to the bigger farmers, the ones with the money, and sometimes they never made it to the smaller farmers who then would have to rush-burn their fields to prepare for the next crop.

8.4 Health and fertilizer

Apart from producing renewable energy, SAEL (interview 30) identified the effects their technology would have on public health as a positive externality coming from their assemblage. This would happen because of the reduced usage of fertilizers as a result of how the absence of burning the soil would leave the nutrients in the soil. Through burning they would need to be replaced by chemical fertilizers for the soil to keep the same yield giving abilities. There is also a similar claim made on Norfund's (2023) announcement of the investment:

> *"High levels of PM 2.5 have been linked to health effects such as asthma and decreased lung function, and the burning of crop stubble also contributes to reduced soil quality, requiring increased use of chemicals which causes other health issues".*

I have already established in the background section that health issues can be caused by the high usage of fertilizer so I will leave that as a black-boxed fact. Still, could the soil benefit from the apparent reduction in fertilizer, if there is an reduction in fertilizer? On SAELs (2024) webpage they write:

> *"Apart from smog and a sharp rise in CO_2 levels, the paddy-straw burning by farmers significantly reduces the organic matter. Loss of major nutrients and microbial biomass in the soil affects crops off the next season. One ton burning accounts for the loss of 5.5 kg of Nitrogen, 2.3 kg of Phosphorous, 25 kg of Potassium and 1.2 kg of Sulphur in the soil. The farmers can thus save Rs. 300 per acre of Fertilizers/Pesticides."*

The professor at PAU (19) disagreed with this statement and argued that ex-situ would increase the need for fertilizers:

> *"The residue should all be there, in the soil. Burning is better than ex-situ if you look at soil health, because in ex-situ you take all the nutrients away, at least when you burn some is left."*

To understand the process that happened within the soil, I used literature to once again extent the understanding of the processes that could not be seen with the naked eye. I do this to properly answer research question 2 and explore how the different assemblages create new realities for their surroundings.

For the soil's mineral nutrients to be destroyed. the soil needs to reach a temperature higher than 350 degrees Celsius (Neary, Klopatek & Debano, 1999). These temperatures are rare even in forest fires. Usually soil stays below 100 degrees, and rarely penetrates deeper than the top centimetre of the soils layer when the biomass above the ground is burning. (Campbell et al, 1994; Certini, 2005). Gupta et al (2004) found the temperature in the soil during burning of residue in Punjab to reach between 33.8-42.2 degrees in depths down to one centimetre. They found this to have negative effects for microbes in the top 1 cm, but also to release between 23-73% of the nitrogen present in *that* layer of the soil. Then again, fire has for a long time been seen as an efficient way of releasing nutrients, and ash is proven to contain a lot of nutrients like potassium, potash, and silica. The residue has extracted nutrients from the soil in its growth phase, and through burning they would be released instantly and returned to the soil so they once again can contribute to the coming crops (Bodi et al, 2014). This means, turning residue into ash is a method to rapidly release the nutrients of the residue for the soil. The consequences of this are that if you are stuck with two alternatives, burning or ex-situ, there would be more nutrients in the soil after burning. Ex-situ might save one type of fertilizer, urea, but other types of nutrients would have to be added with different types of fertilizers. In total there would be a need to add more fertilizer than what has potentially been saved.

8.4.1 Air pollution and ash

In this section the technologies inside of the pipe will be examined to draw attention towards how SAEL is impacting air pollution, but also how they deal with ash, which will give an indication of how SAEL understands soil.

The incinerating farmers in section 6.2 claimed total pollution would stay the same, so how is making energy from the residue through incineration contributing to reducing air pollution? Informant 1 spoke of filters within the pipe, which is confirmed in reports produced by the ADB in relation to a loan application that was approved. According to the ADB (2023a, 2023b & 2023c) reports, all the power plants will be equipped with an electrostatic precipitator (ESP) and a filter bag. The ESP is a so-called filter-less filter that removes particles in the pipe through electrification (Mizuno, 2000). The bag-filter system collects the particles. Wang et al (2014) did a survey on a hybrid system that merged ESP and bag-filter on a coal-fired power plant and found the system to remove 99% of all P.M 2.5 particles. 10% higher than one solely relying on ESP for example. This entails, the power plant is built on state-of-the-art technology, and SAEL will contribute to reducing air pollution.

The ash collected in the filter, and what is left in the generator are being given a second life that could potentially contribute to mitigating the harm inflicted on the soil. The U.B report from 2018 that was produced on behalf of SAEL claimed that the ash would be brought to an ash silo and from there be distributed free of cost. The report states at page 54:

> *"The ash from the silo will be disposed of to farmers, who can use the ash as manure for the crops and to local industries, who will utilize the ash for manufacture of bricks, for road building material, for land filling locally and in Cement Grinding Unit for producing PPC[71]."*

I have not found any overview of how much goes to farmers, and if farmers did collect it in heaps, it could actually in some manner help mitigate the damage of SOM and SOC.

---

[71] The report does not state what is meant by PPC, but it is a form of cement that relies on high level of silica (Jahagirdar, Patki & Metan, 2019) that we now know is prevalent in the paddy residue.

Still, they would have to compete against easier to handle fertilizers in bags of 45-50 kg that you can buy at subsidised prices at fertilizer vendors. From my observations fertilizer vendors seemed to be located in every village across Punjab. I am doubtful if the farmers would make the effort of driving their tractors several kilometres to collect ash to then spread over their fields, a process that would require many more work hours and diesel. Still, I cannot conclude anything from this due to insufficient data, but I found the framing in the report concerning ash and farmers to be telling of how the soil was perceived within this assemblage: "*As manure for the crops*".

8.5 Soil

In the in-situ chapter, informant 19 made the claim that depriving the soil of its biomass would lead to decrease of SOM and SOC. We saw in section 7.2 that the more biomass that stayed in the field, the stronger the biomass will become, and the same logic applies here, extraction leads to degradation.

In the ex-situ assemblage the focus is on extracting the potential resources, and residue in the field is defined as a mediator that needs to be imposed interessement on through incineration for creation of energy. The more-than-human actors, the microbes in the soil, will not get the opportunity to thrive, and we have now seen how the microbes can play three different roles, depending on their assemblage. The incinerating farmers saw them as the villain, in the in-situ assemblage the microbes were the heroes, while in ex-situ the microbes are unrecognised victims.

We have now seen that through the ex-situ assemblage, the soil gets harmed if you understand soil health in contemporary lines that rely on the scholars from biology and ecology (Bellacasa, 2015) But how did SAEL and the investors respond when we discussed soil health and microbes? This is the topic for the next section and will be important for understanding how something becomes an overflow when humans are doing technoscience to fix a problem.

8.5.1 Soil representation

The data presented now will be used for understanding more concretely how perception concerning externalities has been, or not been, worked with. Meaning this is mainly relevant for research question 3 where I will seek to understand how the frame destines the outcome.

It has been apparent from the previous sections that soil, if recognised at all, it was in the relation to fertilizer and yield. I asked informant 31, who represents the investor of SAEL how soil had been recognised before the investment. First, I need to mention that the investor company had gone through a third party to check if SAEL was a sound investment, financially, but they had also checked if it would have any negative social implications. This entails the informant could not be 100% sure that they had not checked how the soil's health is affected. It should have been included in the report if it had been examined[72]. From the informants reply I got the notion that examining how soil is affected would have been too detailed for the scope of the investment, where money and renewable energy had been the main drivers.

The alternative to ex-situ, in-situ, was not seen as a doable alternative. In interview 30, with SAEL, I was told that it had been proved for over two years now that in-situ would not work because the residue would not be able to decompose in time. This the investor

[72] The report is not public.

seemed to agree on. I took this up again with informant 31 when I was alone with the investor, and the idea that residue would not decompose, and hence in-situ would not work was again repeated here. In section 7.3.1 we saw that there were few problems concerning decomposing of residue for the farmers that practiced residue.

Through the last section concerning soil, we have seen how the associations created within the ex-situ assemblage influence the more-than-human actors by depriving them of the biomass that could help built them up and by extension negatively impact the RWS.

8.6 Water

Now I will show how the ex-situ assemblage affects the consumption of water. As we saw in the background chapter, water stress is massive in Punjab, with an unsustainable overconsumption, meaning how one deals with water today, will have big implications for tomorrow. This section will be dedicated to the unrecognised actors within the ex-situ assemblage, relevant for research question 2.

In the in-situ chapter we established how, through informant 19, extracting residue would deprive microbes and SOM to build up and strengthen. This we saw had direct consequences for the soil's water holding capacity. These insights do not need to be discussed again and will now be used again. Where an in-situ assemblage would lead to increased water holding capacity, the opposite would be the case if SOM gets continuously harmed (Cucci et al, 2016). A consequence of this would be increased water use from the Punjabi farmers for the crops to have sufficient water. This would not only effect water usage, but also increase the energy demand of the RWS, since ground water is pumped up using subsidized electricity (Gupta, 2023).

Another aspect of SAEL's impact on water usage in Punjab, is that their technology would rely on enrolling large amounts of water to function. The actor that translates the residue into energy is called *Water cooled vibrating grade*, and it relies on water to stay a stable intermediary in the assemblage. The three previously mentioned SAEL reports by ADB (2023a, 2023b & 2003C) are concerning a new project in Rajastan[73]. It will rely on the same technology as in Punjab, hence its technical data is relevant. The text talks about sourcing ground water for the power plant to function. I chose to include this, even though it is not the same practice as in the power plants I have gained access to through documents, mainly because it can give an insight into how consequences can be worked with by the main actor. On p.62 in the 2023a report:

> *"According to Water Resources Institute (WRI) Aqueduct Baseline water stress analysis, the project site is following in extremely high-risk zone with respect to water stress and is identified as extremely high-water stress area (>80%)."*

Reading through the document, there is no indication that SAEL or ADB has any solutions or regards to it being their responsibility to find a more sustainable alternative or solution. Instead, in the documents section 4.2.7.1 they are mentioning how phase 2

[73] Water resources in Rajastan is scarcer then in Punjab (Singh, 2011a).

of the Indira Gandhi Canal will bring water from the Himalayas in the future, and this is seen as a viable solution[74].

In Punjab, at least for the planned power plant in Faridkot and the already established one in Ferozepur the water will be sourced from the canals that lie in relative proximity to the power plants. The one in Faridkot will require a 2.5 km long water pipe going from the canal to the power plant (Punjab pollution control board, 2018; U.B, 2018).

Back to the technology. The reports (2023a, 2023b & 2023) state that the water-cooled vibrating grade combusting engine is expecting to use 386 m^3 of water daily. One cubic metre is 1000 litres. This adds up 140.890.000 litres annually. To put this in context I need to do some math. One kilogram of paddy demands on average 2500 litres of water[75] (Bouman, 2009; Institution of Mechanical Engineers, 2013). In a report by the Department of Agriculture Punjab (2012) a list is presented with the expected yield per acre depending on which paddy strain used[76]. The average on all varieties combined is 10 quintals of paddy per acre, or 1000 kilos. Adding this up shows that one acre of paddy demands 2.500.000 litres of water, which means SAEL needs to enrol the equivalent water requirements for 56 acres of paddy consumption in Punjab in order to run one power plant[77]. This is not massive by itself. The problem occurs when one adds together all the power plants that are needed for this to be a scalable solution and look at the backdrop of water scarcity in Punjab.

Another actor that would lead to higher water consumption is, as we have made clear earlier, the extra fertilizer that would be needed to adjust for the deprivation of nutrients in the residue. Down to Earth (2019) found one ton of urea to demand between 4 and 12 cubic metres of water[78], depending on the efficiency of the fertilizer plant. Not a massive amount in the larger picture, but as we say in Norway: "mange bekker små, gjør en stor å" which directly translated means many small streams makes a big river.

Summing the latest insights up, it is clear that a substantial amount of water needs to be enrolled in an already water stressed region for the ex-situ assemblage and the RWS assemblage to function.

8.7 Climate and energy production

SAEL's power plants create electricity, a resource which will see (and has seen), a rapid increase in demand in Punjab in the coming years (Singh, Singh & Sharda, 2002; Kaur & Luthra , 2018). This means, it is in this report' interest to peak at the alternative energy sources in Punjab. In this section we will see how, and how much electricity is produced in the public grid in Punjab, and also how much GHG is emitted in the process. This is relevant for understanding how SAEL could potentially contribute to a greener tomorrow.

As it stands today, by far the biggest source of electricity is fossil fuel, with a total of 5680 megawatt in the fiscal year 2019-2020 (PWC, 2020). The fossil fuel sources in the public

---

[74] This project has been in development since 1952 and is also one of the main water sources of Punjab. It will come with its own sustainability issues, especially regarding biodiversity. It will flood an eco-system (Idris, Singh & Johari, 2009).

[75] I suspect the number to be higher in Punjab. No one really had any connection to it when I asked because electricity was free. The only time it seemed to be noticed was every ten years when they had to dig deeper as mentioned in interview 9.

[76] https://agri.punjab.gov.in/sites/default/files/cultivation_of_basmati_rice.pdf

[77] Due to the high-water consumption and the distance that are put between farmers and water due to free electricity one can expect acres of paddy to be somewhat lower, but two wrongs do not make one right. It is still an unsustainable usage of water.

[78]Between 4-12.000 litres.

electricity grid, coal and furnace oil, emitted 26,335,116 tonnes of CO_2-eq in 2018-2019[79] (Nasar, Ashok & Deshpande, 2022). Dividing the latter with the former, brings the number 4,636 kg of CO_2-eq per mw produced in Punjab. SAEL with their four power plants in Punjab has the total capacity to produce 60 mw (SAEL, 2024). The biggest coal plant in Punjab on the other hand, has the capacity to produce 1980 mw (Pillai, 2020). This mean SAELs mw contribution is a drop in the ocean of the energy mix of Punjab. 60 mw will still help avoiding 278,187 kg of CO_2 annually (assuming the same energy mix as in 2018-2019) if SAEL actually replaces other projects. India has the last couple of years had a massive expansion in renewable energy, but its coal consumption is increasing in an alarming rate of 4% for power generation in 2022 with steady increases forecasted (IEA, 2023). Another thing that needs to be highlighted is that SAEL will emit carbon, and the only reason it is seen as renewable is because, as mentioned earlier, the same amount gets captured in the next harvest. With today's CO_2 level in the atmosphere, it is not like it is not enough CO_2 around to be captured (IPCC, 2023), and with an efficiency of 83%, there will still be significant excess emissions related to the production of energy within SAELs power plant.

8.8 Summary - Research question 1

The first part of the ex-situ assemblage I will focus on is related to knowledge, both concerning soil health but also climate change and the need for renewable energy. This will be further discussed in chapter 10 in relation to research question 3, and which "allies" that can be enrolled depending on the framing. Due to the production of renewable energy, a monetized green resource, SAEL is able to enroll finances from international institutions. Money that is allocated to broadening the reach of the assemblage.

Money is also an actor to impose interessement towards the farmers from SAEL. The farmers' interest gets translated through an allurement of a quick fix of the residue, that yields an instant monetised return. This makes ex-situ an attractive option for many farmers who do not have the "right" knowledge concerning soil health, but also not the financial means to attempt to be enrolled in the in-situ assemblage.

The material actors needed for performing the ex-situ assemblage are once again a tractor and a mulcher. The sun is also enrolled within the assemblage. When it shines it can dry the residue, meaning the weather will work as an intermediary or mediator. With rain, the residue will not dry, and the weather will be a mediator causing potential havoc for the assemblage. After the drying, the bailer is important for creating the standard sizes that SAEL requires. Transportation is the last leg of performance the farmer needs to do before the residue then gets brought into the care of SAEL. It will here be incinerated in the boiler and create energy. This process will require more water to be enrolled for the boiler to act as an intermediary.

Through this process the residue and its nutrients become enrolled in a new assemblage. It goes from being a mediator for the RWS, to an intermediary for the ex-situ assemblage if they can be moulded into the standards that SAEL requires. At the same time, the resources within the residue get extracted. This changes the nutrients that are available for the soil, and the SOC and SOM levels. This means other actors, like

[79] This number is found in an excel sheet that can be found by accessing the "Energy emissions estimates 2005-2018" link found on this page https://www.ghgplatform-india.org/energy-sector/. Then search for Punjab. Normal citation in reference list.

water and fertilizer, need to be enrolled to keep the RWS assemblage stable. This process and consequences are what will be the focus in the coming chapter.

9. Research question 2: Assembling Neglected Things

We have now unveiled the actors within the three different residue management assemblages, incineration, in-situ and ex-situ. Through this we have also encountered how the different assemblages make actors mediators, intermediaries and how they can impact other sustainability goals. In the following chapter, there will be a more thorough discussion in relation to research question two: "*What are the futures that the different solution offers, based on how they impact the overall sustainability of the RWS?*"

Here the externalities of the different assemblages, good and bad, will be presented. I will here contextualise the insights that have been found through following the actors, the recognised and not recognised within the respective assemblages. This will be presented with the notion towards *care-studies* where I will reassemble neglected things in line with Bellacasa's (2011; 2017) thinking. The different assemblages will be discussed respectively, but in relation to each other. When this is completed, the findings and insights will be presented in an orderly fashion within a simplified table that will work as a summary of the chapter and set the stage to answer research question 3.

9.1 Incinerating

The incinerating assemblage, the problem that has started it all, has well documented side-effects and consequences related to air pollution, and this is part of why it has been enacted as an issue. The incinerating assemblage problematisation is what enacted the two other issues, and I saw it as beneficial to include the problems that come with burning in the background chapter, since incineration for many years has been the standard. I will now discuss these side effects presented earlier up against the theoretical framework introduced in chapter 2. The goal is to show the side effects, in order to set the two other assemblages in perspective, since they are both out to replace the incinerating assemblage.

The soil, the land under this assemblage, exists under the hegemonic idea of *the law of the minimum,* where soil is the medium between inputs of fertilizers and pesticides and the output of the harvest (Winiwarter, 2014). This makes it a human-centric approach in line with Bellacasas (2015) productivism. Through this, the more-than-human actors that constituted the soil is only recognised as a threat towards the yield, which has made *fire* another important input, intermediary, to ensure output. What matters in this system is to meet the needs of today, without thinking about tomorrow. The soil is a food infrastructure that is still not recognised for its potential collapse, since apart from the burning, everything works fine in the eyes of the public, but also the incinerating farmers. It works fine in the sense that fire ensures the removal of the fungal phantom menace. Through this, the interest of the farmers, and also to a certain extent the nation, food security, is ensured for the year. Fungal outbreaks can spoil the crop, which can endanger food security for India, but also the economy of the farmer's family. A spoiled soil, and a man that cannot provide for his family, is the worst possible outcome for the famer. This makes the incinerating assemblage a sort of performative care, care towards ensuring food security, and care towards ensuring his family's economy. These are positive outcomes from the incinerating assemblage and will be used in order to answer research question 3, but the associations created through this performance radiate and translate the actors bound up in the assemblage in negative ways.

The obvious as stated, is the pollution and the carbon. But the consequences also radiate downwards, as has been mentioned several times, an actor's work depends on the assemblage that constitutes it (Latour, 2007). The fire kills microbes in the top layer of the soil and reduces the biomass. This has, as was discussed in section 4.5, reduced the soils SOC and SOM to drastically low levels, in synergy with the general intensive agriculture that characterises this edition of the RWS. These associations make the RWS require the enrolment of even more water. The sum of these consequences makes the incineration assemblage an unsustainable assemblage, with a potentially devastating outcome that can hamper the food security of millions of people, while at the same time it ravages the lives of the millions of microbes that live in and contribute to the soil.

9.2 In-situ

An assemblage that brings the attention towards the more-than-human relationships, as emphasised by Bellacasa (2017) is the in-situ assemblage. Here the microbes get enrolled as key intermediary actors within the assemblage. It demands more care from the farmer, both in its performances, with activities that need to be performed in correct order for the assemblage to function, but also in the aftermath to avoid fungal outbreaks. One of the main selling points of the in-situ assemblage, from future-makers and enrolled farmers, is bound up in money, and how in-situ will not only reduce fertilizer usage, but also increase the yield. This still puts the soil under the domain of productivism, a human-centric approach, but one that takes better care of the more-than-human actors that it enrols.

Microbes translate the residue into manure, the process where the outcome is so highly valued by the farmers. Through this, the associations in the soil go through profound changes, that leave the actors in the soil looking and working in positively different ways. From the perspective of a soil scientist from the school of biology, the soil would be understood as in general healthier (Bellacasa, 2015), where there is created a multispecies alliance, where microbes are not deprived but is strengthened with a more dynamic soil. SOM and SOC increases. SOM translates the water needs drastically, which is good for the groundwater, which is another pivotal point within the RWS. The level of groundwater depleted in the two other assemblages, incineration and ex-situ, is way too high to be sustainable. The multispecies alliance between the soil's microbes and humans' performances with the residue, reduces the water stagnation in the field, which again reduces the methane emissions. This means that the associations that are enrolled on the ground, in the local, have the potential to mitigate a global problem, climate change. In this version of the RWS, GHG emissions are reduced in numerous ways: soil stores some of the carbon that the paddy residue extracted from the atmosphere, less fertilizer means less GHG emissions, less ground water pumping means excess energy for other purposes, while no water stagnation means drastically less methane emissions.

Still, for the assemblage to translate the interest to a farmer towards being enrolled in the in-situ assemblage, investments are needed. This investment hurdles for acquiring the required tools without a clear sight of the returns, can be a hurdle which excludes the poorest farmers from partaking in the in-situ. For them, the third option, ex-situ, might be a more suitable option.

9.3 Ex-situ

SAEL's ex-situ assemblage comes with the benefit of paying the farmer instantly if the farmer has been able to acquire the required tools. There is not a three to four-year lag of constant expenses, like in the in-situ assemblage, before one sees the benefits. Through this, SAEL's ex-situ assemblage has imposed itself as a new hope for the farmers, promising to remove the residue left by the RWS in a way beneficial to all, but does it have any phantom menaces?

SAEL brings forth solutions that tackle the initial issue, the air pollution, perfectly with advanced filter technologies that captures the particles after incineration. The incinerating process creates what is defined as renewable energy, a sought-after commodity in the green transition. These means there are positive outcomes, outside the field. The problems remain on the inside. As we have seen throughout the findings chapters, there are many benefits of keeping the residue inside the field. At the same time, we have seen that it is directly harmful to extract the residue.

The ex-situ assemblage pulls my thoughts towards Lien's (2017) text on the consequences of introducing wrasse to the salmon farms in Norway, and how solving one problem created new ones. The ex-situ assemblage is under a double productivism where bigger portions of the soil's output has been given a monetized value outside the field, leading to an even more intensive form of extraction. In Lien's text, the focal point is how humans and more-than-humans create alliances and here the text deviates from my empirical data concerning the ex-situ assemblage. The ex-situ assemblage keeps the humans, and the economy, as the focal point, and no alliances between the more-than-human species are created. There is a truth that lies in the statement that the upper layer of the microbes gets spared through avoiding incineration, but overall, the microbes get deprived and do not get recognition within this assemblage. Through the associations created, the SOM and SOC levels deteriorate, which gradually spoils the soil. Due to the scarce soil that exists under the regime of the law of the minimum, more fertilizer and water need to be enrolled to keep the RWS assemblage functional. This comes with high emissions, potentially more than what gets "saved" through the energy production at SAEL, that also needs to enrol a share of Punjab's already scarce water resources in order to function. Shiva (1991; 2015) has warned of the agricultural collapse of Punjab under today's regime, a collapse that will be amplified if ex-situ becomes a standard.

9.4 Ex-situ vs in-situ

Ex-situ tackles the issue of the RWS that has been enacted in the public's awareness, the residue burning. It fails on the other hand to mitigate, but instead accelerates the other unsustainability issues. It is a solution that comes with technological answers to the problem, with the promise of renewable energy that is produced and utilised outside the farm.

The in-situ assemblage is what the local experts at PAU are advocating for. They have a more holistic interest and knowledge surrounding the survival of the RWS. In-situ is in general a solution that is hard to monetize, where both the performance and the value are found within the land, under the soil, thanks to the more-than-human actors.

The two options offer two different futures. From a meta perspective, you would have one agricultural system that is not sustainable due to its persistent overexploitation of the soil under the RWS regime, but able to exist side by side with both humans, and microbes, in-situ. Gradually reducing the energy needs of the RWS. The other future offered by ex-situ is one that has the potential to exist for many years to come, with clean air and higher energy production. Increased energy capacity is doubtful due to all the other areas that needs influx of energy to function within the RWS. If there was any doubt after reading chapter 4.5 that Punjab's soil is in distress and could collapse, the ex-situ assemblage offers an even more exploitive future. It brings with it high chances of an agricultural collapse together with all the more-than-humans that constitute the soil.

It will also bring two different near-futures for the farmers. While the in-situ assemblage brings increased yield and better soil, it comes with high initial costs which is not a problem in the ex-situ assemblage. This is leading towards two classes of farmers. One class that had the opportunity to think and invest long term and will reap the benefits in the future. The other will be constituting the farmers that for a variety of reasons chose to go for instant monetary reward in order to manage the residue. They will have lower yield, and higher costs related to fertilizer, while their soil slowly degrades.

Through this, we can see what has been one of the focal points of early STS inspiration, regarding how different choices lead to different futures, where the most technological advanced is not always the best one (Sismondo, 2010). At times there exist solutions that are good enough. In-situ is one such example. Instead of offering a high-technological solution to a problem, it seeks organic alliances with the more-than-humans within the soil to make their assemblage function.

9.5 Overview of the consequences

The way the different assemblages impacts the sustainability of Punjab can be summarised in a table. Such simplification that the format of a list comes with can lead to some problems that I will try to avoid by first give a disclaimer. This list does not mean that any aspects of the RWS is sustainable, or that the RWS ever can be the most sustainable choice for Punjab. The scope of the report has been to unveil how the three different assemblages impact the sustainability of the RWS, but that does not mean that different cultivation methods with a more sustainable result do not exist. Crop-diversification could help make Punjab agriculture more sustainable but has proven hard to implement for a variety of reasons (Pujara & Shadid, 2016; Kumar & Sangeet, 2019)[80]. Millets for example, is a crop that has gotten a sustainable branding that the Delhi government is now promoting, advocating to brand 2023 as the international year of the millet (Sinha, 2023; The economist, 2024).

[80] Informant 24, 25 and 26, academics working from New Delhi were all advocating for crop diversification as the only sustainable option for Punjab. Interesting data, but it fell outside the scope of the thesis to include.

Here is the list to summarise the different consequences that comes with each assemblage:

Assemblage / **Actors impacted**	**Incinerating**	**In-situ**	**Ex-situ**
Soils microbes	Negative impact. Burning kills microbes in top layer.	Positive impact. Microbes are essential for the doings of the assemblage, and benefits compared to the alternatives.	Disputed impact. Top cm has better terms of living due to absence of fire. Residue extraction is also the extraction of microbe's diet.
SOM	Negative impact. Most of the residue gets spoiled. Some mitigation because the ash becomes part of the soil.	Positive impact. SOM builds up gradually.	Negative Impact. Extraction of residue eliminates the chance of SOM build up.
SOC	Negative impact. Most of the carbon stored in the residue becomes CO_2.	Positive impact. SOC builds up gradually.	Negative impact. Extraction of residue eliminates the chance of SOC build up.
Fungal outbreak:	Positive impact. Burning kills most of the threats.	Negative impact. Due to increased microbial activity, fungal outbreak is an increased risk.	No data. Has not been inside the scope of the actors.
Soils water holding capacity	Negative impact. Due to SOM reduction.	Positive impact. Strong SOM leads to increased water holding capacity within the soil.	Negative impact. SOM is reduced, hence, water holding capacity is reduced.
Water usage	Negative impact. SOM reduction leads to increased water usage.	Positive impact. Water usage is drastically reduced. Groundwater depletion can potentially be halted.	Negative impact. Needs more groundwater due to SOM reduction. The power plant requires 140 million litres of freshwater annually to function.
Fertilizer usage	Disputed impact. Ash returns nutrients, but burning residue deprives the soil of the rest of the nutrients.	Positive impact. Nutrients are recycled.	Disputed impact. Increase in usage of some fertilizer, possible reduction in others.
Food security	Disputed. Reduced risk of fungal outbreak, meaning ensures next harvest. Burning as practice degrades the land, and the soils yield giving abilities.	Positive impact. Yield is increased. Less toll on land, ensures a healthier soil that can be exploited for longer.	Negative impact. Soil is overexploited. SOC is deprived which is key component for ensuring yield.
GHG emissions	Negative impact. High emissions related to burning. Soil loses its ability to handle carbon. Upholds a regime that requires a lot of fertilizer.	Positive impact. Carbon is stored in soil. Lower energy use for water pumps reduces the emissions. Less water stagnation reduces methane emissions. Reduced usage of fertilizers lower emissions related to the RWS. Part of the GHG related to decomposing is released into the	Disputed. Relying on the carbon cycle is disputed by itself. It is still emissions. Produced energy without fossil fuel is positive. Emissions related to performance and transport. Fertilizer usage increases. Emissions related to groundwater extraction will increase in the future.

		atmosphere. Some emissions related to performing in-situ.	
Energy capacity	Negative impact. Will degrade the soil's microbes, meaning groundwater depletion will require a lot of energy. Same goes for fertilizer usage. No extra fuel usage for performing the assemblage.	Positive impact. Energy to water pumps reduced. Less fertilizer required, means less energy needed to produce fertilizer. Some extra use of fuel needed to perform assemblage.	Somewhat positive. Produces energy but will require more electricity in relation to fertilizer production. Since it does not tackle the groundwater depletion problem, the energy requirements will increase as the groundwater well goes deeper. The assemblage that requires most fuel in order to perform.
Socioeconomic/ inequality	Disputed. Everyone can partake, little need for knowledge or investments. Still, if one farmer does in-situ and one does ex-situ differences regarding expenses and yield will lead to increased socioeconomic inequality.	Disputed. Farmers that practice in-situ see better soil, better yield, and reduction in fertilizer expenses. High threshold financially and ideologically to enter, can create big economic differences among farmers.	Disputed. Is a good option with instant money transfers. Higer cost related to fertilizers. Soil deprivation can lead to gradually reduced yield.
Human health	Negative impact. The smog creates severe respiratory issues for millions of people.	Positive impact. Removes the smog. Reduces fertilizer usage.	Positive impact. Removes the smog.

10. Research question 3: Framings and Overflows

In the last chapter the positive and negative consequences of the assemblages were in focus. In this chapter we will explore how the actors allow these incidents to happen, and thus answer research question 3, which is: *How does the way the actors frame their solutions impact which actors are not recognised and which ones are enrolled in their assemblage?*

By answering research questions 3, we will understand how the different assemblages get shaped by the interest of the actors and future-makers and also show how good intentions can bring about bad results. To answer this, I will call upon the theoretical concept developed by Callon (1984), *framing and overflows,* but also Mol's (2008) notion of *care in tension*, to show how the interests are seen as good, depending on which actors are allowed to get recognition inside the frame.

10.1 The framings and overflows of incineration

First off, the incinerating assemblage. The analysis is based on the farmers I interacted with on the outskirts of Bathinda who were burning residue, and their interests. However, they should not be seen as speaking on behalf of all farmers engaging in burning. There are many farmers in Punjab that are well aware of the devastating effects that residue burning brings, but are forced to burn due to a lack of financial means or no viable ex-situ options in their surroundings. It is therefore a challenge that my own narrow framing, or construction of the category "incinerating farmer," may be too broad and generalising when discussed in this context. The framing I propose will not be applicable for every farmer in Punjab.

The incinerating farmers outside Bathinda did show forms of care in their performances of residue management. They cared for feeding the nation, and feeding their family, which places food security within their frame. Their knowledge concerning soil was bound in the chemists' law of the minimum and other aspects of soil health were hence an overflow. Microbes were inside their frame, but as a mediator, a threat towards their interests. Fire was an efficient tool, while the impact of fire, mainly observed as air pollution in other parts of India, stayed outside their frame. Air pollution has however recently been enacted as an issue, and the impacts will probably gradually emerge inside the frame of the farmers. To sum up, the frame of the incinerating farmers was bound in ensuring the next harvest, all the consequences are essentially overflows.

10.2 Future-makers framing

The in-situ and ex-situs farmers and future-makers have the polluting problems of incineration inside their frame and do a fine job tackling it. They frame their assemblages as alternatives to residue burning, a framing that has been increasingly pushed in the wake of the supreme court ruling of 2019. They do not understand burning the soil as a form of care, instead they see care as avoiding burning, but here their coincidental interest stops. By looking at the assemblages' respective names we can extract an indication of where the frame of interest lies.

10.2.1 Framing and solving the problem towards the local

Within the in-situ assemblage all the performative actions and all the results the future-makers are yearning for happen inside the field and the soil. This means the focus is on the local. The future-makers, agricultural experts at PAU, have a vested interest in creating a future where the RWS and the soils of Punjab are intact. They are well aware of the previously mentioned problems the RWS is facing, and these issues have been brought into consideration since they started seeking an alternative towards residue management, years before it was properly enacted as a problem in 2019. This means, in-situ has been developed as a holistic approach that seeks to mitigate the problems of soil deprivation, water extraction and overuse of fertilizers. Within this assemblage, the benefits of the microbes within the soil are enrolled and recognised as an ally, giving them a significant place in the future of the RWS. These benefits are recognised within the frame of the future-makers and the farmers, where the aim is to care for the soil by and through the microbes.

GHG is outside of the frame of the actors and is an overflow. But the way the associations between the actors in the in-situ assemblage influence each other has positive implications for GHG emissions and water usage within the RWS. This leads to less energy use related to water exploitation and lower methane emissions.

An inherent problem of the in-situ assemblage within a capitalist system is its hyper focus on the local. The in-situ assemblage is more in the business of saving money, instead of creating it. There is not created any new commodities to be traded, apart from the government sponsored and produced seeders. This makes it hard for investors working with capitalistic tools to see it as an investment it can support. Also, the in-situ assemblage is currently not framed towards the global problems of climate change, which has proven an effective way to attract attention and involve outside actors. Regardless of its framing, in-situ is having a positive effect on the climate impact by the RWS. In-situs inherent problem in order to gain outside traction is that most of the value is created out of sight, within the neglected actor of the soil.

10.2.2 Framing and solving the problem in the global

The ex-situ assemblage, represented by SAEL, on the other hand, has the focus outside the agricultural field and the soil. Their framing as a producer of renewable energy creates a link to the global problem of climate change, and this is used to enrol the interest of global actors. Inside this assemblage is also the process of monetizing the residue, making it a capitalist commodity that can be traded. This connection between the global problem of climate change, and the monetization of residue, makes residue something that can be handled by a global investor that works with capitalistic tools. This gives the ex-situ an edge. The future that exists within the frame of SAEL is one where care is allocated towards creating renewable energy, eradicating air pollution from residue burning, and increased wealth, for farmers, SAEL and the society through increased energy capacity. These are all good and positive outcomes and promises of a better future.

The problem is what is left out of SAEL's frame, being concerns mostly located inside the very field SAEL is extracting its resources from. This creates overflows which can, and probably will, eradicate the positive results SAEL was envisioned to provide to the future, especially related to increased energy capacity and wealth for the farmers. Their frame arguably includes the top 1 cm of the soil's layer, but their knowledge of and interest towards soil in general, make all the potential possibilities that could exist within the soil a missed future, while all the negative effects that are enhanced by the ex-situ assemblage becomes overflows. The future SAEL is trying to build is one of max exploitation of the soil's resources. Since their knowledge is bound to a law of the minimum, where fertilizer is all the soil needs, the wider problems of the RWS do not get recognised. The microbes are not given a voice within this assemblage and become an overflow. Through the disregard for the soil as a multispecies entity, other aspects essentially also become overflow. The SOM and SOC levels become overflows, which again will lead to the increased need for fertilizer and water exploitation, meaning increased inputs in a system that is already demanding too much from its surroundings. This means, everything that occurs after the performance of ex-situ on the field, are overflows that exist outside the frame of the assemblage.

10.3 Summary research question 3

In this chapter, we have observed how different connotations of care can be in tension. All the future-makers believe that the future they are set out to create is for the benefit of the world. The farmer's understanding is in clear tension with the two other alternatives, in-situ and ex-situ, in their understanding of what is a positive result. The burning famers' performance is bound in the good intension of producing food for society and for family. Ex-situ is also showing care, care towards farmers, public health and the positive result of creating energy. By their framing towards the global, we have seen how ex-situ has been able to rally global green investors towards their cause. The ex-situ performances are in tension with the understanding of soil that the future-makers behind in-situ have. Through SAEL's good intensions and performative care, they are breaking the RWS through exploitation of the residue. In-situ, through its framing does not care for the climate, but has a holistic approach towards the trouble of residue management, resulting in care being applied in the local. Their framing, and care towards the microbes, rally them as allies towards residue management with positive effects across the RWS.

11. Conclusion

This report aimed to explore the effects of various residue management strategies–incineration, in-situ, and SAEL's ex-situ method–and examine how different stakeholders implemented and managed their assemblages, as well as their understanding of the problem and the broader impact of the distinct assemblages.

To do this, the different assemblages have been explored and explained, showing the actors and the interests that are enrolled in the different assemblages. By following the associations, it has become clear that the assemblages' impact more than just the residue and the air quality in New Delhi and offer three distinct futures for Punjab and beyond through how the assemblages treats and understands soil.

Incineration will keep depleting the soil, while the annual smog will keep haunting the inhabitants of New Delhi on an annual basis. For the cash-strapped farmers, this is a rational choice, where also fire works as a preventive measure to protect the crop and feed the nation.

In-situ offers a more sustainable future for the RWS, where the microbes in the soil are being enrolled to decompose the residue. The decomposition brings essential nutrients back into the soil, which builds up SOC and SOM, and increases microbial diversity within the soil. Through this, the farmers are able to increase yield and reduce fertilizer. All these are positive consequences for the soil, but the spillover also includes reduced use of groundwater, which brings energy consumption and methane emissions down. This is possible because the frame that PAU and the farmers are using stays local and seeks to handle several of the problems that the RWS is facing through long-lasting care for the precarious soil.

SAELs ex-situ assemblage looks outwards and seeks to mitigate the global climate crisis by monetizing the residue and turning it into energy. This has helped to enrol global investors which can help the assemblage grow, but it leads to an overexploitation of the soil, which stays outside the frame. By extracting the residue, the soil is deprived of maximum resources, and the soil's attributes change with decreased SOM and SOC. This impacts the RWS, that in order to function, needs to enrol more fertilizer and water. This comes with higher energy consumption and GHG emissions. The future it offers is one where there might not be any residue to turn into energy due to the collapse of the soils of Punjab.

11.1 Further research

It is clear that the underlying problems in the wake of the green revolution are still prevalent in Punjab. The RWS is not sustainable, no matter which assemblage handles the residue. These assemblages work as intermediaries for the time being for the RWS from an ANT-perspective. Seeing it from the vantage point of Innovation studies, one could see this as an actor contributing to a lock-in, where even more investments go into the RWS food infrastructure (David, 2005) and it would be interesting to see how this limited problem solving leads to a solidified lock-in of the RWS.

The report has also looked into how the contemporary Jat-culture can work as a hindrance for moving away from residue burning. At the same time there was also a cultural change happening with the in-situ farmers, where they would "scold" the burning farmers and teach them how to act correctly. An interesting and important future study for researchers would be to investigate how a changing culture changes the worldview of farmers in Punjab and go in further detail on how this produces and distributes knowledge about residue, and about soil and farming in general.

References

- Abdurrahman, M. I., Chaki, S., & Saini, G. (2020). Stubble burning: Effects on health & environment, regulations and management practices. Environmental Advances, 2, 100011. https://doi.org/10.1016/j.envadv.2020.100011
- Aggarwal, P. C., & Mishra, M. S. (1973). The Combine Harvester and Its Impact on Labour: A Study in Ludhiana. Indian Journal of Industrial Relations, 9(2), 293–308. JSTOR.
- Agricultural Department of the Punjab. (2011). Annual Report Draft 2010-2011. https://agri.punjab.gov.in/sites/default/files/ANNUAL_REPORT_DRAFT_2010-11.pdf
- Aloysius, G. (2000). Book reviews and notices: SUVIRA JAISWAL, Caste: Origin, function and dimensions of change. New Delhi: Manohar Publishers. 1998. xii + 278 pp. Notes, bibliography, indexes. Rs. 500 (hardback). Contributions to Indian Sociology, 34(2), 285–286. https://doi.org/10.1177/006996670003400213
- Amundson, R., & Jenny, H. (1991). The place of humans in the state factor theory of ecosystems and their soils. Soil Science, 151(1), 99–109.
- Asdal, K. (2011). Politikkens natur—Naturens politikk. Universitetsforl.
- Asdal, K., & Reinertsen, H. (2022). Doing document analysis: A practice-oriented method. SAGE Publications Ltd ; SAGE Publications Inc.
- Asian Development Bank. (02.2023a). India: SAEL Biomass Energy Project (Initial environmental and Social Examination 56276–001). Asian Development Bank. https://www.adb.org/sites/default/files/project-documents/56276/56276-001-iee-en_1.pdf
- Asian Development Bank. (02.2023b). India: SAEL Biomass Energy Project (56276–001). Asian Development Bank. https://www.adb.org/sites/default/files/project-documents/56276/56276-001-iee-en_0.pdf
- Asian Development Bank. (02.2023c). India: SAEL Biomass Energy Project (56276–001). Asian Development Bank. https://www.adb.org/sites/default/files/project-documents/56276/56276-001-iee-en_0.pdf
- Aslaksen, L. (2021). Fra en ordinær sak til en nasjonal kontrovers: Konkurrerende verdsettinger av vindkraftverk og reindrift: En praksisorientert analyse av saksdokumentene til Storheia Vindpark [UiO]. https://www.duo.uio.no/bitstream/handle/10852/90550/1/TIK4093---Masteroppgave---Linnea-Aslaksen.pdf
- Azhar, B. A. (1962). Rural Multi-purpose Philosophy. Community Development Bulletin, 14(1), 7–10. JSTOR.
- Azungah, T. (2018). Qualitative research: Deductive and inductive approaches to data analysis. Qualitative Research Journal, 18(4), 383–400. https://doi.org/10.1108/QRJ-D-18-00035
- Bachman, L. J., Krantz, D. E., & Böhlke, J. K. (2002). Hydrogeologic framework, ground-water geochemistry, and assessment of nitrogen yield from base flow in two agricultural watersheds, Kent County, Maryland (Report EPA/600/R-02/008). USGS Publications Warehouse. https://pubs.usgs.gov/publication/70188285
- Balwinder-Singh, Eberbach, P. L., Humphreys, E., & Kukal, S. S. (2011). The effect of rice straw mulch on evapotranspiration, transpiration and soil evaporation of irrigated wheat in Punjab, India. Agricultural Water Management, 98(12), 1847–1855. https://doi.org/10.1016/j.agwat.2011.07.002
- Bárcena, T. G., Grønlund, A., O'Toole, & Rasse, D. (2016). Landbruket i møte med klimaendringene. Karbonbalansen i dyrket mark. [Rapport for regjeringen]. Regjeringen.

https://www.regjeringen.no/contentassets/416c222bde624f938710ff36751ef4d6/rapport-landbruk-og-klimaendringer---rapport-fra-arbeidsgruppe-190216.pdf

- Barone, F. (2020, august 20). An Introduction to Fieldwork and Ethnography. Human Relations Area Files - Cultural Information for Education and Research. https://hraf.yale.edu/teach-ehraf/an-introduction-to-fieldwork-and-ethnography/
- Basit, T. (2003). Manual or electronic? The role of coding in qualitative data analysis. Educational research, 45(2), 143–154.
- Beig, G., Sahu, S. K., Singh, V., Tikle, S., Sobhana, S. B., Gargeva, P., Ramakrishna, K., Rathod, A., & Murthy, B. S. (2020). Objective evaluation of stubble emission of North India and quantifying its impact on air quality of Delhi. Science of The Total Environment, 709, 136126. https://doi.org/10.1016/j.scitotenv.2019.136126
- Benbi, D. K., Brar, K., Toor, A. S., & Singh, P. (2015). Total and labile pools of soil organic carbon in cultivated and undisturbed soils in northern India. Geoderma, 237–238, 149–158. https://doi.org/10.1016/j.geoderma.2014.09.002
- Beri, V., Sindhu, B., Bhat, A., & Singh, B. (1992). Nutriend and Soil Properties as Affected by Management of Crop Residue. I Pro. Intl Symposium on Nutrient on Management and Sustained Productivity (Bd. 2, s. 133–135). Punjab Agricultural University: Department of Soil.
- Bernard, H. R. (2011). Research methods in anthropology: Qualitative and quantitative approaches (5th ed). AltaMira Press.
- Bhatt, R., Singh, P., Hossain, A., & Timsina, J. (2021). Rice–wheat system in the northwest Indo-Gangetic plains of South Asia: Issues and technological interventions for increasing productivity and sustainability. Paddy and Water Environment, 19(3), 345–365. https://doi.org/10.1007/s10333-021-00846-7
- Bhattacharyya, R., Singh, K., Grover, R., Bhanja, K., Bhattacharyya, R., Singh, K., & Grover, R. (2022). Estimating minimum energy requirement for transitioning to a net-zero, developed India in 2070. Curr. Sci, 122(5), 517–527.
- Bijker, W., & Pinch, T. (1987). The Social Construction of Facts and Artifacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other. I Social Studies of Science (Bd. 14, s. 17–50).
- Bodí, M. B., Martin, D. A., Balfour, V. N., Santín, C., Doerr, S. H., Pereira, P., Cerdà, A., & Mataix-Solera, J. (2014). Wildland fire ash: Production, composition and eco-hydro-geomorphic effects. Earth-Science Reviews, 130, 103–127.
- Bogdan, R., & Biklen, S. K. (1997). Qualitative research for education. Allyn & Bacon Boston, MA.
- Bot, A., & Benites, J. (2005a). The importance of soil organic matter: Key to drought-resistant soil and sustained food and production. Food and Agriculture Organization of the United Nations.
- Bot, A., & Benites, J. (2005b). The importance of soil organic matter: Key to drought-resistant soil and sustained food production. Food and Agriculture Organization of the United Nations.
- Bouman, B. (2009). How much water does rice use? Rice Today, 8, 28–29.
- Bowker, G. C., & Star, S. L. (1999). Sorting things out: Classification and its consequences. MIT Press.
- Bowonder, B. (1979). Impact analysis of the green revolution in India. Technological Forecasting and Social Change, 15(4), 297–313. https://doi.org/10.1016/0040-1625(79)90023-4
- Brinkmann, S., Kvale, S., & Flick, U. (2018). Doing interviews (Second edition). SAGE.
- Bryant, L. (2015, may 27). Organic Matter Can Improve Your Soils Water Holding Capacity. Natural Resource Defence Council. https://www.nrdc.org/bio/lara-bryant/organic-matter-can-improve-your-soils-water-holding-capacity
- Buttar, G. S., & Kaur, S. (03.02023). Package of Practices for The Crops of Punjab: Kharif 2023 (Bd. 40). Punjab Agricultural University. https://www.pau.edu/content/ccil/pf/pp_kharif.pdf

- Buttar, G. S., Sodhi, G. P. S., Manes, G. S., K, S., Kaur, T., Brar, N. S., Kumar, A., Singh, R., & Kaur, S. (2023). Adoption Pattern of Farm-Machinery based Solutions for In-situ Paddy Straw Management in Punjab. Indian Journal of Extension Education, 59(4), 103–108. https://doi.org/10.48165/IJEE.2023.59421
- Callon, M. (1984). Some elements of a sociology of translation: Domestication of the scallops and the fishermen of St Brieuc Bay. The sociological review, 32(1_suppl), 196–233.
- Callon, M. (1998a). An Essay on Framing and Overflowing: Economic Externalities Revisited by Sociology. The Sociological Review, 46(1_suppl), 244–269. https://doi.org/10.1111/j.1467-954X.1998.tb03477.x
- Callon, M. (Red.). (1998b). The laws of the markets. Blackwell Publishers/Sociological Review.
- Callon, M., & Law, J. (1995). Agency and the Hybrid Collectif. South Atlantic Quarterly, 94(2), 481–507. https://doi.org/10.1215/00382876-94-2-481
- Callon, M., Lascoumes, P., & Barthe, Y. (2009). Acting in an uncertain world: An essay on technical democracy. MIT Press.
- Calvin, K., Dasgupta, D., Krinner, G., Mukherji, A., Thorne, P. W., Trisos, C., Romero, J., Aldunce, P., Barrett, K., Blanco, G., Cheung, W. W. L., Connors, S., Denton, F., Diongue-Niang, A., Dodman, D., Garschagen, M., Geden, O., Hayward, B., Jones, C., … Péan, C. (2023). IPCC, 2023: Climate Change 2023: Synreport Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland. (First). Intergovernmental Panel on Climate Change (IPCC). https://doi.org/10.59327/IPCC/AR6-9789291691647
- Campbell, G. S., Jungbauer, J. D., Bidlake, W. R., & Hungerford, R. D. (1994). PREDICTING THE EFFECT OF TEMPERATURE ON SOIL THERMAL CONDUCTIVITY: Soil Science, 158(5), 307–313. https://doi.org/10.1097/00010694-199411000-00001
- Castells, M. (2009). The Rise of the Network Society (1. utg.). Wiley. https://doi.org/10.1002/9781444319514
- Certini, G. (2005). Effects of fire on properties of forest soils: A review. Oecologia, 143(1), 1–10. https://doi.org/10.1007/s00442-004-1788-8
- Chang, A. J., Fan, J., & Wen, X. (2012). Screening of fungi capable of highly selective degradation of lignin in rice straw. International Biodeterioration & Biodegradation, 72, 26–30. https://doi.org/10.1016/j.ibiod.2012.04.013
- Chaudhary, A., Chhokar, R. K., Yadav, D. B., Sindhu, V. K., Ram, H., Rawal, S., Khedwal, R. S., Sharma, R. K., & Gill, S. C. (2019). In-situ paddy straw management practices for higher resource use efficiency and crop productivity in Indo-Gangetic Plains (IGP) of India. Wheat and Barley Research, 11(3). https://doi.org/10.25174/2249-4065/2019/96323
- Coleman, D. C., Callaham, M. A., & Crossley Jr, D. (2017). Fundamentals of soil ecology. Academic press.
- Cordeiro, E., Arenas-Calle, L., Woolf, D., Sherpa, S., Poonia, S., Kritee, K., Dubey, R., Choudhary, A., Kumar, V., & McDonald, A. (2024). The fate of rice crop residues and context-dependent greenhouse gas emissions: Model-based insights from Eastern India. Journal of Cleaner Production, 435, 140240. https://doi.org/10.1016/j.jclepro.2023.140240
- Corsi, M. (2006). Communalism and the Green Revolution in Punjab. Journal of Developing Societies, 22(2), 85–109. https://doi.org/10.1177/0169796X06065798
- Cropping, P. (2005). Crop residue management for nutrient cycling and improving soil productivity in rice-based cropping systems in the tropics. Adv Agron, 85, 269.
- Cucci, G., Lacolla, G., Crecchio, C., Pascazio, S., & De Giorgio, D. (2016). Impact of long term soil management practices on the fertility andweed flora of an almond orchard. TURKISH JOURNAL OF AGRICULTURE AND FORESTRY, 40, 194–202. https://doi.org/10.3906/tar-1502-87
- D.C. Reicosky, W.D. Kemper, G.W. Langdale, C.L. Douglas, Jr., & P.E. Rasmussen. (1995). Soil organic matter changes resulting from tillage and biomass production. Journal of Soil and Water Conservation, 50(3), 253.

- David, P. A. (2005). Path dependence in economic processes: Implications for policy analysis in dynamical systems contexts. The evolutionary foundations of economics, 151–194.
- Davidson, E. A., & Ackerman, I. L. (1993). Changes in soil carbon inventories following cultivation of previously untilled soils. Biogeochemistry, 20, 161–193.
- De La Bellacasa, M. P. (2011). Matters of care in technoscience: Assembling neglected things. Social Studies of Science, 41(1), 85–106. https://doi.org/10.1177/0306312710380301
- Den Nasjonalie Forskningsetike Komite for Samfunnsvitenskap og Humaniora. (2023). Forskningsetiske Retningslinjer for Samfunnsvitenskap og Humaniora (5.utgave). https://www.forskningsetikk.no/globalassets/dokumenter/4-publikasjoner-som-pdf/forskningsetiske-retningslinjer-for-samfunnsvitenskap-og-humaniora.pdf
- Department of Agriculture, Punjab. (2012). Fertilizer Application for Rice.
- Department of Agriculture, Punjab. (2014). Annual report 2008-2009. Department of Agriculture, Punjab. https://agri.punjab.gov.in/sites/default/files/Annual_Report_2008-09.pdf
- Department of Water Resources, Government of India. (2024, february 27). Canal: About us. https://irrigation.punjab.gov.in/en/canal
- Det Kongelige Utenriksdepartement. (2022, may 2). INSTRUKS FOR NORFUNDS FORVALTNING AV KLIMAINVESTERINGSFONDET FOR FORNYBAR ENERGI I UTVIKLINGSLAND. https://www.norfund.no/content/uploads/2022/11/Instruks-Klimainvesteringsfondet.pdf
- Dey, I. (2003). Qualitative data analysis: A user friendly guide for social scientists. Routledge.
- Dhaliwal, S. S., Naresh, R. K., Gupta, R. K., Panwar, A. S., Mahajan, N. C., Singh, R., & Mandal, A. (2020). Effect of tillage and straw return on carbon footprints, soil organic carbon fractions and soil microbial community in different textured soils under rice–wheat rotation: A review. Reviews in Environmental Science and Bio/Technology, 19(1), 103–115. https://doi.org/10.1007/s11157-019-09520-1
- Dhaliwal, S. S., Naresh, R. K., Walia, M. K., Gupta, R. K., Mandal, A., & Singh, R. (2020). Long-term effects of intensive rice–wheat and agroforestry based cropping systems on build-up of nutrients and budgets in alluvial soils of Punjab, India. Archives of Agronomy and Soil Science, 66(3), 330–342. https://doi.org/10.1080/03650340.2019.1614564
- Dhillon, M. S., Kaur, S., & Aggarwal, R. (2019). Delineation of critical regions for mitigation of carbon emissions due to groundwater pumping in central Punjab. Groundwater for Sustainable Development, 8, 302–308. https://doi.org/10.1016/j.gsd.2018.11.010
- Dobermann, B., & Fairhurst, T. (2002). Rice straw management. Better Crops International, 16.
- Dodan, D., Ram, S., & Sunder, S. (1997). Pattern of rice diseases in Haryana. Plant Disease Research, 12(2), 188–191.
- Doganova, L. (2018). Discounting and the Making of the Future (Bd. 1). Oxford University Press. https://doi.org/10.1093/oso/9780198820802.003.0013
- Down to Earth. (2019). How Green is the Urea Sector? https://www.downtoearth.org.in/news/agriculture/how-green-is-the-urea-sector-64836
-
- Druglitrø, T. (2018). "Skilled Care" and the Making of Good Science. Science, Technology, & Human Values, 43(4), 649–670. https://doi.org/10.1177/0162243916688093
- Dudal, R. (2005). The sixth factor of soil formation. Eurasian Soil Science C/C of Pochvovedenie, 38, S60.
- Duiker, S. W. (2018, february 14). How Much can soil Organic Matter Increase in A year [Agricultural educational]. Farm Progress. https://www.farmprogress.com/soil-health/how-much-can-soil-organic-matter-increase-in-a-year-
- Dumontet, S., Dinel, H., Scopa, A., Mazzatura, A., & Saracino, A. (1996). Post-fire soil microbial biomass and nutrient content of a pine forest soil from a dunal Mediterranean environment. Soil Biology and Biochemistry, 28(10–11), 1467–1475. https://doi.org/10.1016/S0038-0717(96)00160-5

- Dushkin, L. (1967). Scheduled caste policy in india: History, problems, prospects. Asian Survey, 626–636.
- Dutta, A., Patra, A., Hazra, K. K., Nath, C. P., Kumar, N., & Rakshit, A. (2022). A state of the art review in crop residue burning in India: Previous knowledge, present circumstances and future strategies. Environmental Challenges, 8, 100581. https://doi.org/10.1016/j.envc.2022.100581
- Dutta, S. (2012). Green Revolution Revisited: The Contemporary Agrarian Situation in Punjab, India. Social Change, 42(2), 229–247. https://doi.org/10.1177/004908571204200205
- Duxbury, J. (2001). Long-term yield trends in the rice-wheat cropping system: Results from experiments and northwest India. Journal of Crop Production, 3(2), 27–52.
- Effland, W. R., & Pouyat, R. V. (1997). The genesis, classification, and mapping of soils in urban areas. Urban ecosystems, 1, 217–228.
- EFTA-delegasjonen til India. (2023, april 24). [Nyhet]. Stortinget. https://www.stortinget.no/no/Hva-skjer-pa-Stortinget/Nyhetsarkiv/Hva-skjer-nyheter/2022-2023/efta-delegasjonen-til-india/
- Eldridge, R. (2018, Spring). Incorporating Stubble Can Improve Soil COnditions. Victorian Landcare Magazine, 73. https://www.landcarevic.org.au/landcare-magazine/spring-2018/incorporating-stubble-can-improve-soil-condition/
- Eliazer Nelson, A. R. L., Ravichandran, K., & Antony, U. (2019). The impact of the Green Revolution on indigenous crops of India. Journal of Ethnic Foods, 6(1), 8. https://doi.org/10.1186/s42779-019-0011-9
- Ezhiljenekkha, Gb., & MarsalineBeno, M. (2020). Review of Power Quality Issues in Solar and Wind Energy. Materials Today: Proceedings, 24, 2137–2143. https://doi.org/10.1016/j.matpr.2020.03.670
- Falchetta, G., Gernaat, D. E. H. J., Hunt, J., & Sterl, S. (2019). Hydropower dependency and climate change in sub-Saharan Africa: A nexus framework and evidence-based review. Journal of Cleaner Production, 231, 1399–1417. https://doi.org/10.1016/j.jclepro.2019.05.263
- FAO. (2018). Global Soil Organic Carbon Map-GSOmap. FAO.
- Faubion, J. D., & Marcus, G. E. (Red.). (2009). Fieldwork is not what it used to be: Learning anthropology's method in a time of transition. Cornell University Press.
- Ferguson, N. (2021). Doom: The politics of catastrophe (1st [edition]). Penguin Press.
- Fertilizers Europe. (2014). Carbon Footprint Reference Values: Energy Efficiency and Greenhouse Gas Emissions in European Mineral Fertilizer Production and Use.
- Fielding, N., Lee, R. M., & Blank, G. (Red.). (2017). The SAGE handbook of online research methods (Second edition). London : SAGE.
- Fishman, R., Lall, U., Modi, V., & Parekh, N. (2016). Can Electricity Pricing Save India's Groundwater? Field Evidence from a Novel Policy Mechanism in Gujarat. Journal of the Association of Environmental and Resource Economists, 3(4), 819–855. https://doi.org/10.1086/688496
- Frankel, F. R. (1971). India's Green Revolution: Economic Gains and Political Costs. Princeton University Press; JSTOR. http://www.jstor.org.ezproxy.uio.no/stable/j.ctt13x0wb9
- Gangahar, M., & Kapil, P. (2023). Negotiations within a cultural phenomenon: Sidhu Moose Wala and a changing Punjab. South Asian Popular Culture, 21(1), 41–55. https://doi.org/10.1080/14746689.2023.2171312
- Garcha, S., Katyal, P., & Sharma, V. (2016). Microbial diversity in soil under different land use systems in sub-mountainous zone of Punjab. Journal of the Indian Society of Soil Science, 64(3), 271. https://doi.org/10.5958/0974-0228.2016.00038.4
- Ghuman, R., & Dhaliwal, N. (2022). Long-term changes in adoption status of production practices of wheat in sub-mountainous Punjab. Journal of Agricultural Development and Policy, 32(2), 196–203.

- Giardina, C. P., Sanford, R. L., Døckersmith, I. C., & Jaramillo, V. J. (2000). [No title found]. Plant and Soil, 220(1/2), 247–260. https://doi.org/10.1023/A:1004741125636
- Gill, S. S. (2005). Economic distress and farmer suicides in rural Punjab. JPS, 12(2), 220.
- Gill, S. S. (2022). From Disunity to Unity: Organization, Mobilization Strategies and Achievements of the Recent Farmers' Movement in Punjab. I Agrarian Reform and Farmer Resistance in Punjab (s. 118–138). Routledge India.
- Giordano, M., & Villholth, K. G. (Red.). (2007). The agricultural groundwater revolution: Opportunities and threats to development (1. utg.). CABI. https://doi.org/10.1079/9781845931728.0000
- Goel, S., Kansal, A., & Pfister, S. (2021). Sourcing phosphorus for agriculture: Life cycle assessment of three options for India. Resources, Conservation and Recycling, 174, 105750. https://doi.org/10.1016/j.resconrec.2021.105750
- Goel, V. (2011). India's Food Security Strategy and its Impact on the Food Surplus State of Punjab. Journal of Food Products Marketing, 17(5), 487–502. https://doi.org/10.1080/10454446.2011.583536
- Gong, H., Guo, Y., Wu, J., Wu, H., Nkebiwe, P. M., Pu, Z., Feng, G., & Jiao, X. (2022). Synergies in sustainable phosphorus use and greenhouse gas emissions mitigation in China: Perspectives from the entire supply chain from fertilizer production to agricultural use. Science of The Total Environment, 838, 155997. https://doi.org/10.1016/j.scitotenv.2022.155997
- González-Pérez, J. A., González-Vila, F. J., Almendros, G., & Knicker, H. (2004). The effect of fire on soil organic matter—A review. Environment International, 30(6), 855–870. https://doi.org/10.1016/j.envint.2004.02.003
- Gosal, G. (2004). Physical geography of the Punjab. JPS, 11(1), 20.
- Gould, M. Ch. (2015, oktober 16). Compost Increaases the Water HoldingCapacity of Droughty Soils [Educational]. Michigan State University. https://www.canr.msu.edu/news/compost_increases_the_water_holding_capacity_of_droughty_soils
- Government of Punjab-Bathinda. (2024). Bathinda.
- Granjou, C., & Meulemans, G. (2023). Bringing soils to life in the human and social sciences. Soil Security, 10, 100082. https://doi.org/10.1016/j.soisec.2022.100082
- Grover, D., & Chaudhry, S. (2019). Ambient air quality changes after stubble burning in rice–wheat system in an agricultural state of India. Environmental Science and Pollution Research, 26(20), 20550–20559. https://doi.org/10.1007/s11356-019-05395-5
- Gulbrandsen, L. H., Inderberg, T. H. J., & Jevnaker, T. (2021). Is political steering gone with the wind? Administrative power and wind energy licensing practices in Norway. Energy Research & Social Science, 74, 101963. https://doi.org/10.1016/j.erss.2021.101963
- Gupta, D. (2023). Free power, irrigation, and groundwater depletion: Impact of farm electricity policy of Punjab, India. Agricultural Economics, 54(4), 515–541. https://doi.org/10.1111/agec.12773
- Gupta, N. (2019). Paddy Residue Burning in Punjab: Understanding Farmers' Perspectives and Rural Air Polution [Issue Brief]. CEEW.
- Gupta, P. K., Sahai, S., Singh, N., Dixit, C. K., Singh, D. P., Sharma, C., Tiwari, M. K., Gupta, R. K., & Garg, S. C. (2004). Residue burning in rice–wheat cropping system: Causes and implications. Current Science, 87(12), 1713–1717. JSTOR.
- Gupta, R. K., Naresh, R. K., Hobbs, P. R., Jiaguo, Z., & Ladha, J. K. (2015). Sustainability of Post-Green Revolution Agriculture: The Rice-Wheat Cropping Systems of the Indo-Gangetic Plains and China. I J. K. Ladha, J. E. Hill, J. M. Duxbury, R. K. Gupta, & R. J. Buresh (Red.), ASA Special Publications (s. 1–25). American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. https://doi.org/10.2134/asaspecpub65.c1
- Gupta, S., Agarwal, R., & Mittal, S. K. (2016). Respiratory health concerns in children at some strategic locations from high PM levels during crop residue burning episodes. Atmospheric Environment, 137, 127–134. https://doi.org/10.1016/j.atmosenv.2016.04.030

- Hammersley, M., & Atkinson, P. (2007). Ethnography: Principles in practice (3rd ed). Routledge.
- Han, M., Wong, J., Su, T., Beatty, P. H., & Good, A. G. (2016). Identification of Nitrogen Use Efficiency Genes in Barley: Searching for QTLs Controlling Complex Physiological Traits. Frontiers in Plant Science, 7. https://doi.org/10.3389/fpls.2016.01587
- Haraway, D. (1988). Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective. Feminist Studies, 14(3), 575–599. JSTOR. https://doi.org/10.2307/3178066
- Haraway, D. (2006). A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late 20th Century. I J. Weiss, J. Nolan, J. Hunsinger, & P. Trifonas (Red.), The International Handbook of Virtual Learning Environments (s. 117–158). Springer Netherlands. https://doi.org/10.1007/978-1-4020-3803-7_4
- Haraway, D. J. (2008). When species meet. University of Minnesota Press.
- Haraway, D. J. (2016). Staying with the Trouble: Making Kin in the Chthulucene (s. dup;9780822373780/1). Duke University Press. https://doi.org/10.1215/9780822373780
- Hartemink, A. E., Hempel, J., Lagacherie, P., McBratney, A., McKenzie, N., MacMillan, R. A., Minasny, B., Montanarella, L., de Mendonça Santos, M. L., & Sanchez, P. (2010). GlobalSoilMap. Net–a new digital soil map of the world. Digital soil mapping: Bridging research, environmental application, and operation, 423–428.
- Hasler, K., Bröring, S., Omta, S. W. F., & Olfs, H.-W. (2015). Life cycle assessment (LCA) of different fertilizer product types. European Journal of Agronomy, 69, 41–51. https://doi.org/10.1016/j.eja.2015.06.001
- Hay, I., & Cope, M. (2021). Qualitative research methods in human geography (Fifth edition). Oxford University Press.
- Herbert, G. M., & Krishnan, A. (2016). Quantifying environmental performance of biomass energy. Renewable and Sustainable Energy Reviews, 59, 292–308. https://doi.org/10.1016/j.rser.2015.12.254
- Hermann, S. L., Blackledge, C., Haan, N. L., Myers, A. T., & Landis, D. A. (2019). Predators of monarch butterfly eggs and neonate larvae are more diverse than previously recognised. Scientific Reports, 9(1), 14304. https://doi.org/10.1038/s41598-019-50737-5
- Hermansen, E. A. T. (2016). "I Will Write a Letter and Change the World". The Knowledge Base Kick-Starting Norway's Rainforest Initiative. Nordic Journal of Science and Technology Studies, 3(2), 34–46. https://doi.org/10.5324/njsts.v3i2.2164
- Hess, D. J., & Sovacool, B. K. (2020). Sociotechnical matters: Reviewing and integrating science and technology studies with energy social science. Energy Research & Social Science, 65, 101462. https://doi.org/10.1016/j.erss.2020.101462
- Hill, K., Seltzer, W., Leaning, J., Malik, S. J., & Russell, S. S. (2008). The demographic impact of Partition in the Punjab in 1947. Population Studies, 62(2), 155–170. https://doi.org/10.1080/00324720801955206
- Hudson, B. D. (1994). Soil organic matter and available water capacity. Journal of soil and water conservation, 49(2), 189–194.
- Hundal, H. S., Singh, K., Singh, D., & Kumar, R. (2013). Arsenic mobilization in alluvial soils of Punjab, North–West India under flood irrigation practices. Environmental Earth Sciences, 69(5), 1637–1648. https://doi.org/10.1007/s12665-012-1999-y
- Hussain, M., Ahmad, S., Hussain, S., Lal, R., Ul-Allah, S., & Nawaz, A. (2018). Rice in Saline Soils: Physiology, Biochemistry, Genetics, and Management. I Advances in Agronomy (Bd. 148, s. 231–287). Elsevier. https://doi.org/10.1016/bs.agron.2017.11.002
- Supreme court of India.. (2020). IA NOS.158128 AND 158129 OF 2019 IN WRIT PETITION (C) NO.13029 OF 1985, 158128 and 158129, Supreme Court (2020). https://main.sci.gov.in/supremecourt/1985/63998/63998_1985_3_1501_19445_Judgement_13-Jan-2020.pdf
- IAS Parliament. (2023). Over Application of Urea and DAP. IAS Parliament. https://www.iasparliament.com/blogs/pdf/over-application-of-urea-and-dap

- Idris, M., Singh, P., & Johari, S. (2009). Impact Assessment of the Indira Gandhi Canal on the Avifauna of the Thar Desert. I C. Sivaperuman, Q. H. Baqri, G. Ramaswamy, & M. Naseema (Red.), Faunal Ecology and Conservation of the Great Indian Desert (s. 119–135). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-87409-6_11
- IEA. (2021). Energy in India Today: India Energy Outlook 2021. IEA. https://www.iea.org/reports/india-energy-outlook-2021/energy-in-india-today
- IEA. (2023). Coal 2023: Analysis and forecast to 2026 (CC by 4.0). IEA. https://www.iea.org/reports/coal-2023
- Institution of Mechanical Engineers. (2013). Global Food: Waste not, Want Not. https://www.imeche.org/docs/default-source/reports/Global_Food_Report.pdf
- International Energy Agency. (2021). India Energy Outlook 2021 (CC By 4.0). https://iea.blob.core.windows.net/assets/1de6d91e-e23f-4e02-b1fb-51fdd6283b22/India_Energy_Outlook_2021.pdf
- IQAIR. (2024, january 4). Air quality in London Air quality index (AQI) and PM2.5 air pollution in London. IQ AIR. https://www.iqair.com/uk/england/london
- IWWAGE. (2023). WOMEN'S WORKFORCE PARTICIPATION IN INDIA: STATEWISE TRENDS: PUNJAB. https://iwwage.org/wp-content/uploads/2023/01/Punjab_Factsheet_9_jan.pdf
- Jackson, A. L. R. (2011). Renewable energy vs. Biodiversity: Policy conflicts and the future of nature conservation. Global Environmental Change, 21(4), 1195–1208. https://doi.org/10.1016/j.gloenvcha.2011.07.001
- Jahagirdar, S., Patki, V., & Metan, S. (2019). Evaluation of physical and chemical properties of OPC and PPC cement. Int. J. Recent Technol. Eng., 8(2S11), 840–845.
- Jain, A. K. (2023). Greenhouse gas emissions from nitrogen fertilizers. Nature Food, 4(2), 139–140. https://doi.org/10.1038/s43016-023-00706-z
- Jain, A., & Kumar, R. (2007). Water management issues–Punjab, North-West India. Proc paper In: Indo-US Workshop on Innovative E-technologies for Distance Education and Extension/Outreach for Efficient Water Management. ICRISAT, Hyderabad.
- Jain, M. C., Kumar, S., Wassmann, R., Mitra, S., Singh, S. D., Singh, J. P., Singh, R., Yadav, A. K., & Gupta, S. (2000). Methane Emissions from Irrigated Rice Fields in Northern India (New Delhi). Nutrient Cycling in Agroecosystems, 58(1), 75–83. https://doi.org/10.1023/A:1009882216720
- Jasanoff, S., & Kim, S.-H. (Red.). (2015). Chapter 1: Future Imperfect: Science, Technology and the Imaginations of Modernity. I S. Jasanoff, Dreamscapes of modernity: Sociotechnical imaginaries and the fabrication of power (s. 1–34). The University of Chicago Press.
- Jaswinder, K. (2022). Economics of Paddy Cultivation in Punjab. Indian Journal of Economics and Development, 714–720. https://doi.org/10.35716/IJED/21330
- Javid, H. (2011). Class, Power, and Patronage: Landowners and Politics in Punjab. History and Anthropology, 22(3), 337–369. https://doi.org/10.1080/02757206.2011.595006
- Jenny, Hans. (1941). Factors of Soil Formation, a System of Quantitative Pedology: By Hans Jenny. New York: McGraw-Hill Book Company, Inc. XII + 281 pages, illus. $3.50. Agronomy Journal, 33(9), 857–858. https://doi.org/10.2134/agronj1941.00021962003300090016x
- Jethva, H., Chand, D., Torres, O., Gupta, P., Lyapustin, A., & Patadia, F. (2018). Agricultural Burning and Air Quality over Northern India: A Synergistic Analysis using NASA's A-train Satellite Data and Ground Measurements. Aerosol and Air Quality Research, 18(7), 1756–1773. https://doi.org/10.4209/aaqr.2017.12.0583
- Jodhka, S. S. (2006a). Beyond «Crises»: Rethinking Contemporary Punjab Agriculture. Economic and Political Weekly, 41(16), 1530–1537. JSTOR.
- Jodhka, S. S. (2006b). Caste and Democracy: Assertion and Identity among the Dalits of Rural Punjab. Sociological Bulletin, 55(1), 4–23. https://doi.org/10.1177/0038022920060101
- Jodhka, S. S. (2021). Why are the farmers of Punjab protesting? The Journal of Peasant Studies, 48(7), 1356–1370. https://doi.org/10.1080/03066150.2021.1990047
- Jodhka, S. S. (2023). The Indian Village: Rural Lives in the 21st Century. Aleph Book Company.

- Kang, G., Beri, V., Sidhu, B., & Rupela, O. (2005). A new index to assess soil quality and sustainability of wheat-based cropping systems. Biology and Fertility of Soils, 41, 389–398.
- Kashyap, D., & Agarwal, T. (2021). Carbon footprint and water footprint of rice and wheat production in Punjab, India. Agricultural Systems, 186, 102959. https://doi.org/10.1016/j.agsy.2020.102959
- Kaur, B., Sidhu, R. s, & Vatta, K. (2010). Optimal Crop Plans for Sustainable Water Use in Punjab. Agricultural Economics Research Review, 23.
- Kaur, G., & Mavi, H. K. (2016). Farmers 'Suicides in Punjab-Problems and Possible Solutions. Indian Journal of Economics and Development, 12(1a), 329. https://doi.org/10.5958/2322-0430.2016.00085.8
- Kaur, I. (2015). Need of crop diversification to achieve sustainable agriculture in Punjab: A brief review. Indian Journal of Economics and Development, 11(1), 41. https://doi.org/10.5958/2322-0430.2015.00005.0
- Kaur, M., Malik, D. P., Malhi, G. S., Sardana, V., Bolan, N. S., Lal, R., & Siddique, K. H. (2022). Rice residue management in the Indo-Gangetic Plains for climate and food security. A review. Agronomy for Sustainable Development, 42(5), 92.
- Kaur, R. R., & Luthra, A. (2018). Population growth, urbanization and electricity—Challenges and initiatives in the state of Punjab, India. Energy Strategy Reviews, 21, 50–61. https://doi.org/10.1016/j.esr.2018.04.005
- Keil, A., D'souza, A., & McDonald, A. (2015). Zero-tillage as a pathway for sustainable wheat intensification in the Eastern Indo-Gangetic Plains: Does it work in farmers' fields? Food Security, 7(5), 983–1001.
- Khajuria, A. (2016). Impact of Nitrate Consumption: Case Study of Punjab, India. Journal of Water Resource and Protection, 08(02), 211–216. https://doi.org/10.4236/jwarp.2016.82017
- Khan, M., Mobin, M., Abbas, Z., & Alamri, S. (2018). Fertilizers and their contaminants in soils, surface and groundwater. Encyclopedia of the Anthropocene, 5, 225–240.
- King, J. A., King, J. A., Bradley, R. I., & Harrison, R. (2005). Current trends of soil organic carbon in English arable soils. Soil Use and Management, 21(2), 189–195. https://doi.org/10.1079/SUM2005307
- Knorr, K. (1988). The micro-social order: Towards a reconception.
- KRIBHCO. (2024). Di-ammonium Phosphate-DAP. https://www.kribhco.net/dap.html
- Krishan, G. (2004). Demography of the Punjab, 1849–1947. JPS, 11(1), 78.
- Krzywoszynska, A. (2019). Caring for soil life in the Anthropocene: The role of attentiveness in more-than-human ethics. Transactions of the Institute of British Geographers, 44(4), 661–675.
- Krzywoszynska, A. (2021). Soil care: Understanding soil needs, responsibilities, and attentiveness through the concept of care.
- Kumar, A., Kushwaha, K. K., Singh, S., Shivay, Y. S., Meena, M. C., & Nain, L. (2019). Effect of paddy straw burning on soil microbial dynamics in sandy loam soil of Indo-Gangetic plains. Environmental Technology & Innovation, 16, 100469. https://doi.org/10.1016/j.eti.2019.100469
- Kumar, M. (2019). India's Rice Export: What is in it for Farmers? Agrarian South: Journal of Political Economy, 8(|-1), 136–171.
- Kumar, P. (2007). Green Revolution and its impact on environment. International Journal of Research in Humanities & Soc. Sciences, 5(3), 54–57.
- Kumar, P. (2022). Politics of Agrarian Protests: Resistance to Corporatisation of Agriculture in Punjab. Journal of Sikh & Punjab Studies, 29.
- Kumar, P., & Sharma, S. (1998). Suicides in rural Punjab. Institute for Development and Communication, Chandigarh.
- Kumar, P., Kumar, S., & Joshi, L. (2015). Socioeconomic and Environmental Implications of Agricultural Residue Burning. Springer India. https://doi.org/10.1007/978-81-322-2014-5

- Kumar, R. & Sangeet. (2019). Economic Viability of Crop Diversification in Punjab. Journal of Krishi Vigyan, 8(1), 55. https://doi.org/10.5958/2349-4433.2019.00069.2
- Kumar, S., & Kumar, P. (2016). Economic impact of air pollution from agricultural residue burning on human health. Climate Change Challenge (3C) and Social-Economic-Ecological Interface-Building: Exploring Potential Adaptation Strategies for Bio-resource Conservation and Livelihood Development, 297–313.
- Kurinji, L., & Kumar, S. (2021). Is Ex-situ Crop Residue Management a Scalable Solution to Stubble Burning? A Punjab Case Study. New Delhi: Council on Energy, Environment and Water.
- Latour, B. (1993). We have never been modern. Harvard University Press.
- Latour, B. (2007). Reassembling the social: An introduction to Actor-Network-Theory (1. publ. in pbk). Oxford Univ. Press.
- Latour, B., & Woolgar, S. (1986). Laboratory life: The construction of scientific facts (1. Princeton paperback print). Princeton Univ. Press.
- Law, J. (1992). Notes on the theory of the actor-network: Ordering, strategy, and heterogeneity. Systems Practice, 5(4), 379–393. https://doi.org/10.1007/BF01059830
- Le Mer, J., & Roger, P. (2001). Production, oxidation, emission and consumption of methane by soils: A review. European journal of soil biology, 37(1), 25–50.
- Leon Lyles & Bruce E. Allison. (1976). Wind Erosion: The Protective Role of Simulated Standing Stubble. Transactions of the ASAE, 19(1), 0061–0064. https://doi.org/10.13031/2013.35967
- Li, B., & Haneklaus, N. (2022). The potential of India's net-zero carbon emissions: Analyzing the effect of clean energy, coal, urbanization, and trade openness. Energy Reports, 8, 724–733.
- Li, T. (2014). Land's end: Capitalist relations on an indigenous frontier. Duke University Press.
- Lianos, T. P. (1984). Concentration and Centralization of Capital in Agriculture. Studies in Political Economy, 14(1), 99–116. https://doi.org/10.1080/19187033.1984.11675634
- Liu, R., Sanyal, A., & Singh, N. (2021). Environmental Issues, Economic Policies and Agricultural Development: The Case of Punjab, India. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3760297
- Lohan, S. K., Jat, H. S., Yadav, A. K., Sidhu, H. S., Jat, M. L., Choudhary, M., Peter, J. K., & Sharma, P. C. (2018). Burning issues of paddy residue management in north-west states of India. Renewable and Sustainable Energy Reviews, 81, 693–706. https://doi.org/10.1016/j.rser.2017.08.057
- Lovins, A. (2017). Energy efficiency. Energy Economics, 1, 234–258.
- Luo, Z., & Zhou, J. (2022). Thermal conversion of biomass. I Handbook of Climate Change Mitigation and Adaptation (s. 965–1021). Springer.
- Mäkelä, M. R., Donofrio, N., & De Vries, R. P. (2014). Plant biomass degradation by fungi. Fungal Genetics and Biology, 72, 2–9. https://doi.org/10.1016/j.fgb.2014.08.010
- Malhotra, K. K. (2014). THE EIGHTEENTH CENTURY SIKH SOCIAL ORDER: IDENTITIES AND DIFFERENTIATION. Proceedings of the Indian History Congress, 75, 409–414. JSTOR.
- Malik, K., Rani, M., Sharma, P., & Bhardwaj, A. K. (2022). Rice straw compost: A sustainable residue recycling solution for soil health and productivity enhancement in the rice-wheat cropping system. Journal of Natural Resource Conservation and Management, 3(2), 143–151.
- Mann, K., & Chauhan, S. (2023). The Extent of Indebtedness among Farming Households in Punjab. Annals of the National Association of Geographers, India, 43(1).
- Menegat, S., Ledo, A., & Tirado, R. (2022). Greenhouse gas emissions from global production and use of nitrogen synthetic fertilisers in agriculture. Scientific Reports, 12(1), 14490. https://doi.org/10.1038/s41598-022-18773-w
- Mishra, V., Asoka, A., Vatta, K., & Lall, U. (2018). Groundwater Depletion and Associated CO 2 Emissions in India. Earth's Future, 6(12), 1672–1681. https://doi.org/10.1029/2018EF000939

- Misselbrook, T., Menzi, H., & Cordovil, C. (2012). Preface–recycling of organic residues to agriculture: Agronomic and environmental impacts. Agriculture, Ecosystems & Environment, 160, 1–2.
- Mizuno, A. (2000). Electrostatic precipitation. IEEE Transactions on Dielectrics and Electrical Insulation, 7(5), 615–624. https://doi.org/10.1109/94.879357
- Mohd Kusin, F. (2015). The impact of nitrogen fertilizer use on greenhouse gas emissions in an oil palm plantation associated with land use change. Atmósfera, 28(4), 243–250. https://doi.org/10.20937/ATM.2015.28.04.03
- Mol, A. (2008). The logic of care: Health and the problem of patient choice. Routledge.
- Mol, A., Moser, I., & Pols, J. (2010). Care in practice: On tinkering in clinics, homes and farms. Transcript.
- Murty, D., Kirschbaum, M. U., Mcmurtrie, R. E., & Mcgilvray, H. (2002). Does conversion of forest to agricultural land change soil carbon and nitrogen? A review of the literature. Global change biology, 8(2), 105–123.
- NASA. (2022, november 1). Smoky Skies in Northern India. Earth Observatory NASA. https://earthobservatory.nasa.gov/images/150555/smoky-skies-in-northern-india
- Nasar, R., Ashok, K., & Deshpande, T. (2022). Greenhouse Gas Emissions Estimates from the Energy Sector in India at the sub-national level (version 4.0). https://www.ghgplatform-india.org/energy-sector/
- Neary, D. G., Klopatek, C. C., DeBano, L. F., & Ffolliott, P. F. (1999). Fire effects on belowground sustainability: A review and synreport. Forest ecology and management, 122(1–2), 51–71.
- Nieder, R., & Benbi, D. K. (2008). Carbon and nitrogen in the terrestrial environment. Springer Science & Business Media.
- Nijjar, B. S. (2008). Origins and history of Jats and other allied nomadic tribes of India, 900 B.C. - 1947 A.D. Atlantic Publ.
- Norfund. (2023, january 15). Norway's Climate Investment Fund to Invest in SAEL to Develop 3000MW Clean Energy. Norfund. https://www.norfund.no/norways-climate-investment-fund-to-invest-in-sael-to-develop-3000mw-clean-energy/
- North, R. J. (2006). Assessment of real-world pollutant emissions from a light duty diesel vehicle.
- O'Reilly, K. (2005). Ethnographic methods. Routledge.
- Pachauri, R. K., & IPCC (Red.). (2008). Climate change 2007: Contribution of ... to the fourth assessment report of the Intergovernmental Panel on Climate Change. 4: Synreport report: [a report of the Intergovernmental Panel on Climate Change] / ed. by Rajendra K. Pachauri. IPCC.
- Pandey, P., & Sharma, A. (2021). Knowledge politics, vulnerability and recognition-based justice: Public participation in renewable energy transitions in India. Energy Research & Social Science, 71, 101824. https://doi.org/10.1016/j.erss.2020.101824
- Papadopoulos, D. (2011). Alter-ontologies: Towards a constituent politics in technoscience. Social Studies of Science, 41(2), 177–201. https://doi.org/10.1177/0306312710385853
- Parayil, G. (1992). The Green Revolution in India: A Case Study of Technological Change. Technology and Culture, 33, 737–756.
- Patel, R. (2013). The Long Green Revolution. Journal of Peasant Studies, 40(1), 1–63. https://doi.org/10.1080/03066150.2012.719224
- Patton, M. Q. (2005). Qualitative research. Encyclopedia of statistics in behavioral science.
- Paul, E., & Frey, S. (2023). Soil microbiology, ecology and biochemistry. Elsevier.
- Paustian, K., Collins, H. P., & Paul, E. A. (1997). Management controls on soil carbon. Soil organic matter in temperate agroecosystems, 15–49.
- Pegels, A. (2010). Renewable energy in South Africa: Potentials, barriers and options for support. Energy Policy, 38(9), 4945–4954. https://doi.org/10.1016/j.enpol.2010.03.077

- Pillai, V. (2020, september 4). Our Power Plant Has Contributed Immensely To Punjab's Economy: Talwandi Sabo Power Ltd. Transmission & Distribution Indioa: Your >Bridge to the power Transmission & Distribution Industry. https://www.tndindia.com/power-plant-contributed-immensely-punjabs-economy-talwandi-sabo-power-ltd/
- Prasad, R. (2005). Rice–Wheat Cropping Systems. I Advances in Agronomy (Bd. 86, s. 255–339). Elsevier. https://doi.org/10.1016/S0065-2113(05)86006-7
- Proceedings of the public hearing conducted on 18.10.2018 in connection with the application filed by M/s Sukhbir Agro Energy Ltd., under the EIA notification dated 14.9.2006 for establishment of Bio-mass based Power Plant of 18 MW in the revenue estate of Village Hakumat Singh Wala, Tehsil & District Ferozepur. (2018). https://ppcb.punjab.gov.in/sites/default/files/documents/PHSukhbirAgroFZR(Eng)18.10.2018.pdf
- Proceedings of the public hearing conducted on 18.10.2018 in connection with the application filed by M/s Sukhbir Agro Energy Ltd., under the EIA notification dated 14.9.2006 for establishment of Bio-mass based Power Plant of 18 MW in the revenue estate of Village Hakumat Singh Wala, Tehsil & District Ferozepur. (2018). pa
- PRS India. (2024). Punjab Budget Analysis 2023-24. PRS India. https://prsindia.org/budgets/states/punjab-budget-analysis-2023-24
- Puig De La Bellacasa, M. (2015). Making time for soil: Technoscientific futurity and the pace of care. Social Studies of Science, 45(5), 691–716. https://doi.org/10.1177/0306312715599851
- Puig de la Bellacasa, M. (2017). Matters of care: Speculative ethics in more than human worlds. University of Minnesota Press.
- Puig De La Bellacasa, M. (2019). Re-animating soils: Transforming human–soil affections through science, culture and community. The Sociological Review, 67(2), 391–407. https://doi.org/10.1177/0038026119830601
- Puigde la Bellacasa, M. (2014). Encountering bioinfrastructure: Ecological struggles and the sciences of soil. Social Epistemology, 28(1), 26–40.
- Pujara, M. K., & Shahid, A. (2016). Crop Diversification: Challenges of Switching Crops in Punjab. Indian Journal of Economics and Development, 12(1a), 579. https://doi.org/10.5958/2322-0430.2016.00126.8
- Punjab Data. (Unknown date). Crops Grown in Punjab. Punjab Data: Know everything about Punjab. https://punjabdata.com/Agriculture-In-Punjab.aspx
- PWC. (2023). Punjab State Energy Action Plan (Executive Summary). Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. https://www.peda.gov.in/media/Punjab_EAP_Designed_Doc.pdf
- Ramakumar, R., Tata Institute of Social Sciences, & National Bank for Agriculture and Rural Development (India) (Red.). (2022). Distress in the fields: Indian agriculture after liberalization (First edition). Tulika Books.
- Randhawa, M. S. (1977). Green Revolution in Punjab. Agricultural History, 51(4), 656–661. JSTOR.
- Ranguwal, S., Sidana, B. K., Singh, J., Sachdeva, J., Kumar, S., Sharma, R. K., & Dhillon, J. (2023). Quantifying the energy use efficiency and greenhouse gas emissions in Punjab (India) agriculture. Energy Nexus, 11, 100238. https://doi.org/10.1016/j.nexus.2023.100238
- Rasmussen, P. E., Goulding, K. W., Brown, J. R., Grace, P. R., Janzen, H. H., & Korschens, M. (1998). Long-term agroecosystem experiments: Assessing agricultural sustainability and global change. Science, 282(5390), 893–896.
- Raudales, R. E., Parke, J. L., Guy, C. L., & Fisher, P. R. (2014). Control of waterborne microbes in irrigation: A review. Agricultural Water Management, 143, 9–28. https://doi.org/10.1016/j.agwat.2014.06.007
- Ravindra Brahmachari Chidanandjee. (2009). Ethics and values of Sikhism. Anmol Publications.
- Rawal, N., Ghimire, R., & Chalise, D. (2017). Crop yield and soil fertility status of long-term rice-rice-wheat cropping systems. International Journal of Applied Sciences and Biotechnology, 5(1), 42–50.

- Reddy, J. P., Dubey, N., Avinashe, H. A., Ram, K., Rohith, K., & Sree, C. C. (2019). Stubble burning in Punjab: A review. Journal of Pharmacognosy and Phytochemistry, 8(1S), 186–191.
- Rock, P. (2014). Symbiolic Interactionism and Ethnography. I P. Atkinson, A. Coffey, S. Delamont, J. Lofland, & L. Lofland (Red.), Handbook of ethnography (Reprinted). SAGE.
- Rodell, M., Velicogna, I., & Famiglietti, J. S. (2009). Satellite-based estimates of groundwater depletion in India. Nature, 460(7258), 999–1002. https://doi.org/10.1038/nature08238
- Rosegrant, M. W., Koo, J., Cenacchi, N., Ringler, C., Robertson, R. D., Fisher, M., Cox, C. M., Garrett, K., Perez, N. D., & Sabbagh, P. (2014). Food security in a world of natural resource scarcity: The role of agricultural technologies. Intl Food Policy Res Inst.
- Rubio, M. B., Quijada, N. M., Pérez, E., Domínguez, S., Monte, E., & Hermosa, R. (2014). Identifying Beneficial Qualities of Trichoderma parareesei for Plants. Applied and Environmental Microbiology, 80(6), 1864–1873. https://doi.org/10.1128/AEM.03375-13
- Sachs, J. D., Woo, W. T., Yoshino, N., & Taghizadeh-Hesary, F. (2019). Importance of Green Finance for Achieving Sustainable Development Goals and Energy Security. I J. D. Sachs, W. T. Woo, N. Yoshino, & F. Taghizadeh-Hesary (Red.), Handbook of Green Finance (s. 3–12). Springer Singapore. https://doi.org/10.1007/978-981-13-0227-5_13
- SAEL. (2022). SAEL.co. sael.co. www.sael.co
- SAEL. (2024). SAEL: Waste-to-Energy Projects. SAEL. https://www.sael.co/copy-of-solar-energy
- Sætre, S., & Østli, K. (2021). Den nye fisken: Om temmingen av laksen og alt det forunderlige som fulgte (2. opplag). Spartacus.
- Said, E. W. (2003). Orientalism (Facsimile edition). Penguin.
- Sanchis, E., Ferrer, M., Torres, A. G., Cambra-López, M., & Calvet, S. (2012). Effect of water and straw management practices on methane emissions from rice fields: A review through a meta-analysis. Environmental engineering science, 29(12), 1053–1062.
- Sanders, P. (2023). Toward a Mutually Beneficial Partnership with India to Improve US Strategy in the US Indo-Pacific Command. MILITARY REVIEW.
- Sandhu, J. S. (2014). GREEN REVOLUTION: A CASE STUDY OF PUNJAB. Proceedings of the Indian History Congress, 75, 1192–1199. JSTOR.
- Sapkota, T. B., Jat, M. L., Shankar, V., Singh, L. K., Rai, M., Grewal, M. S., & Stirling, C. M. (2015). Tillage, residue and nitrogen management effects on methane and nitrous oxide emission from rice–wheat system of Indian Northwest Indo-Gangetic Plains. Journal of Integrative Environmental Sciences, 12(sup1), 31–46.
- Sarathchandra, S. U., Ghani, A., Yeates, G. W., Burch, G., & Cox, N. R. (2001). Effect of nitrogen and phosphate fertilisers on microbial and nematode diversity in pasture soils. Soil Biology and Biochemistry, 33(7), 953–964. https://doi.org/10.1016/S0038-0717(00)00245-5
- Satish, P. (2006). Institutional Credit, Indebtedness and Suicides in Punjab. Economic and Political Weekly, 41(26), 2754–2761. JSTOR.
- Schlamadinger, B., & Marland, G. (1996). The role of forest and bioenergy strategies in the global carbon cycle. Biomass and Bioenergy, 10(5–6), 275–300. https://doi.org/10.1016/0961-9534(95)00113-1
- Schlenker, W. (2019). Agricultural Productivity and Producer Behavior. University of Chicago Press. https://doi.org/10.7208/chicago/9780226619941.001.0001
- Sengupta, N. (1985). Irrigation: Traditional vs Modern. Economic and Political Weekly, 20(45/47), 1919–1938. JSTOR.
- Serikstad, G. lene, Pommeresche, R., McKinnon, K., & Hansen, S. (2018). Karbon i Jord- Kilder, Håndtering og Omdanning (3/9/2018). NORSØK. https://orgprints.org/id/eprint/34314/1/NORS%C3%98K%20Rapport%20nr%209%20Jordkarbon.pdf
- Shadlen, K. (2008). Globalisation, Power and Integration: The Political Economy of Regional and Bilateral Trade Agreements in the Americas. The Journal of Development Studies, 44(1), 1–20. https://doi.org/10.1080/13562570701722089

- Shah, T., Giordano, M., & Mukherji, A. (2012). Political economy of the energy-groundwater nexus in India: Exploring issues and assessing policy options. Hydrogeology Journal, 20(5), 995–1006. https://doi.org/10.1007/s10040-011-0816-0
- Sharma, A., & Brar, A. S. (2022). Investigation on baler technology for ex situ paddy residue biomass management with energy consumption analysis for wheat establishment. International Journal of Environmental Science and Technology, 19(7), 6267–6284. https://doi.org/10.1007/s13762-021-03444-6
- Sharma, B. D., Kumar, R., Manchanda, J. S., Dhaliwal, S. S., Thind, H. S., & Singh, Y. (2016). Mapping of Chemical Characteristics and Fertility Status of Intensively Cultivated Soils of Punjab, India. Communications in Soil Science and Plant Analysis, 00103624.2016.1208756. https://doi.org/10.1080/00103624.2016.1208756
- Sharma, S., Singh, P., & Kumar, S. (2020). Responses of Soil Carbon Pools, Enzymatic Activity, and Crop Yields to Nitrogen and Straw Incorporation in a Rice-Wheat Cropping System in North-Western India. Frontiers in Sustainable Food Systems, 4, 532704. https://doi.org/10.3389/fsufs.2020.532704
- Shiva, V. (1991). The violence of the green revolution: Third World agriculture, ecology, and politics. Zed Books ; Third World Network.
- Shiva, V. (2015). Soil not oil: Environmental justice in an age of climate crisis. North Atlantic Books.
- Shukla, S., Upadhyay, D., Mishra, A., Jindal, T., & Shukla, K. (2022). Challenges Faced by Farmers in Crops Production Due to Fungal Pathogens and Their Effect on Indian Economy. I V. R. Rajpal, I. Singh, & S. S. Navi (Red.), Fungal diversity, ecology and control management (s. 495–505). Springer Nature Singapore. https://doi.org/10.1007/978-981-16-8877-5_24
- Sidhu, B., & Beri, V. (2008). Rice residue management: Farmer's perspective. Indian Journal of Air Pollution Control, 8(1), 61–67.
- Sidhu, B., Rupela, O., Beri, V., & Joshi, P. (1998). Sustainability implications of burning rice-and wheat-straw in Punjab. Economic and political weekly, A163–A168.
- Sidhu, R., Vatta, K., & Lall, U. (2011). Climate change impact and management strategies for sustainable water-energy-agriculture outcomes in Punjab. Indian Journal of Agricultural Economics, 66(3).
- Sigl, L., Falkenberg, R., & Fochler, M. (2023). Changing articulations of relevance in soil science. Studies in History and Philosophy of Science, 97, 79–90. https://doi.org/10.1016/j.shpsa.2022.12.004
- SIKT. (2023). SIKT: Årsarapport 2023. SIKT. https://cms.sikt.no/sites/default/files/2024-04/Sikt-arsrapport2023.pdf
- Singh, A. (2011b). Generation of Electricity from Paddy Stubble.
- Singh, A., Kaur, M., Kang, J., & Goel, A. (2013). Happy seeder and rotavator technology for in-situ management of paddy straw. International Journal of Advanced Research, 1(8), 372–379.
- Singh, B., & Singh, Y. (2004). Chapter 18: Management of Crop Residues in Rice-Wheat Cropping System in the Indo-Gangetic Plains. I S. Singh, V. Nayyar, & J. Singh (Red.), Nutritinet management for Sustainable Rice-Wheat Cropping System. National Agricultural Technology Project, Indian Council of Agricultural Research, New Delhi and Punjab Agricultural University, Ludhiana, India. file:///C:/Users/ander/Downloads/Chap18CropResidues_Rice-WheatBook_2003.pdf
- Singh, G., Jalota, S. K., & Singh, Y. (2007). Manuring and residue management effects on physical properties of a soil under the rice–wheat system in Punjab, India. Soil and Tillage Research, 94(1), 229–238. https://doi.org/10.1016/j.still.2006.07.020
- Singh, G., Singh, P., Sodhi, G., & Tiwari, D. (2020). Adoption status of rice residue management technologies in south western Punjab. Indian Journal of Extension Education, 56(3), 76–82.
- Singh, I., & Bhangoo, K. S. (2013). Irrigation system in Indian Punjab.
- Singh, J. (2018). Paddy and wheat stubble blazing in Haryana and Punjab states of India: A menace for environmental health. Environmental Quality Management, 28(2), 47–53.

- Singh, J., Singh, J., Kumar, H., Singh, S., Sachdeva, J., Kaur, B., Chopra, S., & Chand, P. (2019). Management of paddy straw in Punjab: An economic analysis of different techniques. Indian J. Agric. Econ, 74(3), 301–310.
- Singh, J., Srivastava, S., Kaur, A. P., Jain, R., Immaneulraj, K., Raju, S., & Kaur, P. (2017b). Farm-size efficiency relationship in Punjab agriculture: Evidences from cost of cultivation survey. Indian Journal of Economics and Development, 13(2a), 357–362.
- Singh, K. (2011a). Groundwater depletion in Punjab: Measurement and countering strategies. Indian Journal of Agricultural Economics, 66(4).
- Singh, N. (2021). Agrarian crisis and the longest farmers' protest in Indian history. 30(3), 66–75.
- Singh, P. (2022). Farm Laws, Federalism and Farm Protests: India and Punjab. Journal of Sikh & Punjab Studies, 29.
- Singh, P. B. (1985). CANAL IRRIGATION SYSTEM IN PUNJAB AND ITS IMPACT. Proceedings of the Indian History Congress, 46, 476–482. JSTOR.
- Singh, P., & Benbi, D. K. (2020). Nutrient management impacts on net ecosystem carbon budget and energy flow nexus in intensively cultivated cropland ecosystems of north-western India. Paddy and Water Environment, 18(4), 697–715. https://doi.org/10.1007/s10333-020-00812-9
- Singh, R. P., & Kaskaoutis, D. G. (2014). Crop Residue Burning: A Threat to South Asian Air Quality. Eos, Transactions American Geophysical Union, 95(37), 333–334. https://doi.org/10.1002/2014EO370001
- Singh, S., & Benbi, D. K. (2016). Punjab-Soil Health and Green Revolution: A Quantitative Analysis of Major Soil Parameters. Journal of Crop Improvement, 30(3), 323–340. https://doi.org/10.1080/15427528.2016.1157540
- Singh, S., & Sharma, S. (2020). Temporal changes in rhizosphere biological soil quality indicators of wheat in response to nitrogen and straw incorporation. Tropical Ecology, 61(3), 328–344. https://doi.org/10.1007/s42965-020-00092-8
- Singh, S., Kaur, P., Sachdeva, J., & Bhardwaj, S. (2017a). Profitability Analysis of Major Crops in Punjab: Some Evidence from Cost of Cultivation Survey Data. Indian Journal of Economics and Development, 13(1), 71. https://doi.org/10.5958/2322-0430.2017.00010.5
- Singh, S., Singh, J., & Sharda, A. (2002). Energy and power use pattern in production agriculture in Punjab (India). Agricultural Engineering Today, 26(5and6), 74–83.
- Sinha, P. K. (2023, october 29). Revolution in Punjab Agriculture: The Emergence of Agripreneurs and the Millet Renaissance. https://medium.com/@pritamkumarsinha/revolution-in-punjab-agriculture-the-emergence-of-agripreneurs-and-the-millet-renaissance-e20254d4a2b0
- Sismondo, S., & Sismondo, S. (2010). An introduction to science and technology studies (Second edition). Wiley-Blackwell.
- Skilbrei, M.-L. (2019). Kvalitative Metoder: Planlegging, Gjennomføring og Etisk Refleksjon (2. utg.). Fagbokforlaget.
- Sonmez, I., Kaplan, M., & Sonmez, S. (2007). Investigation of seasonal changes in nitrate contents of soils and irrigation waters in greenhouses Located in Antalya-Demn region. Asian Journal of Chemistry, 19(7), 5639.
- Srivastava, R., Sarkar, D., Mukhopadhayay, S. S., Sood, A., Singh, M., Nasre, R. A., & Dhale, S. A. (2015). Development of hyperspectral model for rapid monitoring of soil organic carbon under precision farming in the Indo-Gangetic Plains of Punjab, India. Journal of the Indian Society of Remote Sensing, 43(4), 751–759. https://doi.org/10.1007/s12524-015-0458-0
- Star, S. L. (1999). The Ethnography of Infrastructure. American Behavioral Scientist, 43(3), 377–391. https://doi.org/10.1177/00027649921955326
- Star, S. L., & Ruhleder, K. (1996). Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces. Information Systems Research, 7(1), 111–134. https://doi.org/10.1287/isre.7.1.111
- Stockmann, U., Adams, M. A., Crawford, J. W., Field, D. J., Henakaarchchi, N., Jenkins, M., Minasny, B., McBratney, A. B., Courcelles, V. de R. de, Singh, K., Wheeler, I., Abbott, L.,

Angers, D. A., Baldock, J., Bird, M., Brookes, P. C., Chenu, C., Jastrow, J. D., Lal, R., … Zimmermann, M. (2013). The knowns, known unknowns and unknowns of sequestration of soil organic carbon. Agriculture, Ecosystems & Environment, 164, 80–99. https://doi.org/10.1016/j.agee.2012.10.001

- Stram, B. N. (2016). Key challenges to expanding renewable energy. Energy Policy, 96, 728–734. https://doi.org/10.1016/j.enpol.2016.05.034
- Streefkerk, R. (2019, april 18). Inductive vs. Deductive Research Approach | Steps & Examples. Scribbr. https://www.scribbr.com/methodology/inductive-deductive-reasoning/
- Summerell, B., Klein, T., & Burgess, L. (1988). Influence of stubble-management practices on yellow spot of wheat. Agricultural Research, 34, 39–46.
- Sun, S. (2023). Numer of smartphoneusers in India in 2010 to 2023, with estimates until 2040 (in millions) [datasett]. https://www.statista.com/statistics/467163/forecast-of-smartphone-users-in-india/
- Sverdrup-Thygeson, A. (2020). På naturens skuldre: Hvordan ti millioner arter redder livet ditt. Kagge forlag.
- Thagaard, T. (2018). Systematikk og innlevelse en innføring i kvalitative metoder (5. utg). Fagbokforl.
- The Department of Agriculture Punjab. (2012). Cultivation of Basmati Rice. The Department of Agriculture Punjab. https://agri.punjab.gov.in/sites/default/files/cultivation_of_basmati_rice.pdf
- The Economist. (2023, june 13). America is courting India in part for its growing economic clout. The Economist. https://www.economist.com/asia/2023/06/13/america-is-courting-india-in-part-for-its-growing-economic-clout
- The Economist. (2024, march 7). Indian food is great. Perhaps too great.
- The Fertilizer Association of India. (2023). Annual Review of Fertilizer Production and Consumption 2021-2022. The Fertilizer Association of India. https://www.faidelhi.org/member/AR-21-22.pdf
- Tsing, A. L. (2005). Friction: An ethnography of global connection. Princeton University Press.
- Tsing, A. L. (2015). The mushroom at the end of the world: On the possibility of life in capitalist ruins. Princeton University press.
- U.B. CONSULTANTS PRIVATE LIMITED & PROJECT & MANAGEMENT CONSULTANTS. (2018). Sukhbir Agro Energy Limited TEV Study for 18 MW Biomass Project (Rice Straw Based) at Faridkot [TEV-Study]. SAEL. https://forestsclearance.nic.in/writereaddata/Addinfo/0_0_101125122412181ProjectSummary1.pdf
- UIO. (2023). Klassifisering av data og informasjon. UiO.no. https://www.uio.no/tjenester/it/sikkerhet/lsis/tillegg/lagring/infoklasser.html
- UiO. (2023). Lagringsguiden. https://www.uio.no/tjenester/it/sikkerhet/lsis/tillegg/lagringsguide.html
- University of Chicago. (2021). India Fact Sheet Update [Air Quality Life Index]. University of Chicago. https://aqli.epic.uchicago.edu/wp-content/uploads/2021/08/IndiaFactSheet_update-.pdf
- Unruh, G. C. (2000). Understanding carbon lock-in. Energy Policy, 28(12), 817–830. https://doi.org/10.1016/S0301-4215(00)00070-7
- Veblen, T. (1898). Why is Economics Not an Evolutionary Science? The Quarterly Journal of Economics, 12(4), 373–397.
- Vidyarthi, H. (2013). Energy consumption, carbon emissions and economic growth in India. World Journal of Science, Technology and Sustainable Development, 10(4), 278–287.
- VON TUNZELMANN, A. (2017). INDIAN SUMMER: The secret history of the end of an empire. SIMON & SCHUSTER LTD.
- Wang, A., Song, Q., Tu, G., Wang, H., Yue, Y., & Yao, Q. (2014). Influence of flue gas cleaning system on characteristics of PM2.5 emission from coal-fired power plants. International

Journal of Coal Science & Technology, 1(1), 4–12. https://doi.org/10.1007/s40789-014-0001-x

- Wang, H., Gao, J., Li, X., Zhang, S., & Wang, H. (2015). Nitrate Accumulation and Leaching in Surface and Ground Water Based on Simulated Rainfall Experiments. PLOS ONE, 10(8), e0136274. https://doi.org/10.1371/journal.pone.0136274
- Wang, J., Rothausen, S. G., Conway, D., Zhang, L., Xiong, W., Holman, I. P., & Li, Y. (2012). China's water–energy nexus: Greenhouse-gas emissions from groundwater use for agriculture. Environmental Research Letters, 7(1), 014035.
- Watts, N., & Scales, I. R. (2015). Seeds, Agricultural Systems and Socio-natures: Towards an Actor–Network Theory Informed Political Ecology of Agriculture. Geography Compass, 9(5), 225–236. https://doi.org/10.1111/gec3.12212
- Webster, J., & Weber, R. (2012). Introduction to fungi (3. ed., 5. print). Cambridge Univ. Press.
- Winiwarter, V. (2014). Environmental History of Soils. I M. Agnoletti & S. Neri Serneri (Red.), The Basic Environmental History (Bd. 4, s. 79–119). Springer International Publishing. https://doi.org/10.1007/978-3-319-09180-8_3
- Winner, L. (1980). Do Artifacts Have Politics? Daedalus, 109(1), 121–136. JSTOR.
- Wolf, E. C. (1986). Beyond the Green Revolution: New approaches for Third World agriculture. Worldwatch Inst.
- Xia, L., Lam, S. K., Wang, S., Zhou, W., Chen, D., & Yan, X. (2020). Optimizing nitrogen fertilization rate to enhance soil carbon storage and decrease nitrogen pollution in paddy ecosystems with simultaneous straw incorporation. Agriculture, Ecosystems & Environment, 298, 106968. https://doi.org/10.1016/j.agee.2020.106968
- Yin, R. K. (2018). Case study research and applications: Design and methods (Sixth edition). SAGE.
- Zeleke, T. B., Grevers, M. C. J., Si, B. C., Mermut, A. R., & Beyene, S. (2004). Effect of residue incorporation on physical properties of the surface soil in the South Central Rift Valley of Ethiopia. Soil and Tillage Research, 77(1), 35–46. https://doi.org/10.1016/j.still.2003.10.005
- Zhao, X., Yuan, G., Wang, H., Lu, D., Chen, X., & Zhou, J. (2019). Effects of Full Straw Incorporation on Soil Fertility and Crop Yield in Rice-Wheat Rotation for Silty Clay Loamy Cropland. Agronomy, 9(3), 133. https://doi.org/10.3390/agronomy9030133
- Zou, Y., Feng, H., Wu, S., Dong, Q., & Siddique, K. H. M. (2020). An Ammoniated Straw Incorporation Increased Biomass Production and Water Use Efficiency in an Annual Wheat-Maize Rotation System in Semi-Arid China. Agronomy, 10(2), 243. https://doi.org/10.3390/agronomy10020243

CICERO is Norway's foremost institute for interdisciplinary climate research. We help to solve the climate problem and strengthen international climate cooperation by predicting and responding to society's climate challenges through research and dissemination of a high international standard.

CICERO has garnered attention for its research on the effects of manmade emissions on the climate, society's response to climate change, and the formulation of international agreements. We have played an active role in the IPCC since 1995 and thirteen of our scientists contributed the IPCC's Sixth Assessment Report.

CICERO was founded by Prime Minister Syse in 1990 after initiative from his predecessor, Gro Harlem Brundtland. CICERO's Director is Kristin Halvorsen, former Finance Minister (2005–2009) and Education Minister (2009–2013). Jens Ulltveit–Moe, CEO of the industrial investment company UMOE is the chair of CICERO's Board of Directors. We are located in the Oslo Science Park, adjacent to the campus of the University of Oslo.