University of Southampton

Faculty of Art and Humanities

Winchester School of Art

Cultural Techniques of the Green Surface

Agriculture, Plant Physiology and the Planetary Living Image

by

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Thesis for the degree of Doctor of Philosophy

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Abstract

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This research presents a vegetal genealogy of the contemporary interweaving between the surfaces of the Earth and their visual mediations. Based on the media theoretical framework of cultural techniques analysis, it proposes an excavation of an agricultural past in the notion of operational images. To do so, the study explores three specific historical cases where imaging practices were interweaved with the observation and measurement of vegetal growth. First, a large-scale agricultural programme in the middle of the 20th century is analysed in relation to its use of aerial photogrammetry. Second, a series of photographic experiments in plant physiology related to the development of industrial agriculture at the turn of the 20th century is scrutinised. Finally, the notion of the biosphere as it developed as an up-scaled planetary surface after these researches in plant physiology is examined in relation to current material accounts of the image.

As a practice-based research, this project is developed as a critical technical practice in the context of media art. In particular, it explores a space of operations that are produced beyond the surface of the screen, exposing material aspects of the current entanglement between imaging techniques and the transformation of the surfaces of the world. In this vein, the aesthetic dimension of cultural techniques is explored through the presented practices. In this regard, the research unfolds the links with agriculture and plant physiology as a series of chains of operations where the visual emerges as a layered interplay of materials and scales. That is, this interplay is explored in a series of installations and screen-based works that address critically the image-based mediation of the surfaces of the Earth in terms of elemental cultural techniques.

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Research Thesis: Declaration of Authorship

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I declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

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3. Where I have consulted the published work of others, this is always clearly attributed;
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5. I have acknowledged all main sources of help;
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Signature:		Date:	

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In Alvin Lucier's *I am sitting in a room*, the sound of his speaking voice is modulated and gradually replaced by the natural frequencies of the room where it is being recursively played back again and again. Similarly, a continuous feedback has characterised and shaped also the transition of the slurred thoughts that made up the initial research project into this finished text. If it were a room, it would be a room full of people, without whom this research would be inconceivable and to whom I would like to express my gratitude.

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The interview before my admission to the PhD program of the Winchester School of Art took place the day my partner María Andueza came to term. A week later our son Timeo was born. These have been then four years of parenting and research, simultaneously. If they have been the most intense and joyful of my life, it is because of the support of María. This work would not have been physically, emotionally and creatively possible without María and Timeo being part of it. Every sentence and every mechanism involved owes its existence to them.

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Introduction

This research proposes an agricultural genealogy of the contemporary operational relation between the surfaces of the Earth and their visual mediations. To do this, it explores an entanglement between vegetable growth and the formation of images since the experimental practices of plant physiology in the last decades of the 19th century. This interweaving has been particularly present in the context of agricultural operations since then, and it can be found, for instance, in the impact of aerial photography on the development of large-scale agricultural programmes from the 20th century. It is also characteristic of the technologies known as *precision farming* since the 1990s and driven by machine vision systems. Or, more recently, it is epitomised by the use of image-based machine learning techniques applied to the administration and prediction of crops.

In all these different contexts vegetal surfaces appear as a green film whose form and movements are measured and analysed through techniques linked to visual media. It is there that a remarkable convergence takes place. On the one hand, in the plants, due to processes such as photosynthesis, light is transformed into vegetable matter. On the other, in the media practices considered — analogue and digital imaging, mainly — light is registered on their photosensitive surfaces; that is, light is inscribed in two surfaces at the same time. In these situations where visual media are used to quantify vegetable growth, two different forms of light apprehension are encountered, whereby a space of possible transfers between them can be considered. These transfers are the main object of study in the present research.

In order to explore this interweaving, I have analysed three study cases where techniques linked to visual media can be related to the observation and manipulation of vegetal growth. The first case is centred on the so-called Spanish *Inner Colonisation*, an agrarian reform and land settlement programme carried out during Franco's dictatorship. This large-scale development of new agricultural techniques in the mid-20th century will be observed in relation to the use of many significant visual and graphical operations, such as aerial photographic images or the design of an infrastructured soil that was connected to new circuits of water. The second case deals with the experimental practices that characterised plant physiology at the turn of the 20th century; namely, the material culture of a scientific discipline that was influential in the development of agriculture. In particular, I will explore the use of techniques linked to photography in its laboratories and outdoor practices, and will analyse their impact on the knowledge produced about the movements and the growth of plants. Finally, the third case will consider Vladimir I. Vernadsky's theoretical work in the 1920s on the notion of the biosphere. His model of the

Earth's living crust will be read in media theory terms and related to the photographic work of the plant physiologists addressed in the second case.

Therefore, the central object of inquiry is not a photographic condition of vegetal matter, nor a vegetal deep time of the image, but rather the sites of transfer between the growth of the plant and the formation of the image. The focus is placed on the practices and material contexts where the photographic started to replace vegetal growth. In this vein, the research — both in its theoretical and installative dimensions — will rely on the media theory notion of cultural techniques. With the aid of these, the different techno-scientific transformations operating on the surface of vegetation will be addressed as sites where a parallel differentiation in the media practices at play was produced. This differentiation will be referred to as the operational, as defined by Harun Farocki (Farocki, 2004), and will be observed in practices on the surfaces of plants or agricultural fields. This has led to study Giuliana Bruno's critical work on what she calls the surface tension that grounds, materially, the formation of images. Imaging will be analysed in this research as a practice that goes beyond the camera and the eye. Camera-less set-ups will be considered among irrigation techniques, the wrapping of plants and the covering of soils, and they will be addressed as a set of cultural techniques around the operational image that will be explored, additionally, as an installative practice.

As practice-based research, this is a project developed in the context of media art. It is being conducted in terms of what has been defined as a critical technical practice (Agre, 1997; Dieter, 2014), and it seeks to expand the understanding of the conditions and goals of the current entanglement between visual culture and the control and transformation of the surfaces of the world. In doing so, this project seeks to unfold the links with agriculture through a series of installations where the visual is approached as a layered interplay of materials and scales. Hence, this cultural techniques approach is proposed as the source of a practice. In other words, it aims to define and respond to a practice that understands the visual as a continuous assembly of material operations — the visual, as demonstrated below, will be presented as the production of a set of interactions that glue together a compound of non-human scales and agencies.

Research questions

The principal aim of this research is to understand three different cases of techno-scientific developments around vegetal growth — agriculture, plant physiology and biogeochemistry — in media theory terms. Two questions will be considered in relation to them. On the one hand, is the notion of cultural techniques useful in order to propose them as sites where a particular distinction was produced in the relation between the images and the surfaces of the world? On the other, in which ways is this distinction related to the notion of the operational?

The second main research question proposes these as cases where the image is produced as a set of material operations on the surface. This, in particular, is explored as a practice through a series of installations presented with this dissertation: can imaging be performed spatially as sequences of operations in order to bring the extractive, colonial and dispossessing contexts where the operational image is produced to the foreground?

In addition to these, the three cases separately address a set of secondary research questions that belong to their specific domains. First, the analysis of Spanish *Inner Colonisation* is presented as a case of visual agriculture linked to the ways that aerial photography and the systems of machine vision have been understood in media theory, primarily after the work of Paul Virilio and Harun Farocki. Second, the study of the use of photographic techniques in the context of experimental practices in plant physiology at the turn of the 20th century is presented as a case where photographic theory meets science studies, and the links to each will be aptly established. Finally, the third case proposes a media theory reading of Vladimir I. Vernadsky's book *The Biosphere*, which will be contextualised in relation to cultural historical approaches to the material culture that surrounded his research.

Lastly, an additional objective of the research is to contextualise this operationalisation of vegetal growth in circuits of the image in relation to the contemporary literature in media theory that has approached the geological, the chemical and the atmospheric as critical domains.

Structure and context of the research

The operational aerial image

To think about the contemporary interweaving of the surfaces of the Earth and the visual, leads to the complex of technologies and systems we refer to as satellite imagery. Viewed from above, surfaces of the Earth acquire a new status. They become legible and, as such, enter into new circulations — see, for example, the project *Terrapattern* by Golan Levin, David Newbury and Kyle McDonald:[1] in their platform, satellite images of several cities, analysed with machine learning techniques become searchable; clicking on a spot on the satellite-based map, the tool finds other locations that look similar to it. The map makes it possible to automatically locate recognisable

[1] It is an open source project released to the public. See the website: http://www.terrapattern.com

sites from the air: swimming pools, parking lots or even illegal mines (Levin, Newbury and McDonald, 2016). Land becomes media and, accordingly, it is operationalised within new circuits. It is used as such in surveys, surveillance, employed for cadastres and inventories, or as design tools within architecture and urbanism studios: satellite and aerial images are so tightly interlaced in everyday operations that they have changed our relationship with territories. As architect Liam Young from Unknown Fields Division has claimed, "it is the technologies through which we see and experience the world that now define how we make it" (Young L., 2015), or, in media theorist Bernhard Siegert words, "the map is the territory" (2011, p. 13): images within the data ensembles[2] of map servers are instruments, not mere representations. They newly produce the territory as a space of possibility: what can be done, thought or communicated relies on them.

The first case analysed in this research, the Spanish *Inner Colonisation*, displays agriculture that was augmented precisely because of the use of newly available aerial photographs. Considered from the point of view of a State-driven occupation of land, it is a similar case to the colonisation of the Negev desert, as described by Eyal Weizman in *Hollow Land* (2012) or in *The Conflict Shoreline* (Weizman and Sheikh, 2015). There, the assimilation of land into the realm of images is related to what Weizman describes as "aerially enforced colonisations", the practice of the "economically efficient, quick, clean, mechanical and impersonal alternatives that air power could provide to the otherwise onerous and expensive tasks of colonial control" (Weizman, 2012, p. 239). Leaving aside the links between colonisations and *inner colonisations*, which will be analysed in the first part of the first chapter, the view from airplanes completely refashioned the management of territories. As anthropologist James C. Scott emphasises in *Seeing Like a State*, "it would be hard to exaggerate the importance of the airplane for modernist thought and planning" (1999, p. 58). Images from above made lands mutate.

The performativity of images in relation to the control and transformation of territories has been profusely developed, particularly regarding its links with the techno-military complex. Paul Virilio's seminal work has already addressed the deep nature of this entanglement, with his work unveiling not only the environmental nature of non-human vision (Virilio, 1994; 1999) but also a very distinct contraption of space in the light-speed of the image that gives rise to a new spatio-temporal reference frame (Virilio, 2000) that encompasses the military in its conceptualisation and design. In cultural historical terms, Caren Kaplan presents this contraption as a gradual unfolding of the aerial since the early reconnaissance aircrafts and watching architectures of the 18th century (Kaplan, 2017). The aerial subsumed the spatial into the visual, draping the world

[2] Inside map databases, satellite images are automatically processed and rectified to give rise to complex data constructs, in between the static image and the interactive software, as new media theorists Ingrid Hoelzl and Rémi Marie (2014) have shown.

with images and restructuring, in turn, its geography (Pickles, 2004; Cosgrove, 2008; Graham, 2016), to the extent that the power of this vision can be traced not only in the multiplication of aircrafts, but also in built environments (Bishop and Phillips, 2004), giving rise to air-ground entanglements such as the air-target (Adey, 2011), Lisa Parks' notion of the footprint (Parks, 2009) or Ryan Bishop's elaboration of the "ground of the image" (Bishop, 2011).

Beyond this image-earth relation, this performativity has affected aesthetics and visual cultures in a broad sense. As Ryan Bishop and John Phillips have argued (2010), the visual experimentations in the 20th-century avant-garde are a reaction to this visual primacy. Harun Farocki's notion of operational images (Farocki, 2004), a visual regime that allows automatic processes to monitor and exert their power on the seen instead of simply representing it, highlights the transformation of the visual as an extension of the manufacture of the military industries in the everyday. He recalls, in this sense, Virilio's play on words: images by precision-guided weapons are images aimed at us. This concept is put forward in Steven Shaviro's notion of the post-cinematic, where, beyond policing, images and audio-visual production in general are considered as "machines for generating affect, and for capitalising upon, or extracting value from, this affect", lying "at the very heart of social production, circulation and distribution" (2010, p. 3). Images are the "state of matter" through which capital pervades everything, continues Hito Steyerl. In this vein, she underlines how images have started "pouring across screens and invading subject and object matter": "reality itself is postproduced and scripted, affect rendered as after-effect… image and world are in many cases just versions of each other" (Steyerl, 2013). Due to the ubiquity of visual surveillance systems (Bridle, 2013) and the large amount of content shared in centralised social media platforms, they have become the main machine-readable trace of human activity, to the extent that, in an AI oriented economy, even "your pictures are looking at you", to use Trevor Paglen's words, as these images are used to feed and train the deep neural networks used in prediction environments (Paglen, 2016).

Under these circumstances, enveloped by a visual regime of performing images, where images are "the state of matter", matter itself seems to be set aside, as a moulding material. Or, as Paul Virilio observes: the "environment projects an image of a de-materialising world" (1994, p. 13). Contemporary digital practices within agriculture literally display this argument, as the first chapter will show. As a matter of fact, some art and design projects have already instanced these technologies, where agriculture becomes something akin to a printing activity. The *FarmBot,* for instance, by an open-source company in California, is one example. It is a large-scale, computer numerically controlled (CNC) farming machine that pours seeds, water and fertilizers to a raised-bed box of soil, where vegetables are grown. Similarly, on a larger scale but of a more speculative and experimental nature, the *Avena+ Test Bed* project by computational designer Benedikt Groß consisted of printing an algorithm-generated image with oat, on a field of 11.5 hectares, using so-called precision farming tools. In both cases, it is the image that moulds growth.

Plant sciences and the material cultures of imaging

In the second chapter the focus rests on the experimental practices in plant physiology that observed vegetable growth as an interaction between the plant and the light that surrounds it. Remarkably, during the decades around the turn of the 20th century, camera-less techniques that originated in the domain of photography were applied to measure this interweaving between plants and light. Thus, the emphasis in the chapter is placed on the analysis of this material culture. In particular, the use of photographic surfaces as an instrument to model, quantitatively, the form and growth of plants is presented as another case of cultural techniques. That is, photographic techniques became cultural techniques when observed in relation to the photographic models of plant growth they generated.

This connects this part of the research to the attention that imaging processes have received in the domain of Science Studies, and cultural histories of science in particular. In a similar way to Jonathan Crary's unveiling of several modes of vision linked to the popularisation of different optical devices (1999), Klaus Hentschel's vast survey of scientific visual cultures (2014) argues for the differentiation of several "scopic domains" in relation to typical experimental set-ups (ibid., p. 18). In this vein, case studies of the use of photography as part of 19th- and early 20th-century scientific practices can be found in relation to specific domains: for instance, as a reference to a 19th century situated scientific *persona* (Daston and Galison, 2007, p. 115–190), as a chrono-technical practice that allowed otherwise invisible phenomena to be visualised (Kremer, 2012), as a tool that expanded the recognition and classification of natural patters and forms (Thomas, 1998; Hentschel, 2002) or as pedagogic media that transformed educational practices (Anderson and Dietrich, 2012).

Photographic practices such as the ones considered in this second chapter additionally call for an approach that emphasises the relevance of the material contexts at play in the interweaving of imaging and scientific practices. In this sense, a discussion on the making of images is already present in the ground-breaking work of Steven Shapin and Simon Schaffer on the early modern experimental practices by Robert Boyle (Shapin and Schaffer, 1984, p. 18). Moreover, the work of art historian Svetlana Alpers on the relevance of the context of the early modern Dutch painters' craft in relation to the specific descriptive character of their pictures is cited as a reference. Map-making practices, telescopes, camera obscura and other devices highlight, in her account, a material culture that is brought to the foreground when analysing their paintings. In a similar vein, in his *Image and Logic* (1997) Peter Galison scrutinises the development of particle physics in relation to the vision devices at play: specific scientific cultures are not only produced by techniques in laboratories. Rather, they determine which natural phenomena are filtered and recognised in consequence as scientifically relevant. Similarly, Henning Schmidgen has shown how the architectures and technologies used for projecting living tissues in the lecture halls of the late 19th century redefined physiology as a sort of *anatomia animata* (Schmidgen, 2012). In sum, as the art historians assembled in the book *The Technical Image* argue (Bredekamp, Dünkel and Schneider, 2015), the image appears as a "cultural technology" when observed in relation to its techniques in the context of science (ibid, 2015, p. 1). It is an active agent that intervenes in the knowledge produced.

The cultural technical approach to the case of plant physiology considered results in a characterisation of the leaves of plants as if they were photographic developments of light, an entanglement that I will address for convenience as plant-image. Beyond the link with cultural studies of science, this chapter is also related to contemporary discourses on photographic theory; to post-photography in particular, where in order to exert their power images don't need to surface in any paper or on any screen. A photographic disposition, in Joanna Zylinska's terms (2018), or a post-photographic condition, in Joan Fontcuberta's words (2016), grounded in the ubiquity of cameras and digital networks, mediates the visual in photographic terms. The notion of photography in these theoretical works is widened, so much so that fossilised matter (Zylinska, 2018, pp. 104–128) or prehistoric insects trapped in amber (Fontcuberta, 2016, p. 170) start to be considered as photographs. Therefore, these inquiries leap into, after the work of Siegfried Zielinski (2008) and Jussi Parikka (2015b), that which is referred to as the deep time of media. This specific research project does not seek to propose a vegetal deep time of imaging, however. The interweaving with plants in my case is delimited to the time of the modern photochemical experiments linked to the development of photography that were exposed in detail by Josef Maria Eder (1905) and analysed by Friedrich Kittler (2009). If for the German media theorist photography happens in a context characterised by the ability to control and reproduce photochemical effects, then this research shows how this techno-scientific culture absorbed plant growth once chemistry started to assimilate vegetal growth and agriculture. And by doing so, in this transfer to the vegetal, photography acquired new scales. Considered from this escalation, this chapter is related, finally, to Michelle Henning's *Photography: The Unfettered Image* (2018), a trajectory of analogue photographic practices sketched as a genealogy of the contemporary, all-encompassing circulation of images.

The entanglement between plants and photography could have been understood in relation to other approaches, such the notion of machinic phylum and the affirmative philosophy of Spinoza, Deleuze and Guattari, Donna Haraway or Isabelle Stengers. The limitations of space and time have prevented me from following this direction. The related relevance that the domain of Plant Studies is acquiring today will be addressed in the chapter, however, through the works of Michael Marder (2013; 2015) and Emmanuelle Coccia (2018).

The planetary surface

The third chapter examines the notion of the biosphere as it was elaborated by Russian biogeochemist Vladimir I. Vernadsky. In his work, the biosphere was presented as the living crust of the Earth together with its non-organic milieu of inert matter. They were considered as a whole and modelled in terms of a surface that enveloped the planet and transformed it in turn. He analysed this surface as a dynamical organisation of energy and matter, comparable to a thermodynamic engine. As acknowledged from the different disciplinary domains that have addressed his work, this thermodynamic perspective relates it to the earlier developments of the bioenergetic notion of metabolism, linked to Marxist ecology (Foster, 2000), such as the ones continued by the German physician Julius R. von Mayer,[3] and by chemist and early agricultural engineer Justus von Liebig,[4] in addition to those by Ukrainian physician Sergei A. Podolinsky.[5] As part of this tradition, his work relied on a quantitative approach based on methods that allowed him to obtain numerical estimations of energy flows. Furthermore, this relates[6] his work to contemporary quantitative approaches to planetary phenomena, such as the well-known studies on the human impact on Earth by Vaclav Smil (2015) and on the notion of the Anthropocene by Paul Crutzen (2002). In addition, and beyond the relation to the notion of metabolism, Vernadsky's was a holistic project that sought to merge together biology and geology into a planetary-scaled living organism. To this effect, from a cultural studies of science perspective, his work has been addressed as a marker of a characteristic style of thinking whose ramifications can be traced in later developments of Russian systems science and cybernetics (Rispoli, 2014). Accordingly, in relation to the set of models elaborated decades later by James Lovelock and Lynn Margulis, his biosphere is recognised today as an early form of the Gaia model (Grinevald and Rispoli, 2018).

The third chapter will be devoted then to Vernadsky's work on the notion of the biosphere, which was discussed mainly in two essays gathered in the book *The Biosphere*, initially published in 1926. This means that other works by Vernadsky, such as his concept of biogeochemical functions

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[3] As analysed by the historian of science Jacques Grinevald (Grinevald, 1999).
[4] See, for instance, the work of political economist John B. Forster (Foster, 2000).
[5] Podolinsky's work is of particular interest in the context of the ecological economy (Martinez-Alier, 2003).
[6] See, in this vein, the following work in the domain of geochemistry: (Edmunds and Bogush, 2012, p. 1882).

— linked to the contemporary definition of environmental services (Smil, 2002, p.10) — won't be considered in this study. This excludes also his writings on the noosphere[7], influenced by the work of Pierre Teilhard de Chardin and Édouard Le Roy (Vernadsky, 1945). Following the cultural techniques approach, the discussion will be focused instead on the means that ground Vernadsky's argument rather than his own elaborations on the interweaving between humans and the planet's geology. As in the case of the plant physiologists' experiments in the second chapter, his biosphere will be read as a cultural marker where the influence and scope of the cultural techniques linked to photography can be observed.

Instead of addressing Vernadsky's work as a whole, then, the aim of this chapter is to frame instead his 1920s model of the biosphere in its cultural context and to scrutinise it as a media theoretical object. In addition to this, his study on the biosphere will not be analysed in the chapter in relation to its thermodynamic character. Instead, I propose to understand his notion of living matter — defined as the ensemble of living beings in the planet — as an upscaling of the vegetable surface as it was conceptualised by the plant physiologists reviewed in the second chapter. While the influence of some of these scientists is underscored by historian of science Jacques Grinevald (Grinevald, 1999), this reading of Vernadsky's work in relation to plant physiology has not been done before. This link is, therefore, of great interest in the context of this research, for it presents a case where the photographic approach to the formation of plants was scaled up to the planet as a whole. In view of the above, the aim of the third chapter is to scrutinise, characterise and contextualise this escalation.

The core question, then, is how the photographic plants were brought up to the planetary scale. The chapter does not address the planetary living surface as a question of how to think in terms of "Earth magnitude", in Timothy Morton's words (2016, p. 22), or of how vegetal growth could be related to new cartographies apt for Gaia, as in Bruno Latour's search for Gaia-graphies (Latour, 2017). Instead, it is focused on the identification of mechanisms that were related directly or indirectly to Vernadsky's upscaling. In this vein, the chapter recalls both the notion of becoming planetary as it has been developed by Jennifer Gabrys in her *Program Earth* (2016) and the idea of "infrastructural globalism", as discussed in Paul N. Edwards' *A Vast Machine* (2013, pp. 23-25): in the two cases, the global emerges as a result of a complex interweaving of data, models and the spread of measuring stations. The global is not assumed or given, but is produced instead by the sensing networks. As a result, in the chapter the work of various historians of science will be referred to so as to show how a large network of agricultural stations and greenhouses

[7] Nor other related elaborations such as the notion of the semiosphere, developed by Yuri Lotman during the last decades of the 20th century under the influence of Vernadsky's writings (Mandelker, 1994).

connect Vernadsky's biosphere to the work of the plant physiologists in the second chapter, and with these networks, the colonial background of what has been named the Plantationocene (Haraway, 2015); that is, the logistical circuits of the systematic displacement of animals and plants. Thus, Vernadsky's biosphere will appear from this point of view as a notion which does not differ from the infrastructural worlds of logistical media discussed by Ned Rossiter (2016). In other words, the biosphere as an upscaling of the vegetable plant will mirror the parallel circumvallation of plants and seeds linked to colonial programmes of agricultural research.

In addition, and on a final section, a media theory analysis of Vernadsky's argumentations will be pursued. Joseph Vogl's work on scientific instruments (2007) and Wolfgang Ernst's notion of the micro-temporal (2016) will be referred to in order to frame the biogeochemist's model of the Biosphere against the background of the transformations that the chemical industry of his time was bringing into the societies of the early 20th century. The double bind addressed by Jussi Parikka's notion of medianatures (Parikka, 2011) will appear again in this chapter. The Gaian macro lens that characterises Vernadsky's work will be observed in the micro-scale of the chemical process. Before the image-plant was rendered as a global surface, the planet's ability to create circuits and planetary shells had been already seized by the chemical complex. This links, then, this reading of Vernadsky's argumentation to Esther Leslie's work on the replacement of the surfaces of the world by chemical substitutes (Leslie, 2006), and, in a broader sense, to the increasing number of publications on the relation between media and matter. Here I am thinking of John D. Peters' *The Marvelous Clouds* (2016), Jussi Parikka's trilogy (2007; 2010; 2015b), Nadia Bozak's material analysis of cinema (2011), Douglas Kahn's account of electromagnetism (2013) and Shannon Mattern's work on the media articulations of dust and mud in urban life (2017). A similar take can be observed in the analysis by Siegfried Giedion on large-scale agriculture, where he explores the immensity of the grasslands in the American Midwest and where the non-human scale of time is brought to the foreground and understood later as the signature of the subsequent mechanisation: "The elimination of time, together with the mystery of dimension, produced the mechanisation of agriculture" (Giedion, 1970, p. 142). Vernadsky's upscaling of the image-plant, in this case, is also demonstrably produced: photography, agriculture and plant physiology were all practices of the same mysterious photochemistry that links the Earth to the Sun.

Methodology: cultural techniques for practice-based research

This practice-based exploration of the three case studies that follow relies on the framework of cultural techniques. On the one hand, it has been used in the dissertation as a media theoretical approach aimed to describe the different binds between vegetal growth and the image discussed in the project. On the other, it grounds the practice-based work in which imaging processes are presented as material chains of operations where different scales coalesce.

In Germany, cultural techniques emerged out of a context of discussions between media theory and cultural studies (Siegert, 2013, pp. 1–6). After the fall of the Berlin Wall, separated visions converged in the notion of cultural techniques, an old 19^{th}-century term linked to agricultural engineering (Winthrop-Young, 2013). As Bernard Siegert explains, the concept recalled, on the one hand, a common interest in anthropotechnical processes linked to the differentiation between the human and the animal, such as domestication or breeding. On the other hand, it emphasised the radical technicity of this distinction (Siegert, 2013, p. 6–9). It involves a post-human turn, continues Siegert, related to the North American post-humanistic approach to the anthropological difference, while focusing, however, on the media-technological and culture-technical processes involved in the distinction.

Cultural techniques can be understood as chains of operations that precede the distinctions that operate at the core of a society: distinctions such as human-animal, natural-cultural or signal-noise. In this way, they are defined as the "operative chains that precede the media concepts they generate" (Siegert, 2015, p. 11). Ploughing, for instance, has been presented as a practice that led to the notion of property (Vismann, 2013, p. 84), whereas doors are considered to have produced the categories of inside and outside, as well as their cultural ramifications (Siegert, 2015, pp. 192–208). Interestingly, cultural techniques can be understood recursively. For instance, following Siegert's explanations, the distinction between the inside and the outside as performed by the barn door in the cattle shed introduces a second distinction in the category of animals: the differentiation between wild and domestic animals (Siegert, 2015, p. 14). They become pervasive; they are repeated, reshaped, extended and brought to every scale, insisting on previous distinctions and creating others. As in the case of the doors: they are present in situations that range from the sacred space and the animal fence to the symbolic flow within computer logic gates (Siegert, 2015, p. 203).

Consequently, in this project the notion of the operational image is broken down into a set of cultural techniques connected to scientific and agricultural practices linked to vegetal growth. In other words, different moments linked to the image becoming operational in these contexts will be scrutinised. In terms of cultural techniques, this means that the operational in images will be found in arrangements that, literally, won't be imaging practices. In the experiments analysed in the second chapter, for instance, no standard picturing will be considered, but only the measuring of set-ups where certain photographic techniques were arranged to produce series of observations. This genealogy of the operational image is linked to processes of measuring time, enveloping plants, pulverising pesticides and flooding fields with water, among others, and in all these cases, and through these material manipulations, the image will be shown to be practiced on the vegetable surfaces of the world, be it plant leaves or agricultural terrains.

This differentiates this research from other projects related to the operational image. Since its early definitions — such as Allan Sekula's[8] (1984) or Harun Farocki's (2004) — the operational image has been conventionally associated with a privileged and inaccessible point of view. The cameras placed in the aircraft (Kaplan, 2013), in orbit (Virilio, 1999), in the traffic pole (Bridle, 2013), at the border checkpoint (Mattern, 2018) or even near the ceilings of children's rooms (Lupton and Williamson, 2017) are examples of these sites of authority. Additionally, and emphasising a different notion of inaccessibility, the current context of mass circulation and the exchange of images produced mostly outside vantage points has also been linked to the operational. As examples of this, the importance of the processing activity in data centres where most online visual content is stored (Paglen, 2016) or the assimilation of vast sets of images into widespread machine learning models (MacKenzie and Munster, 2019) have been pinpointed as sites where images become operational. Despite this variety, in all these situations the operational always recalls a sort of vanishing point in the image: it signals an implicit centralised position from which power is irradiated. The operational, in some sense, tends to remain connected to heaven.

In this regard, my research attempts instead to approach the operational image from a different perspective. In terms of Giuliana Bruno's notion of the surface (2014), my aim is to address the operational as it happens in the material encounters of what later becomes an image. From Bruno's position, images are first of all — when observed from a material point of view — a surface condition. For instance, with analogue photographs the difference lies in the photosensitive paper against the background of the album; a monitor in a wall relies on a geologic complex of interweaved materials that distinguishes it from the clay of the bricks where it has been hung; the projected movie occupies the space between the inside and the outside of a theatre. Before the existence of the image there was an assemblage of material textures that created the distinction in the surface that becomes an image.

Giuliana Bruno's work does not only address the physical presence of printed, projected or screened images in a space, as the examples above suggest. Whenever the photographic or filmic cut is produced, the surfaces in the physical space of the scene merge and develop, from a material point of view, the visual result, even before the image is registered. Bruno draws on

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[8] Allan Sekula introduced the notion of instrumental photography in very similar terms to the ones that characterise operational images (Sekula, 1984).

examples of this in the role of fashion in Wong Kar-wai's films, the role of glitter and speed in early 20th-century cities and the cinema of the time, or the visual regime of the textures of decay in the city of La Habana. In all these examples there are relationships that operate in the surfaces at play, characterising the way the produced images mediate, afterwards, the scenes and spaces portrayed. It is as if the image were a modulation of a signal space of folds and surface tensions previously present in the scene.

Despite her study is restricted to a series of cases that only involve urban and indoor spaces, the notion of surface can be extended to vegetable surfaces such as plants, agricultural landscapes and environments as seen from the air. This expansion is undertaken in this project. As this research seeks to show, the green surfaces of the Earth have been the subject of a series of operations that have ended up introducing them in the circuits of the image. As already mentioned, this is done through the cultural techniques approach and Bruno's notion of the surface. In this process of becoming image the emphasis has been put on the practices and experiments that, beyond the ones that involve standard media devices — such as photographic cameras, for instance — prepared vegetal growth as a visual surface.

This has been the main methodological vector in conducting this practice-based research as a whole. The aim of this project is to understand, as a media practice, three cases of scientific and technological formulations of vegetal growth linked to the development of industrial agriculture. In order to achieve this, I have chosen to tackle visual media in terms of cultural techniques of the surface, and the green surface in particular. In other words, I have tried to emphasise in the understanding of vegetal matter as image that which happens outside the camera and the eye; that is, operations on the terrain, on the surface of the plant or on the theoretical assumptions in the models of green matter. As I will show, plants have been brought to the surface of the image through the use of slits of photographic paper literally attached to their leaves; trees have been introduced in *camera obscuras* of controlled light; pesticides envelop vegetable production with chemical sheaths; geotextiles, landscape fabric and harvesting nets wrap the earth as part of the visual circuits of contemporary plantations. All these are cases where the image literally wraps the vegetal. These basic operations of wrapping and enveloping are explored in this research, both theoretically and from a practice point of view.

Next, I will review and contextualise the installations produced as part of this research. They will be described individually later in the text, at the end of the main sections of each chapter, and will be discussed in groups as they are related to the contents of each chapter. Thus, the three works developed in relation to the first case are addressed in the research as *Plantations*; the three projects related to the chapter on plant physiology as *Defoliations*; and, finally, the three linked to the planetary as *Transplants*. The reasons behind these categories — mostly devised as guidelines — will be explained next, together with more details on the methodological aspects of this research.

The plantation in the image

The study of the case of the Spanish *Inner Colonisation* places this research in the wider domain of the practices that have analysed and explored the interweaving of aerial images and the ground. This led initially to focus on works where the aerial appears in a position from which the surface of land is transformed into a visual archive. As Eyal Weizman put it, seen from the air "the surface of the earth appears itself as if it was a photograph, exposed to direct and indirect contact, physical use, and climatic conditions in a similar way in which a film is exposed to sun's rays" (Weizman, 2015 p. 12). The ground, understood as a "material witness" — to use Susan Schuppli's words (2012, p. 133) — becomes, primarily, the object of forensic practices. The *Ground Truth* (2016-ongoing) project by Forensic Architecture can be considered an example of these. Thus, archives of aerial imagery are systematically explored to support with evidence facts of ongoing legal causes on behalf of dispossessed communities in the Negev desert. A different take on this forensic stance is observed in productions such as the ones by Mitra Azar[9] or those by Unknown Fields Division.[10] In these projects, the contemporary image is confronted with the consequences its own existence brings to landscapes due to the extractive activities that sustain it; or rather, that sustain the infrastructures of "a world where everything has become a screen" (Young L., 2015). In addition, and beyond the direct application of this forensic approach, other practitioners have addressed the ground as an inextricable form of memory. In works by Jananne Al-Ani[11] or Larissa Sansour and Soren Lind[12], for instance, landscape is displayed as a temporally complex information surface, scratched with cryptic marks and signs of vanished people and distant pasts, and thus open to speculative readings.

In parallel, a completely different perspective is in operation when the ground is considered as a visual texture that displays encoding patterns related to the ones that characterise the digital image. Not by chance, agricultural patterns, patchworks and irrigation circles abound in these productions. In this way, crop fields as pixelated patterns were part of James Bridle's *The New Aesthetic* tumblr (Kwastek, 2015, p. 83) and also feature prominently in the post-photographic

[9] In this vein, see *Argan39* (2018) on the mining sites in Sardinia.
[10] See, for instance, the *Madagascar Expedition Portraits* (2013).
[11] See *Shadow Sites I* and *II* (2010 and 2011), part of her research on the aesthetics of disappearance (Al-Ani, 2010).
[12] *In the Future, They Ate From the Finest Porcelain*, Larissa Sansour and Soren Lind (2015).

work on satellite images by Mishka Henner. If they are clear examples of surface tension in Bruno's sense,[13] her abovementioned texturological approach to moving images[14] is even more manifest when these become animated sequences. In the fast time-lapses made of satellite images such as the ones by Maria Constanza Ferreira[15] or Páraic McGloughlin,[16] the agricultural folds of the Earth's surface act as visual anchors that order and arrange the images in the timeline. The resulting videos are then streams encoded in the agricultural *punctum*. Seen from the point of view of Keller Easterling's association of infrastructural space to spatial software (Easterling, 2014, p. 22), these sequences can be understood to subsume the surfaces of large-scale agriculture as if they were a video codec.[17] They exploit the relation between the aerial view and its intrinsic calculability, a relationship that is finally epitomised in the generative artworks where the images of lands are merged with algorithmic textures, such as the ones by Gregory Chatonsky,[18] Gene Kogan,[19] or the duo Driessens and Verstappen.[20]

My work *Reading Stones* recalls this ordering quality of the aerial. The piece does not rely, however, on satellite or aerial images, and is performed with a standard smartphone and presented as a text score. This downscaling is deliberate and characteristic of most of the projects that I am presenting with this dissertation. They rely on easily identifiable gestures, performed as simple and repeatable operations. There are no black boxes, and every step of the processes that build up any of the installations is displayed and explained. In this sense, they unfold in the exhibition space the request for "problematizing, theorizing, critiquing, and historicizing the visual process as such", in William J.T. Mitchell's words (2007, p. 403). In other words, they are installed as operations meant to bring to the scale of the work the process of formation (the cultural techniques) of the operational image discussed in the dissertation.

The main methodological guideline in the project is formally emphasised in the practice-based work: to understand the image as a material tension on the surfaces of things. If operational images have been described to have "draped the planet with a militarised image of itself" (Stahl, 2010, p. 86), this project thus seeks to present the remnants of the clothes of this dressing process. Along these lines, a photograph discovered by Malaysian artist Simryn Gill in relation to her work on plantations clarifies this process. The pictured rows of rubber trees are accompanied

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[13] Where the grids in the fields resonate with the grids in the image sensor.
[14] Here I am referring to Bruno's analysis of Hong Kai-war's films (Bruno, 2014, pp. 35–54).
[15] See *Via* (2018), https://vimeo.com/251388560
[16] See *Arena* (2018), https://vimeo.com/259989412
[17] See Adrian McKenzie's article on the role of codecs in relation to the modulation of images in (Fuller, 2008, pp. 48–55).
[18] *Neural Landscape Networks* (2016), where satellite imagery is mixed with fragments of machine learning.
[19] *Invisible Cities* (2016), machine learning-based style transfer for aerial images of cities.
[20] *Evolved Cultures* (2008), artificial landscapes made by cellular automata.

with the caption: "They've tamed our trees and made them march in rows" (Gill and Taussig, 2017, p. 11) — following that description, the trees march as if they were soldiers. While the military analogy is certainly the excesses of a creative journalist, the rows in the photographed forest instance the greedy architecture of plantations, characterised by its topological ability to upscale, as anthropologists Anna L. Tsing and Noboru Ishikawa have pointed out.[21] In the following chapters, plantations will be discussed as visual objects, which is why, as the work *A Mechanical GIF* was meant to show, the aim of this project is not solely to address the projective force of the operational images. Rather, it seeks, reciprocally, to present and emphasise the bits of plantationism that have made up the contemporary image.

Figure 1 "They've tamed our trees and made them march in rows". Source: (Gill and Taussig, 2017, p. 11)

The defoliated image

In the second chapter of this research, a series of experimental set-ups related to photographic manipulations and measurements of the plant leaf is analysed in detail. In the decades around the turn of the 20th century, plants were addressed literally as photographic surfaces. In parallel, time-lapses were being produced with the aid of early cinematographic apparatuses, where the growth of plants was accelerated and brought to the temporal scale of human perception. This early form of cinema has been related to a set of other filmic practices coined by media theorist Graig Uhlin

[21] Plantations, Tsing writes (2015, p. 53), consist of a set of modular "self-contained, interchangeable project elements" put into operation through a repeatable sequence of instructions. In Ishikawa's view, plantations are not the trees or palms, but their spatial movement: "the object of appropriation has shifted from biomass on land to land itself" (Ishikawa, 2013).

as "vegetal filmmaking" (2015): the "vegetal being is given expressive form through a filmmaker's particular deployment of plants as a structuring element of their work" (ibid., p. 202). In these productions, argues Uhlin, the flow of the cinematic frames is linked to the folds and movements of the vegetable surface. Andrei Tarkovsky's film theory of sculpted time would be an example of this (ibid., pp. 210–212). The work of artist Elke Marhöfer, where the camera is approached as an intensive force in relation to nature (Marhöfer, 2016), or the dissection of the anthropomorphic gaze in Marine Hugonnier's *Apicula Enigma* (2013), can be signalled too as additional examples in the same vein. But Uhlin's link also happens in material terms. He cites *The Kiss* (1999), for instance, by John Smith, where the stamen and petals of a flower are shown in motion to the viewer. Time is not being accelerated, however; an invisible surface of glass, the film unveils later, is being pushed against the flower to physically produce these movements. Literally, the image and the flower are made to meet: this is not a symbolic link, but a transfer operation. The image is produced as the flower is crushed.

Once again, this brings to mind Bruno's material account of images. She recalls how Lucretius described them as being "peeled off from the surfaces of things", as if they were the flying skin of a moulting snake (Bruno, 2014, p. 2). In works such as *The Kiss*, or in my own *The Quivering of the Reed*, the image seems to rely on the peeling off of the vegetable; it is as though the aforementioned transfer involved a defoliation of the plant. In architect and researcher Hannah Meszaros' research (2018), the defoliation of the Amazon's canopies is addressed as a visual operation that allows the extension of the surveying capabilities of aerial vision. This same form of defoliation is explicitly performed in Regina José Galindo's *Mazorca* (2014), where the artist is hidden in the centre of a Guatemalan cornfield and brought to visibility by four reapers clutching machetes. In a different but related vein, in artist Wietske Maas' writings (2015), human vision is presented as a sensorium inherited from the vegetal world, made possible by vegetable proteins in the eyes that protect them from the harming strength of sunlight. Animals don't secrete these proteins: vision and the production of mental images, therefore, requires eating plants. Similarly, media theorist Nadia Bozak places (defoliated) vegetable matter — from the deep times of the biosphere — at the centre of visual media (2011): photographic film would not be possible without the photosynthetic forests that slowly liquefied into petroleum.

The defoliating character of imaging is addressed explicitly in my *The Growth of the Eye*, in which a film on the subjectivation nature[22] of visual media is made by cutting, measuring and ordering leaves of grass. The simplicity of the process recalls the modest character of the experimental

[22] See, for instance, Cubitt's commentary on "the move from the older '-graph' suffix to our now common usage of 'audio' and 'video,' literally 'I hear,' 'I see'" (Cubitt, 2014, p. 12).

practices reviewed in the chapter. Observed in relation to the complex equipment at play in the physics laboratories of their time,[23] the ones on plant physiology were much simpler in terms of techniques, and related to the craft of photography of the end of 19th century. This fact has oriented the installation work presented in this chapter towards some of the instruments and methods used in these laboratories. Thus, the chapter is related to art practices linked to media archaeology (Hertz and Parikka, 2012). The installations in this project can be connected to Zoe Beloff's techniques of de-familiarisation (Beloff, 2011), which can also be observed in Jim Campbell's screen works. As sequences of operations, these installations can, furthermore, be related to Julien Maire's dissected film devices, where cameras and projectors are open and dissected, transforming, in turn, the exhibition space into a sort of "experimental film studio" (Hoskins and Holdsworth, 2015, p. 31). Interestingly, while these works install the "discursive formations" that envelop media as apparatuses (Huhtamo, 1996, p. 239), they also introduce the materialities embedded in media devices in the space, albeit in an untamed form.

Defoliation produces void forms that need to be refilled. Extraction is followed by synthesis and replacement, following the works of Esther Leslie and Michelle Henning.[24] The notion of synthetic vegetable forms and landscapes engendered by media can be observed in this vein in various works. Joan Fontcuberta's *Herbarium* (1982-1985), for instance, makes botanic photography generate vegetable creatures out of industrial detritus; also, Jesse McLean's *Climbing* (2009) presents a never-ending scrolling mountain range as if it were produced for otherwise geology-demanding digital devices; Geraldine Juarez's *Prospekt* (2018) can be seen as an example of the forms of virtual landscapes that critically mirror the data-driven cultures of Virtual Reality; and in Anna Ridler's machine-learned flora of *Myriad (Tulips)* (2018), finally, the contemporary interweaving of technology and finance materialise in vegetable forms.

Understanding the photographic mediation of the plant surface in terms of defoliation acknowledges, once again, the characteristic double bind of media. Performed in the practice-based space, the processes of defoliation recall, equally, the vegetable nature of imaging, together with the circuits where it is circulated.

Surface transplants

The third case in the research deals with Vernadsky's elaboration of the notion of the biosphere. In particular, it sets out to understand it as an upscaling of the image-plant defined by the plant

[23] See for instance (Galison, 1997).
[24] On synthetic worlds, see (Leslie, 2006); on the character of photography as "universal equivalent", see (Henning, 2018, pp. 105–126).

physiologists before him. Now, a remarkable corollary of Vernadsky's upscaling is enunciated: at one point in his text on the biosphere he observes that the land on Earth, seen from outer space, would appear as green (Vernadsky, 1998, p. 59). Besides its inexactitude, the image proposed by the biogeochemist shares the possibility with the well-known *Blue Marble* of a totalising vision of the planet. Vernadsky's biosphere, as discussed further on in the chapter, is subsumed by the green it is modelled after. Seen from this point of view, the chapter can be read as a contextualisation of this green globalising force: as already mentioned, the colonial background of experimental stations and the chemical industry will be addressed in this vein.

Vernadsky's description of the planet from space recalls at this point the concern with the image of the globe, which has been taken into account in the whole research, and in this third chapter in particular. The gaze from nowhere entailed by this image has been criticised from many different corners. For Michel Serres, it lifts humans to the position of orbital wanderers (Serres, 1995, p. 120), around a planet that becomes increasingly alien to them, Ursula K. Heise adds (Heise, 2008, pp.17-67), distancing "the knowing subject from everybody and everything in the interests of unfettered power", in Donna Haraway's words (Haraway, 1991, p. 581). Following these critiques, different alternatives from this totalising image have been proposed. Bruno Latour, for instance, has suggested placing the notion of Gaia at the centre of an aesthetic project that looks for Gaia-graphies aimed to enhance the capacity "to 'perceive' and to be 'concerned'" (2017, p. 145) about processes taking place at different scales. He thinks of them as sensors (ibid., p. 139): as circuits, diagrams or networks that connect the viewer to loops surrounding her. The book *Terra Forma* (Arènes, Grégoire and Aït-Touatim, 2019), published at the time of writing, is the first outcome linked to Latour's project. A second related alternative to the globe is what Benjamin Bratton has addressed as cosmograms (2013), world-visualisations explicitly aimed at transforming the processes that take place in it, in a similar way as map services affect the traffic of mapped cities (ibid., p. 187). If Latour speaks about sensors, then Bratton's cosmograms are actuators: they are designed to act. The installations and visualisations by the architecture studio Territorial Agency, such as *The Anthropocene Observatory* (2013–2014), would be an example of these, as they were meant to be used as tools and resources in a parallel discussion of the Anthropocene. Another example is *Geocinema*, an ongoing project by Asia Bazdyrieva, Alexey Orlov and Solveig Suess, originated in Bratton's *The New Normal* think-tank. The project, which can be related to the visual experimentation of Godfrey Reggio's *Qatsi* trilogy, [25] seeks to propose a new genre[26] of image-

[25] The *Qatsi* trilogy: *Koyaanisqatsi* (1983), *Powaqqatsi* (1988), and *Nagoyqasti* (2002). See in this respect (Cubitt, 2013).
[26] See https://geocinema.network (Accessed the 15 April 2019).

making through a series of documentary episodes that are conceived as a conflation of the different agencies of planetary-scaled vision.

Both approaches, Latour's and Bratton's, rely on the possibility that using Lev Manovich's words can still be referred to as the language of new media. These authors recall the possibility of "an alternative syntax, grammar, vocabulary — even a new anatomical channel of cognition" (Bratton, 2013, p. 182); as a channel and a language, however, it keeps the tension between the designing or map-making *persona*[27] and the user untouched. Thus, in this research I have tried to avoid this tension as a methodological premise, and have attempted to distance myself also to a different one, pointed out by Shannon Mattern. In a brief paper, *Clouds and Fields* (2016a), she critically indicates a recurrent space of artistic practices which, through field trips, guided tours or works performed in remote places of the world, re-enact the position of the colonial explorer. That is, the fieldworker that brings her audience to undiscovered sites of an infrastructural world in constant transformation.

In contrast to these approaches, this project seeks to emphasise the fact that the globe is embedded in the encounter of processes that gave rise to the contemporary operational image. Images of the planetary are thus set aside in favour of the mechanisms that give rise to them. This is an aesthetic move that is related to what Bruno Latour, in a context that differs from his recent work on Gaia, has addressed as the aesthetics of matters of concern (2008, pp. 29–50). In his words, "a matter of concern is what happens to a matter of fact when you add to it its whole scenography, much like you would do by shifting your attention from the stage to the whole machinery of a theatre" (ibid., p. 39). From this perspective, in a similar vein as Julia Varela's pulverised plasma TV screens — part of her work *Mehr Fantasie* (2017–2018) — or Ralf Baecker's *Rechnender Raum* (2007), where a mechanical calculation space is built without electronic computers, in the pieces proposed in this chapter images are deliberately blackened and replaced by the material constructs that brought them to the planetary scale. In this respect, in *Still Life with Screensavers and Landscape Fabric* several monitors and screens are enveloped with weed mats, a landscape fabric used in agriculture. In *When The Auroras Descended to Earth*, also, the screen of a projector is replaced by the black surface of a solar panel. Finally, in *Mawat*, the dispossessed after a process of agricultural colonisation are addressed through a black surface of computer fans, which, instead of images, emits air and sound.

As Bernhard Siegert has observed in relation to Parmigianino's *Self-Portrait in a Convex Mirror* (1524), the modern painter's bust and hand are scaled up to the planetary in the surface of a

[27] This agent is, in their view, an assemblage of agencies, human and non-human.

globe-shaped mirror thanks to the use of cartographic projection techniques. It is the same set of techniques that Svetlana Alpers located in the Dutch realists of the 16th and 17th centuries (1984). It is, in Donna Haraway's words, the "persistence of vision" modelled after a conquering gaze (1991, p. 581). Cultural techniques arisen from colonial and industrial contexts produce, at the same time, the transformations of the thick surfaces of the world, as well as the means to represent them. This is a project that seeks to explore them as matters of concern.

Chapter 1 Visual Agriculture

1.1 Introduction

In this chapter, the Spanish *Inner Colonisation*, a large-scale agricultural and land settlement programme executed by Franco's dictatorship, will be examined regarding its relationship with the use of technologies of visual media. I will show how this programme was understood as a process where land was partitioned with the aid of visual operations and monitored as such, with these operations involving multiple scales at the same time. First, the programme developed several plans where vast Irrigation Zones were spread over land; then, to be operative, these Zones were segmented in rational agricultural units; inside them, finally, the plots were gradually administered as technical surfaces quantitatively monitored and improved. I will emphasise how in all of these scales the role of the visual was constitutive, and, in addition, I will discuss how these operations were part of the industrialisation of agriculture that took place in the 20th century, and how through them agriculture has evolved to become, literally, a visual practice extended by mechanical devices operating in the air and on the ground.

The case will be developed with the use of the cultural techniques analysis. The irrigation plans that sustained this agriculture will be understood, then, as programmes defined against a notion of the parasitic, unproductive land. Moreover, this cultural technical approach will highlight the emphatic role of aerial images; their characteristic monitoring and registering view of lands, together with their use as maps for the serialised completion of infrastructure, will position them as the dominant media technique at play.

1.1.1 Spanish Inner Colonisation

At the end of the Spanish Civil War in 1939, the country faced the devastation of a large number of territories that had been exposed to a three-year period of intense destructive forces. The government of the resulting dictatorship of Franco launched several post-war reconstruction programmes aimed mainly at restoring the destroyed infrastructure and geared towards attenuating the starvation effects of the brutal war among the population. In parallel, other plans were also quickly initiated and designed to support the recovery of economic activities, such as the development of industry, housing and agriculture. These were long-term plans managed, respectively, by the *Instituto Nacional de la Industria* (industry), *Instituto Nacional de la Vivienda* (housing) and the *Instituto Nacional de la Colonización* (agriculture).

In this chapter I will examine the operations carried out by the latter, operations related to an agricultural programme managed by a *National Institute* significantly called "*of Colonisation*" (INC). Consequently, I am going to analyse a space of practices where the development of agriculture was considered the vehicle of a programme of land repurposing linked to a revalorisation of agrarian surfaces. The chapter will explore a colonisation plan that involved the expropriation of plots, the introduction of new techniques — water infrastructures in particular — and the accommodation of new settlers. It was called *Inner Colonisation*. The Spanish law defined this *Inner Colonisation* as that which is put into practice by the State as:

> "an administrative activity, of a technical and legal nature, that transforms the agronomic and economic characteristics of specific extensions of land as well as the social organisations within them, creating rational units of agricultural production whose property is delivered to certain farmers, with the aim to ease the fulfilment of their individual and familiar needs, provide stability to the society as a whole and augment the production" (Leal, 1969, p. 116).

Its technical nature, its aim to augment the production of the crops in order to align them to the needs of a national demand and, afterwards, to their exportation; the proposed rationalisation of space in terms of units of agricultural practice; and the subsequent transformation of the economic and social structure will characterise a set of developments whose particular interweaving with visual operations will be addressed in the following pages.

This inwards mode of colonisation was practiced in Spain way before Franco's dictatorship. Since the 18th century, and with particular emphasis during the second half of the 19th century, there has been knowledge of the modernisation of agriculture involving the law-enforced expropriation of terrains (Gómez Benito, 2004, p.66). With many territories characterised by the presence of powerful landowners, expropriation was the only means to enforce, on the one hand, a greater distribution of land property, and to develop, on the other, irrigation infrastructures. So-called colonisations had been put into practice since the 18th century, and conceived as a politics of rationalisation of land-use, combining the foundation of settlements with modernised agricultural methods (Gutiérrez et al., p. 109).

22. Intervenciones del I.N.C./I.R.Y.D.A. (Archivo José Tamés)

Figure 2 Map of the operations developed by the INC and by the institute that continued its development activities as part of the democratic State (IRYDA). The areas around the foundation of the new towns are the outcomes of the former. Source: (Villanueva and Leal, 1990)

What distinguished the *colonisation* by the INC in relation to these precedents was its scale. Undertaken by an authoritarian dictatorship over three decades — from 1939 to 1973 — the actions of the Institute involved the excavation of a vast network of water canals, the set-up of large Irrigation Zones around the main river basins and the foundation of approximately 300 new settler towns to put them into production.[28] As a programme, it merged together three main strategic lines: an Agrarian Reform, a Land Settlement programme and a Hydraulic project (Gómez Benito, 2004). And, singularly, only one institution managed it,[29] the INC, which was able as a consequence to design and execute Plans that involved an immense variety of procedures: expropriations all over the territory, big movements of the population, infrastructure works, drainage of ponds, soil levelling, the supply of machines and fertilizers, formative practices, finance capabilities and a centralised management of the information gathered in the continuous

[28] As an activity developed in parallel to the research, over three weekends scattered between April and June of 2017 I proposed to digitise and upload with a creative commons license the data relative to the INC. The proposal was accepted as part of a collaborative production workshop linked to Data Journalism, and a group of collaborators was gathered to produce a first complete digital inventory of the settler towns, together with other infrastructures. It is an open-data initiative that can be accessed here: <https://medialab-prado.github.io/poblados-colonizacion-colonias-penitenciarias/index.html > [Accessed 30 April 2019].

[29] The INC wasn't in charge of the main water infrastructures, such as dams and reservoirs. This was the task of the Ministry of Public Infrastructure (MOPU).

monitoring of the process. It was, therefore, a huge institution at the time and it gave rise to one of the most ambitious reforms in the recent economic history of Spain, “the largest urban operation within rural zones ever practiced in Spain” (Gómez Benito, 2004, p. 84), that contributed to changing, as a result, the face of its rural landscape.

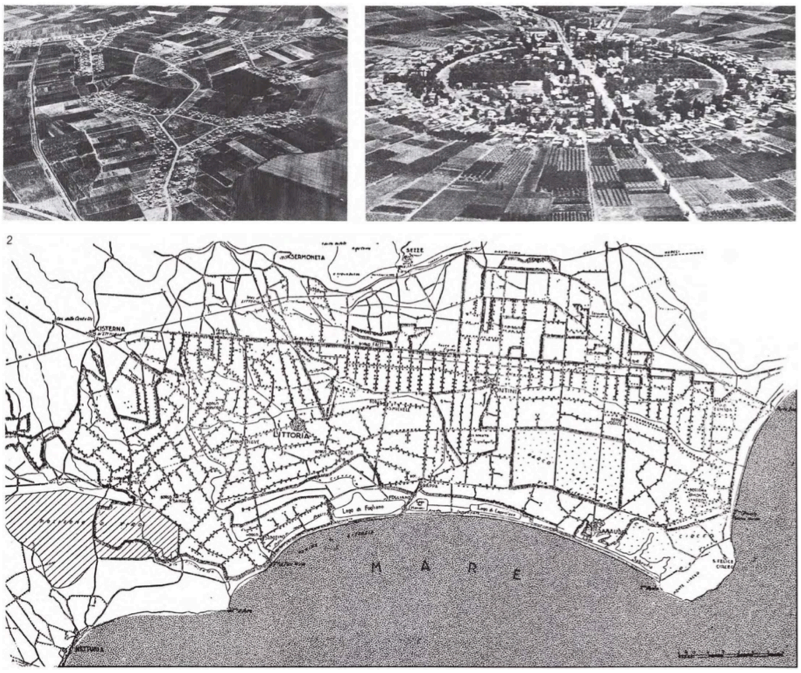


Figure 3 Top: aerial images of the Moshavs Nahalal (founded in 1923) and Omen (f. 1958) Bottom: water infrastructure grid of the colonisation of the Italian Agro Pontino (1932). Source: (Tames Alarcón).

Many similar plans, albeit with local differences, had already been accomplished in other countries. Most of them took place before the Second World War;[30] a fact that highlights that, in relation to these, the Spanish one was a late colonisation. In detailed and exhaustive documentation work carried out by the Spanish government in 1925, thirty-four individual countries were analysed in relation to their existing agrarian and repopulation reforms.[31] The

[30] Two important exceptions are remarkable, as their influence on Spanish *inner colonisation* has been highlighted several times. Firstly, the North American large irrigation programme, the Columbia Basin Project, whose final execution works took place between 1948 and 1952 (Bloodworth and White); it had been designed since the 1920s but it was only after the war that water started to arrive to the fields. Secondly, the agrarian reform performed by the Italian Christian Democrats after the war, also as a sister project of the *colonisation* (see for example Tordesillas; Gómez Benito, 2004).

[31] *La colonización y repoblación interior en los principales países y en España* (1925) – The colonisation and internal repopulation in the main countries and in Spain — published during the dictatorship of Primo de Rivera (1923–1930), consisted of three volumes where the following cases were examined: “Germany, Austria, Hungary, Belgium, Denmark, France, Finland, Netherlands, England, Ireland, Italy, Norway, Portugal, Russia, Sweden, Switzerland, India, Japan, Siberia, Korea, Algeria, Egypt, Tripoli, Tunisia, South Africa, Argentina, Brazil, Canada, United States, Mexico, Uruguay, Australia, New Wales and New Zealand” (Tordesillas, 2010, p.185).

common double dimension of these — an intensification of agriculture production and the settlement of new populations — identified them in several cases as colonisation processes, specifying in some cases that it was an "inner" or "internal" colonisation, in contrast to the more usual outwards sense of the word. Some of them are remarkable examples, as they inspired, in turn, the Spanish one: Mussolini's several *bonifiche,*[32] the Portuguese *Internal Colonisation,* the German *Innere Kolonisation* or the Israeli Moshaves and Kibbutzs.

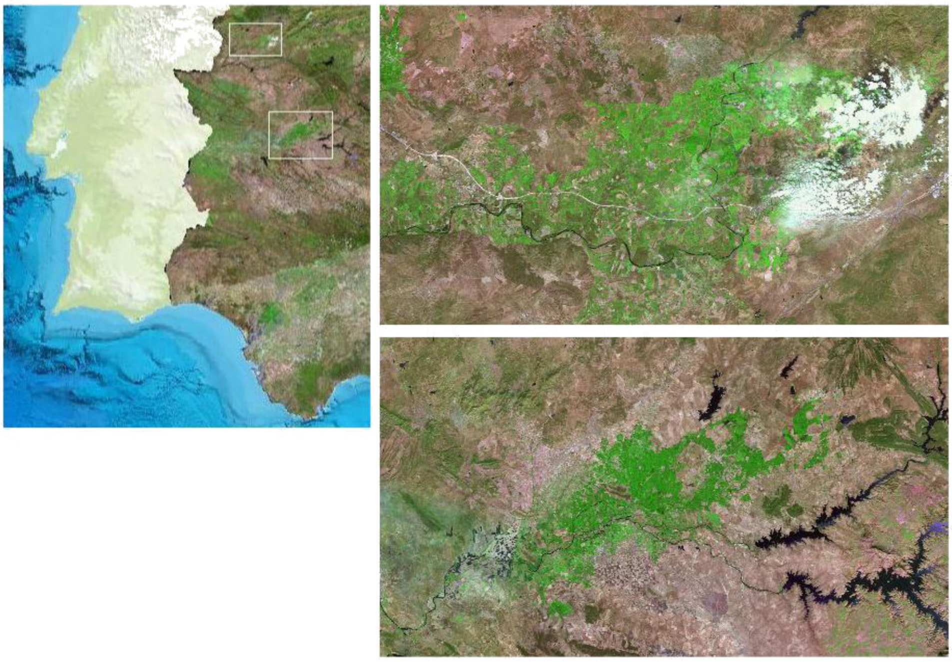


Figure 4 Two Irrigation Zones, depicted as green areas by the satellite, after being filtered by vegetation activity data.

Before continuing, it is necessary to clarify that during its existence, its methodology and scope did not remain constant. Three periods have been distinguished, of approximately ten years each (Delgado, 2013, p. 79–80). Briefly exposed, an autarchy model confident of private initiative characterised the first decade: landowners, supported by public resources, would lead the transformation of the land and settle the peasants. The model proved to be a total failure (Tordesillas, 2010, p. 191), and, beginning in the 1950s, a new law with a much more engaged State was proposed. This second period turned out to be the golden decade of colonisation (Delgado, 2013, p. 80): big plans, such as the *Plan Jaén* or *Plan Badajoz* were implemented, and were coupled with industrialisation programmes. In 1962, however, these plans were criticised by a World Bank report as they involved big amounts of national debt. As a consequence, new economic criteria started to evaluate the programme, which resulted in the estrangement of the

[32] Among these, the *integrale* (1924–1950) was the most influential for the Spanish programme (Gómez Benito, 2004, p. 75).

whole project (Villanueva and Leal, 1990). During the last decade, as a consequence, the INC became a passive technical manager; a mediator, in fact, that gradually facilitated the introduction of big food and agriculture companies in a progressively liberalised economy (Gaviria, Naredo, Serna, 1978, p. 435).

In retrospect, the temporal and spatial extent of the *Inner Colonisation* favoured the spread of irrigation infrastructures and the introduction of new techniques within Spanish agriculture, and, in fact, it resulted in the doubling of the overall irrigation surface and refashioned the map of cultivations and exploitations (Gómez Benito, 2004, p. 83). As a colonisation programme, however, it did not succeed in redistributing the property of land (Gómez Benito, 2004, p. 77) due to several loopholes and practices of political clientelism (Gaviria, Naredo, Serna, p. 262). It operated, instead, as an ideological tool of a paternalist State, an over-scaled investment that was profitable, nevertheless, from the point of view of the political propaganda of an authoritarian dictatorship (Gaviria, Naredo, Serna, p. 18). Despite its economic inefficiencies, it still contributed to changing the extractive relationship to soil; the gradual transformation of agriculture into the fully mechanised and industrialised land practice that would turn Spain, in spite of its low precipitation levels, into a major exporter of fruit and vegetables — yet already as a democratic State.

Figure 5 Settlers working within an Irrigation Zone. Source: Mediateca del Ministerio de Agricultura y Pesca, Alimentación y Medio Ambiente

1.1.2 Parasitic lands, or the erasure of the remains of an exterminated past

One of the main constraints that *inner colonisations* had to face was the limitations of available land. As one of the leading theorists involved in the Spanish *Inner Colonisation*, Alejo Leal García, stated: “the transformation into irrigation is one of the means that can be used to satisfy the needed amount of agricultural products; a means that is chosen as it is estimated that the arable surface cannot be augmented noticeably and because the simple improvement of cultivations only increases by an insufficient factor its productivity” (Leal García, p. 113). These colonisations needed to face the growth of agriculture (in itself an activity about growth).

New methods needed to be applied, and in Spain, the first to come to mind, even though it was known for some time, was irrigation. Although the INC also supported practices related to dry agriculture, its main goal was the replacement of dry plots and wastelands with irrigated lands. This meant that the problem of productivity in the Spanish case was understood, briefly, in terms of land; that is, to improve agriculture involved the improvement of land, and not, initially, its mechanisation or the chemical manipulation of natural processes. The colonisation plans, therefore, aimed to “revalorise” the territories through water. It was, therefore, a project of “revalorisation” linked to the surface, as Leal García explains: “this revalorisation can be considered from several points of view, such as the value or price of the lands, the indices of seeded surface, the performance of exploitations and the indices of employment” (Leal García, p. 112). For the colonisations through irrigation, then, land — and the societies settled on it — was the target to transform.

As a matter of fact, Franco’s colonisation programmes were initially conceived as that which has been called an *Agrarian Counter-Reform* (Barciela, 1996). The government before the Civil War, the *República*, had promoted an expropriation programme aimed at the distribution of land. By doing so, the *República* responded to the demands of peasant movements, which had started to collectivise their uneasiness over their labour conditions, to the point of even occupying lands in the tumultuous 1930s (Gaviria, Naredo, Serna, p. 18). It is an established fact that, as a consequence, the big landowners affected were part of the lobbies supporting the military coup that gave rise to the War (Barciela, 1996, p. 354; Gómez Benito, 2004, p. 77). Besides the violence of the war in these lands,[33] this resulted in the initial aim of Franco’s colonisation being to counter the reform of the *República* (Barciela, 1996, p. 354). Namely, when the new plans were addressed, they were emphatically presented as a transformation of wastelands, which were rendered in miserable conditions, populated by “rotten burgs” (Alagón Laste, 2015, p. 2) that had

[33] The striking and murderous violence of the Civil War in the affected lands, in Extremadura particularly, are related to this agrarian conflict (Gaviria, Naredo, Serna p. 17).

witnessed[34] a "buried war" (p. 21). The land of New Spain was defined in opposition to a parasitic past that, despite the effectiveness of the armed struggle, still needed to be eradicated. In Franco's words, just before the end of the Civil War, "Spain is still at war against every enemy from the inside and the outside" (Gutiérrez et al., p. 13). That is to say, at the same time that the military government started to seek out, to pursue, to imprison and to sentence to death the supporters of the *República*, the unproductive land started to be mapped, addressed and "redeemed", in their own words (Gaviria, Naredo, Serna, p. 18). As I will show in the pages that follow, this entailed a remarkably visual agriculture practiced over surveyed lands.

1.1.3 The production of empty life

After the initial spirit of counter reform, the *Inner Colonisation* gradually became a programme managed by a technocrat elite of the dictatorship (Gómez Benito, p. 69). Once the problem of land was solved through expropriations, agriculture needed to be modernised. The programme had to adopt the improvements in management as well as the technical advancements that the other large-scale irrigation networks had achieved. In particular, the experience of the integral approach of the Columbia Basin Project in the United States (Bloodworth and White) was particularly relevant for Spanish managers (Tordesillas, p. 192; Gómez Benito, 2004, p. 75).[35] Two different technological realms needed to be addressed. On the one hand, the mechanisation of agriculture, which had been a determining factor in the celebrated case of the large-scale cultivation of cereals in the American Midwest (Giedion, p. 130–168). On the other, the techno-scientific expansion of industrial agriculture, initiated in the experimental practices around the biochemistry of soil and plants that took place in Germany, which relied on the spread of synthetic fertilizers and pesticides (Smil, 1991).

With the aid of these techniques, the resulting agriculture progressively assumed the mechanisation of human and animal workforces, the acceleration of plant growth due to chemical additives and the homogenisation of soils, seeds and cultivation processes. After the Second World War this ensemble of techno-scientific developments became a standardised set of patents, technologies and strategies of management and communication that was dubbed, before the end of the 1960s, the Green Revolution (Matson, 2011). A quantitative, industrial agriculture that since then has gradually been able to absorb a large variety of extensions, topographies and qualities of soils, while increasing the growth rates and frequencies,

[34] And still do, in the form of bombs and bones.
[35] "The agricultural technology in broad terms, and particularly, irrigation engineering, has hugely advanced and is of maximum interest for us to know and analyse it, because of the similarity in soils and climate between the American West and our arid Spain" (Martínez Borque, p. 51).

traditionally imposed by the climatic interweaving between plant species and the seasons of the year.

In this case of technological escalation, it is not land but a different flow of energy and matter that is partitioned. These are technologies that transform the growth and production of vegetal life, giving rise to a new distinction between improved and non-improved nature. This intensification of productivity has been linked by writer and activist Vandana Shiva to the notion of the *Bio Nullius*, an extension of the colonial *Terra Nullius* where “the Earth is defined by her colonizers as dead matter, deemed unable to create, and farmers… deemed to have empty heads that cannot innovate” (Shiva, p. 33). The old farmers, together with their old and unimproved nature, become the parasite of a parasitic activity or, as Shiva puts it, a *biopiracy*. A piracy that updates Michel Serres’ observation about husbandry: it “parasites their reproduction. The production of living systems is their reproduction. Animal raising and vegetable farming are practices that are parasitic on the reproduction of living things” (Serres, 2007, p. 82). Although this will be expanded upon in the next chapters, this parasitic growth will resonate with the escalation of vision that I am going to pursue next. It is the “inner” in *Inner Colonisations*: “The colonies have now been extended to the interior spaces… from microbes and plants to animals, including humans” (Shiva, p. 40). The vegetal covers of the Earth, surveyed and monitored, were parasited and hollowed by a parallel growth: that of the visual media that grew out of them.

Figure 6 *Reading Stones* [mixed media], in the *Zero Gravity* exhibition in Matadero Center for the Arts, Madrid (2015). Detail.

Plantation 1. *Reading Stones*

2016. Mixed media. Glass box, book, stones, paper labels. Variable dimensions

A reading stone is an amplifying lens. When placed on the surfaces of printed texts or images it eases the reading and observation of details. Reading Stones is in this case a set of instructions devised to provide a method to read a landscape:

"Walk to a depopulated area, in the countryside. Measure each of the stones you find, and write down the magnitudes. Count how many times each of these measurements is repeated. Return home, choose a book and, from the beginning to the end, count how many times each of the words is repeated during the text. Compare the repetition frequencies between stones and words."

Figure 7 documents one of these readings. It was performed with a smartphone attached to a selfie stick. The images registered by the phone were processed by an algorithm that with the aid of computer vision techniques located and measured each detected pebble (Figure 8). Thus, the distribution of the sizes of the stones is obtained. This statistic was then compared to the frequencies of the words in a specifically chosen book. That is, if a stone had a size that appeared with the same frequency as the ratio of appearance of a word in the text, a relation stone-to-word was established.

The landscape was, in this sense, read and re-ordered. This technique is analogue to one used to decipher encrypted texts[36]. The experience isn't meant to detect, read or document traits, as in a forensic approach; nor to isolate, label and register the elements, as in an inventory. It is a method and a walking piece meant to explore a surface encounter: the landscape and the measuring vision as a mutual exchange of counts and frequencies.

It is an act of visual intervention; of producing the landscape as a radically mediated surface.

[36] The substitution cypher replaces each of the letters of the initial message with a different one – and always the same. This way, if the replacement rule is to take the following letter in the alphabet, we would cipher EARTH as FBSUI. Messages encoded with this method are easily broken if long enough: the different letters in a language follow a recognisable statistical distribution, which the replaced ones would follow too.

Figure 7 A still of the video documentation of the measuring process.

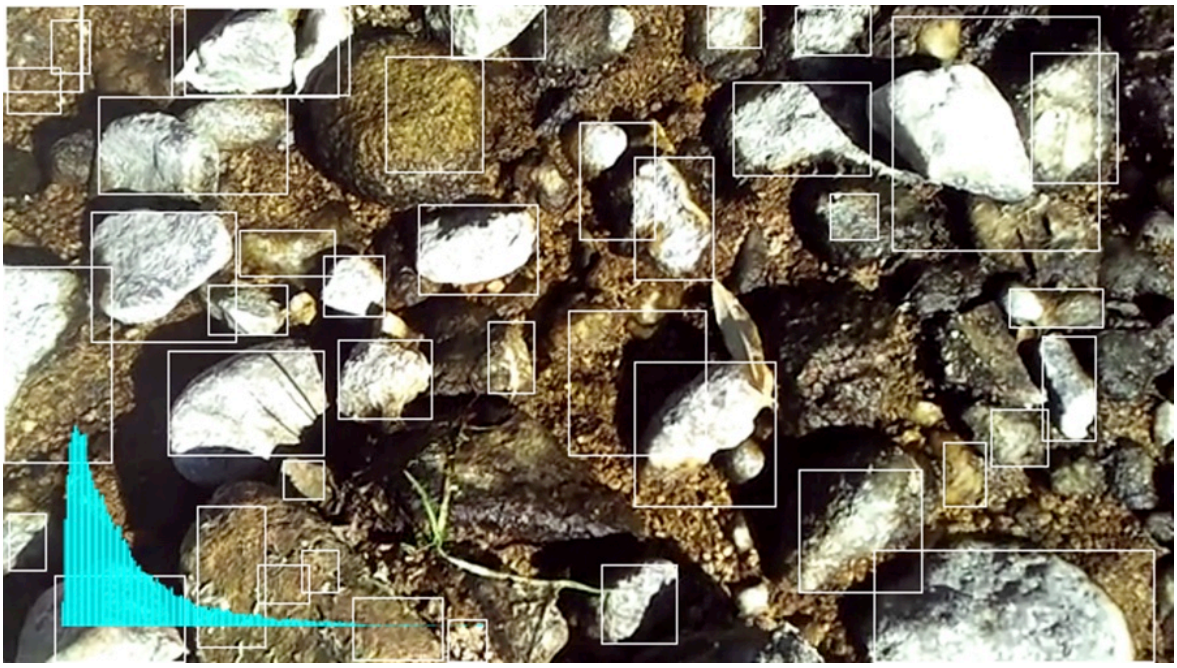


Figure 8 Computer vision algorithm analysis of the sizes of the stones detected in a frame.

Figure 9 *Reading Stones*, as part of the *Zero Gravity,* Matadero Center for the Arts (2015).

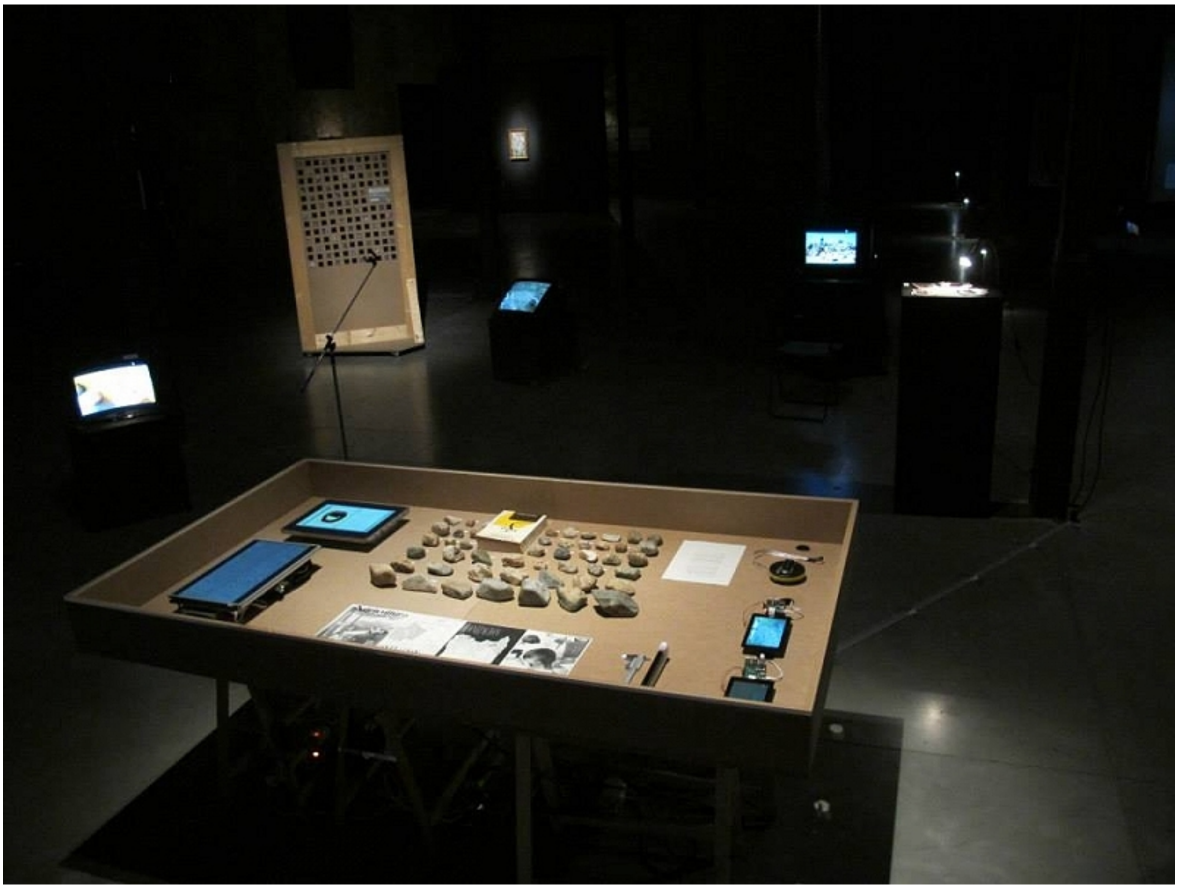
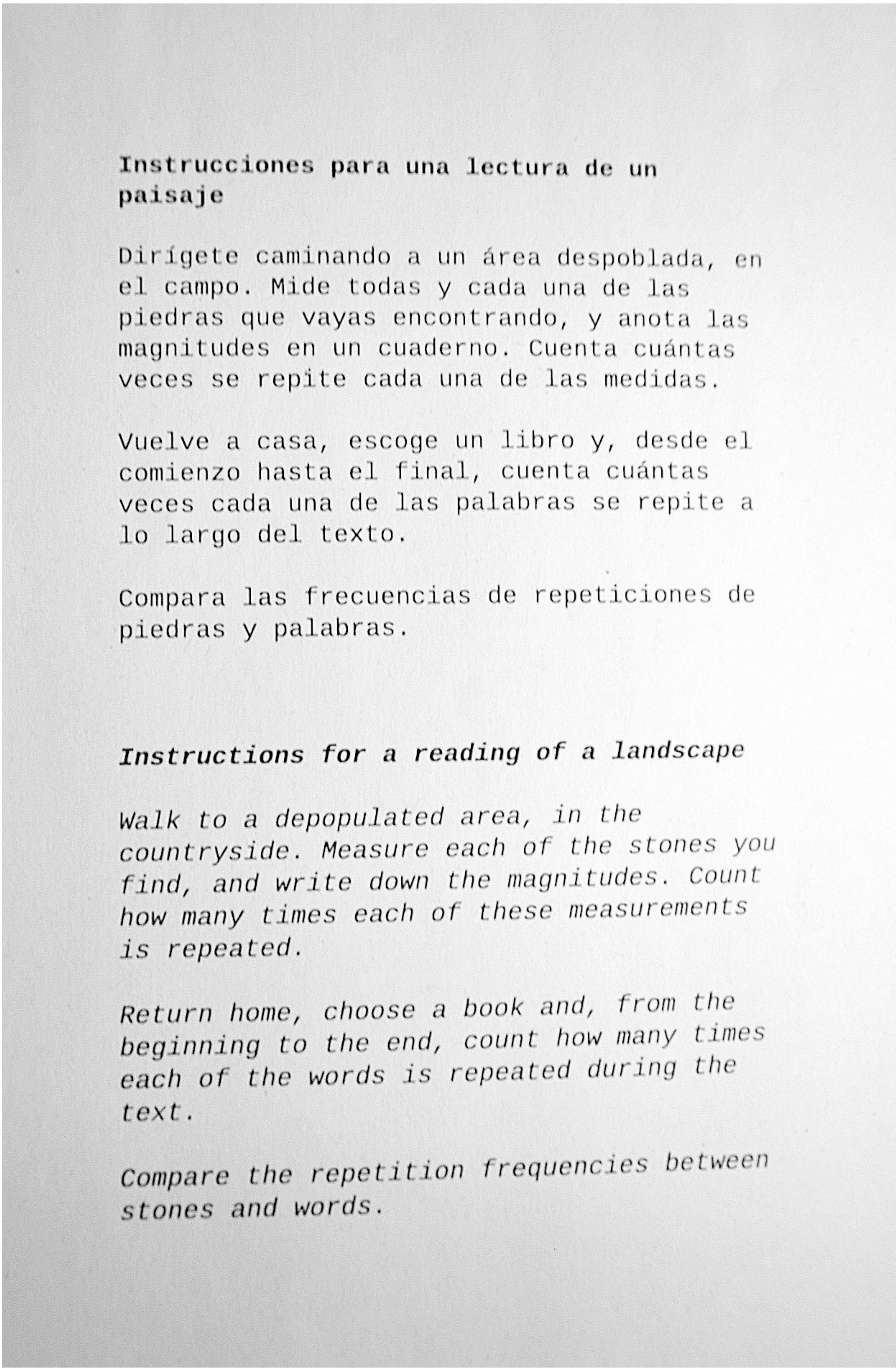


Figure 10 *Reading Stones*, as part of the *Zero Gravity* exhibition in Matadero Center for the Arts, Madrid (2015). Photograph courtesy of José Otero.



Instrucciones para una lectura de un paisaje

Dirígete caminando a un área despoblada, en el campo. Mide todas y cada una de las piedras que vayas encontrando, y anota las magnitudes en un cuaderno. Cuenta cuántas veces se repite cada una de las medidas.

Vuelve a casa, escoge un libro y, desde el comienzo hasta el final, cuenta cuántas veces cada una de las palabras se repite a lo largo del texto.

Compara las frecuencias de repeticiones de piedras y palabras.

Instructions for a reading of a landscape

Walk to a depopulated area, in the countryside. Measure each of the stones you find, and write down the magnitudes. Count how many times each of these measurements is repeated.

Return home, choose a book and, from the beginning to the end, count how many times each of the words is repeated during the text.

Compare the repetition frequencies between stones and words.

Figure 11 *Reading Stones*. Instructions for a reading of a landscape

1.2 Partitioning space

One of the most salient characteristics of the Spanish *Inner Colonisation* is its use of aerial imagery, both as propaganda and in its operations. Through these images, there is an emphasis placed on the accomplishment of the productivity that the programme was meant to introduce all around the national geography against an unproductive past. Together with the images of dynamically ordered landscapes and infrastructures, the emphasis on the idea of building a new world is particularly striking in the new towns that were erected to host settlers. Remarkably, their rational and serialised architecture and their overdesigned urbanism notably favoured aerial shots. Seen from the air, the settlements appear as scaled mock-ups, as "toy towns" (Sabio, p. 104) freshly emerged from their drawings, in a state still between the graphical and the physical.

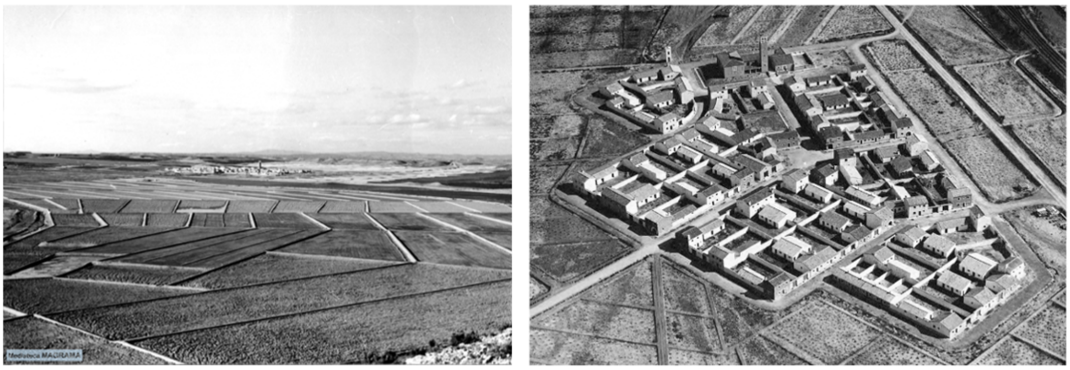


Figure 12 Images of the irrigation system (left) and San Jorge, a new settler town. Source: Mediateca del Ministerio de Agricultura y Pesca, Alimentación y Medio Ambiente.

In the context of an *inner colonisation* that performs the acts of completely refashioning a landscape, these images emphasise the process itself. Indeed, they can be understood as *phatic images*.[38] Phatic exchanges, like banal verbal messages and images in social media (Frosh, 2015), are meant to affirm and to point out the channel that builds up the relationship. That is, the phatic addresses the channel; it is not meant to express thoughts or to coordinate actions, but to constitute a situation, to establish the basis of a relationship. The aerial images displaying the operations of the production of a large-scale order designed from above can be taken as constitutive acts akin to breaking silence with a banal comment before a conversation starts: they signal the medium, they foreground the situation they themselves create. Seen from this point of

[38] Virilio uses the same expression in his discussion of the vision machine. In his case, however, a different notion is meant: the phatic image is for him the one designed to trap the attention through the alteration of the context of emission or reception: "*The phatic image* — a targeted image that forces you to look and holds your attention — is not only a pure product of photographic and cinematic focusing. More importantly it is the result of an ever-brighter illumination, of the intensity of its definition, singling out only specific areas, the context mostly disappearing into a blur." (Virilio, p. 14).

view, the Spanish agricultural programme – as with the Italian or the Israeli ones if we focus on their images too — is created and iterated by these images. They are programmes about the aerial becoming of vision; they are aerial colonisations practising a visual agriculture. The extent and the different scales of its visual character will be discussed in the following sections: from the scale of the territory as a whole, to the Irrigation Zones and the extent of the cultivated plots. The culture practiced by this agriculture will be a visual one, iterated, reverberated, amplified and emphasised in the interweaving of these scales.

Before continuing with the Spanish colonisation, I will firstly analyse a German case that preceded it: the *Innere Kolonisation*, which the Spanish authorities analysed as a reference (Tordesillas, p. 185). By doing so, I will show how these programmes can be addressed as an inwards remediation of the colonial agenda of the vanishing empires. Furthermore, this will link these processes to a particular context of visuality, using Nicholas Mirzoeff's term (2011), where the unproductive is rendered as an invisible background. This precedes the visual operations that will then be executed.

1.2.1 The colonial perception of emptiness

Pressured by the lower prices of cereals that came from America and inspired by the government-sponsored settlements he visited both in the US and Canada, German economist Max Sering developed as an Habilitation in 1884 a rational land allocation project meant to increase production in the provinces of East Germany. The *Innere Kolonisation* — as he named it — was presented as an agrarian economist argument willing to enhance the Reich's politics in relation to the *Ostsiedlung* (Eastern Settlement), a settlement plan based on a fund that financially helped Prussian farmers to buy land and move to the East. While the original programme of the government favoured German landowners acquiring large inefficient estates employing seasonal workers, Sering's thesis devised instead an "agrarian-industrial state" (Nelson, 2010, p. 449) constituted by committed "peasants turned into landowners, as in western America" (Sering, p. 98). In 1919, right after the end of the First World War, Max Sering was promoted to lead the *Kolonisation* and appointed to write a new Settlement Law. The Weimar Republic, forced to give up its foreign colonies after the Treaty of Versailles, needed its domestic food production to be strengthened in order to replace the incoming flows of external resources that had been cut. Moreover, as the regions of Posen and West Prussia were gone too, the government wanted the eastern provinces to be further populated in order to prevent future annexations. Sering's ideas on *inner colonisation* as a densification of the productive land were then applied, and further expanded, in his newly funded Research Institute for Agriculture and Settlement (Nelson, 2010, p. 454). Beginning in the 1930s, however, when the new Nazi managers came in with their racebased politics, his position became increasingly unstable. His was an assimilationist colonisation model, committed “to raise the cultural level” through the Germanisation of the local Polish residents, although opposed to any ideas of purification (Nelson, 2010, p. 440). Yet, despite Sering’s differences with the racial programme, his settler colonialism and the following expansionist plan — the infamous *Generalplan Ost* (General Plan East) — shared a common abstraction: the colonial notion of empty space.

In the analysis of German *inner colonisation* undertaken by cultural historian Robert L. Nelson through its links to the settler programmes in North America, there is an observation that where colonisation meant “bringing under plough any ‘unused’ or ‘wasted’ property” (Nelson, 2011, p. 162), an abstracted view of space was in operation. It was, in particular, a notion that likened the absence of German culture and productivity to the concept of emptiness (Nelson, 2010, p. 456). Moreover, this emptiness is related by Nelson to the principle of *vacuum domicilium* described by John Locke, allegedly operating in the English occupation of American lands: “in a pattern to be repeated throughout the history of colonialism, Natives who failed to practice modern modes of production disappeared into the empty backdrop of nature" (Nelson, 2011, p. 165). Interestingly, two invisibilities were produced at the same time in the encounter of settlers with the territory: on the one hand, that of native populations; on the other, that of the territory itself, allowing the clearing, replacement and cultivation of land. This double operation of emptiness — instrumental and representational — collapses, however, in Nelson’s analysis, and becomes the consequence of a “colonial gaze” (Nelson, 2011, p. 169). It is a gaze, in Nelson’s words, “that produces empty space in the eyes of the colonizer… followed by new, proper settlers and correct modes of production" (Nelson, 2011, p. 169). Yet this gaze relies on the assumption of a pre-existing and untouched cultural subject, the coloniser. This cultural subject is the one that is able both to represent and intervene, although this can be addressed otherwise. This is what I will do next: echoing Siegert’s *The map is the territory* (2011), this cultural historical approach will be reformulated in media theory terms of cultural techniques.

1.2.2 The medial production of empty space

Instead of a gaze that produces empty space, cultural techniques allow the analysis to move away from the authorial subject and consider instead material epistemic orders emerged from the interplay of specific practices and circulations. It is possible, therefore, to consider this emptiness as part of a “medial a priori” (Horn, p. 8), operating in the colonial if, alternatively, we take into account the tools, techniques and practices put into play rather than relying only on an acculturated subject.

In the case of these colonial apprehensions of space that underlie *inner colonisations*, we need to take into account that the demarcation lines were no longer drawn with a plough on the surface of the ground, but rather by the surveyor's hand on a sheet of paper. A new set of techniques to partition space was thus put to work. These are graphic procedures that Siegert himself has profusely discussed through the analysis of several cases of cultural techniques: seafaring, gridding and projecting (Siegert, 2015). These first-order drawing techniques produced a second-order distinction, a differentiation of culture and nature that produced as a result the colonial demarcation of humans: the settlers, on the one side, and previous inhabitants, thrown to the backdrop of nature, on the other. In this vein, human cultured lands became lands to be re-cultured. The culture-nature distinction is performed again. That is, the agricultural appears in recursion, introducing a new differentiation. This time, in new, uncanny terms: "It is this act of creating space within emptiness that turns humans into the most uncanny of creatures — cultural beings" (Siegert, 2015, p. 70). From this point of view, it is agricultural media that cultivates subjects, and not vice versa.

Next, I am going to follow this path through two different developments: first, Siegert's account of the use of grids and lattices during the 16th-century colonisation of America, and second, the crucial role played by aerial photography during the agrarian inner colonisations of the last century.

1.2.3 The cultural techniques of grids

In his work on the role of maps in the foundation and early urbanism of Spanish colonial cities in America, Bernhard Siegert remarks that urban settlements were not planned and built on the basis of an actual number of settlers, but were instead devised with future growing populations in mind. Initial drawings and plans used by the founders of these cities consisted of boundless grids as abstract layouts, apt to be used at the same time as "plans, registers and cadastres" (Siegert, 2015, p. 107). They had an indexing character, and were able to address both the settlers already present and the future ones. For Siegert, they were tools that enabled and sustained "the possibility of writing empty spaces, that is, the ability to literally reserve a space for the unknown" (p. 107). Grids introduced, therefore, the fundamental separation between data and address: "Persons… are turned into data that can be stored for subsequent retrieval by the correct addresses that logically and temporally precede them" (Siegert, 2015, p. 107). Settler homes, institutions or businesses would become the data to populate a space of addresses — the land reserved for the city — which would then coincide with the paper surface: an addressable, graphical emptiness. Which means that this *tabula rasa* would not necessarily stem from an already acculturated colonial gaze, but would be inscribed instead in colonial media. Grids, coming from Antiquity and used during the Reconquista, were already identifying urban order with political order; as a Renaissance graphical tool, additionally, they entailed the technics of a "data space" (Siegert, 2015, p. 100) to allow that "everything is assigned its own place" (p. 108).

Grids produced the abstract empty space needed to manage and address the settler space, together with its future inhabitants. As Siegert has also insisted, its use in the colonisation of America is linked to the importance that the Spanish Authorities assigned to the problem of idlers. As "the New World was a paradise for idlers, a realm of lazybones, gamblers, and loose women" (Siegert, 2015, p. 91), it was crucial to devise a system against the vagabond — originally the *bagamundo*, the idler world wanderer — the parasite that threatened the economic activities in the New World, as well as the stability of Spanish cities. As shown by Siegert, the grid-shaped cities, in this vein, performed the disciplinary and governmental need.

Remarkably, a similar condition characterised the settlements of the *inner colonisation*. As the programme was also used as a propaganda tool for the dictatorship, the everyday life of settlers took place in an utterly controlled environment. Dwellers were individually selected, trained and constantly monitored, in order to avoid problems inside new towns. In addition to this, their continuity in the programme relied on a contract that entailed many forms of enclosure: serialised single family cells; a bureaucracy that managed, at the same time, domestic issues, the maintenance of towns and the productivity of fields; up to 10 different kinds of guards and keepers dependent on a public administration; or the power of a public servant or inspector working for the INC who could expel any settler if he or she did not "meet with their obligations normally" (Gaviria, Naredo, Serna, p. 356).

What is more, the notion of idleness is key, as I will show next, to characterising land in relation to the visual practices of agrarian colonisation.

1.2.4 The parallel spread of the seen and the seeded

Cultural techniques such as the grid are practised, learnt and disseminated in time and space, and are also embedded, reshaped or codified within different tools, devices or media. This is the case, for instance, with photogrammetric equipment used in aerial surveys. Provided currently with GPS receivers and other movement tracking devices, digital cameras for aerial photography are able to produce images suitable for being automatically rectified with the adequate software and exported to fit within grid-based tiled maps (Jacobsen et al., p. 84). Although the first military and commercial procedures of aerial photographic surveys needed large amounts of time of skilled interpreters to build up the photo-mosaics with the aid of existing maps (Saint-Amour, p. 243), they have been used, at least since the 1910s, as a measuring tool. Through them, military and civilian infrastructures were located and cadastral information retrieved and added with precision to the grids of cartographic maps. As we will see next, aerial surveys became particularly apt for 20th-century development and land reform plans in Europe, where the scale of operations such as water infrastructures or urbanisations met the spatial extent of the aerial perspective. Wastelands had become empty; there was a need to monitor them in order to start making them productive.

In 1926, during the dictatorship of Miguel Primo de Rivera, a new administrative entity was defined in Spain: the River Basin Authorities. Instead of the province or other political-geographical demarcations, the physical river basin and its connected waters became the territorial unit used to organise water planning in an integral approach (Martín-Retortillo, p. 105). By these means, one single institution supervised all possible uses of fluvial waters, such as irrigation, transport and energy. The law of 1926 that stated the creation of the Basin Authorities also demanded the complete and precise cartographies of the territories under their control, detailed enough to display their divisions into plots. As the existing resources were inadequate, and in order to acquire this material quickly, the services offered by a private company[39] that pioneered and promoted aerial photography were contracted, as the only means to technically render it possible (Fernández, 1998, p. 223). The first set of official aerial photographic images of Spanish land dates from this time, and the use of aircrafts to produce cartographic documents was soon extended to the completion of an updated cadastre. The number of acres of land photographed from the sky then grew sustainably, until the Civil War brought everything to a halt.

Years later, after the Second World War, it was the US Army Map Service that continued aerial mapping, completing two orthophotography surveys of the whole Spanish territory in 1945–1946 and 1956–1957 (Quirós and Fernández, p. 190). They belonged to the so-called *Casey Jones Project*, devised to map from the air the territories of Portugal, Italy and Spain (Pérez, Bascón and Charro), as part of a defensive strategy against a hypothetical conflict with the USSR (Quirós and Fernández). Remarkably, although the resulting maps were not shared by the US with the Spanish Army until 1959, copies of the first flights in the 1940s have been found in one — and only one — of the archives of Franco's institutions: inside the National Institute of Colonisation, the INC (Pérez, Bascón and Charro, p. 22). Taking into account the initial secret nature of these mappings (p. 15), this should be considered proof of the Institute's strong interest in the aerial.

[39] One of the partners and initial president of the company CEFTA was Julio Ruiz de Alda (Fernández 222), one of the founders of the fascist movement in Spain, the *Falange Española*. He was a pioneer of aviation in Spain and a personal friend of the then dictator José Antonio Primo de Rivera and very close to his fascist government (Barciela, p. 355).

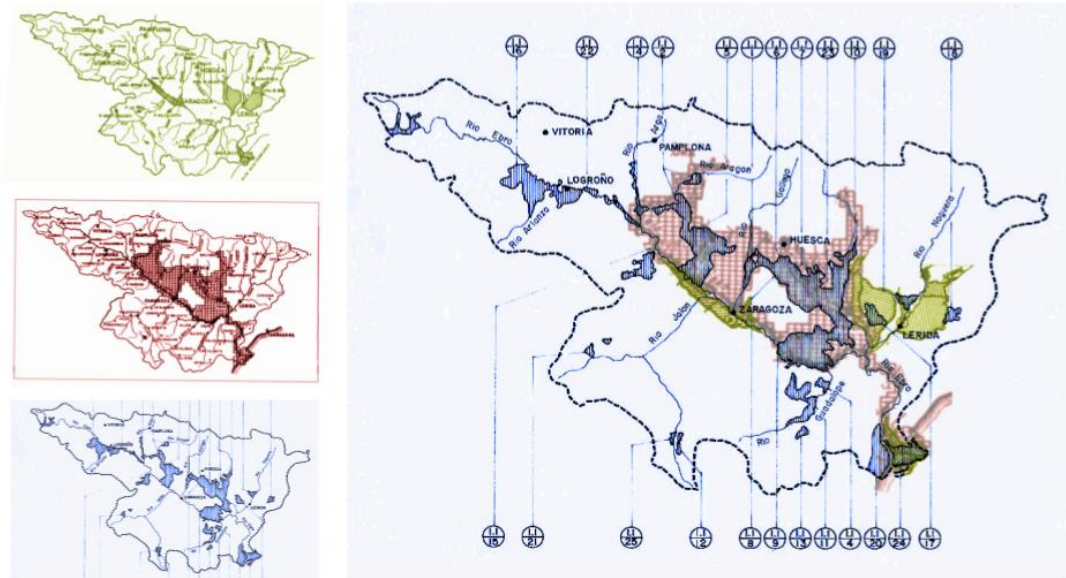


Figure 13 Maps of the Ebro River Basin, with Colonisation Zones before Franco (top, green), the areas covered by the first aerial mapping (middle, red) and the Zones by the INC (bottom, blue). Right: overlapped. Compiled by the author with maps obtained from (Fernández, 1998) and (Villanueva and Leal, 1990).

During the Spanish *Inner Colonisation*, therefore, the same land was, on the one hand, measured, parcelled and populated and, on the other hand, photographed frame by frame by fleets of aircrafts. In some respects, as shown below, these were two coupled envelopes growing at the same time: a surface of hundreds of thousands of acres of uncultivated land transformed into green areas of productive yields, entangled with the organised grid of images taken from airplanes. Figure 13 shows the evolution of these extensions plotted over the basin of the Ebro River. The left side of it contains three maps, with the two on the top drawn during the second half of the 1920s, i.e. before the Civil War, and the one on the bottom in 1970. The green one on the top displays the Irrigation Zones that were colonised in plans previous to Franco's programme. The red one in the middle shows a grid of aerial photographs linked to the law of 1926, commissioned by the River Basin Authority to the private company CEFTA in 1929 (Fernández, 1998, p. 118). Finally, the blue one at the bottom, drawn up 50 years later, depicts all irrigation zones produced by Franco's plans within this basin. Overlapped, these images strikingly coincide between the red areas mapped during the first cartography of the Ebro basin and the spread of the blue Irrigation Zones afterwards, during Franco's colonisation. In particular, almost every zone in the left bank of the river lies within the areas mapped during those first flights.

The images of the Ebro basin above acknowledge, on the one hand, that several of Franco's irrigation plans had been previously developed by technical commissions working for the previous government of the *República*, which was already known (Gómez Benito, 2004, p. 72). On the other, and crucial to this research, they evidence the principal role that aerial vision had in the design of these transformations of the territory. A feature that is also emphasised by the exceptional presence of copies of US flights in the archives of the INC.

Seen from this sequence of layers, the red squares of the aerial grid seem to extend the initially colonised terrains, depicted in green on the map. The new Irrigation Zones created by the INC, the blue areas, thus seem to appear as a material development of the aerial photographs. To observe them as temporal cuts in a 50-year line suggests how the agriculture practiced in this colonisation was akin to a photographic transfer: it is as if the vegetables grown had been printed on the terrain after the image. In other words, these images display the large-scale practice of agriculture that took place in Spanish colonisation plans as a visual activity. Related, not only to the photosynthetic activity of plants, but also to the photosensitive surfaces of the photographic plates.

To sum up, this colonising agriculture performed the grid and, once again, following Siegert, an empty space was extended to the vast banks of the main river basins in Spain. In addition to this, the use of aerial photographs seems to suggest the emergence of a visual mode of cultivation — literally, a visual culture. Defined against traditional unproductive practices, discarded to the background of an extended nature, these emerging practices would stem from a second-order distinction between culture and nature involved in this new agricultural split. These extractive *inner colonisations* didn't seek to expand the surfaces of arable land through outwards colonising practices, but rather to intensify the production by modernising it. This new agriculture needed to establish a new relation with soil. Soil alone, an *idle soil*, became a parasite inside the domains of a State that looked for productivity. As one of the members of the INC wrote, "at the sight of so many lands that will be fertile, it seemed to me that the whole land of Bardenas was a sleeping paradise" (Sabio, 2010, p. 118). The idle soil needed, then, to be mapped, conveniently recognised and identified in order to be awoken and put into production. With the aid of the addressed space of the pictorial grids and with the measuring and monitoring details of aerial photogrammetry, agriculture became a media-based activity. The parasite needed to be controlled; it became the excluded third, and gave rise in return to a media apprehension of soil and agricultural production.

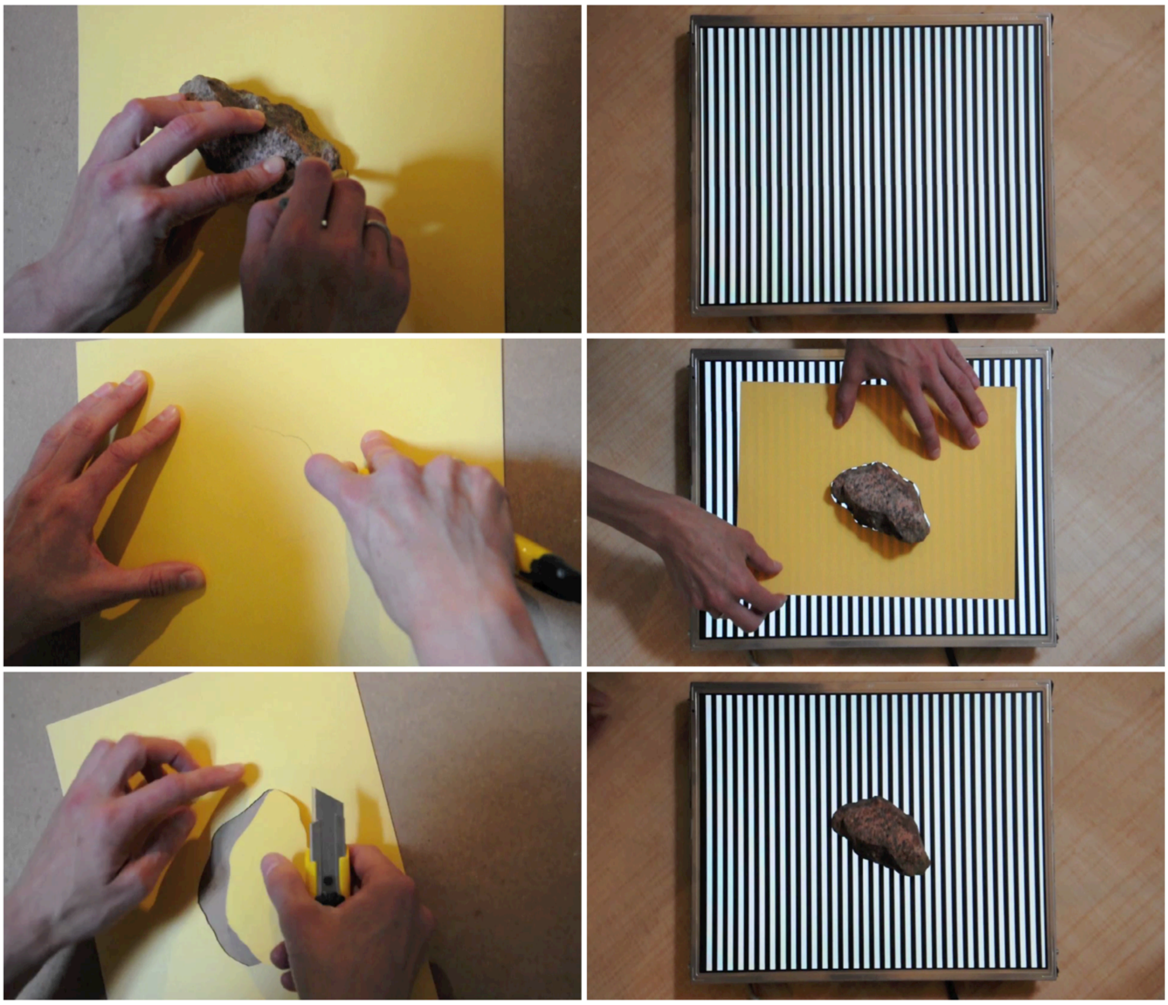


Figure 14 Stills from the video that documents *Marching Ants Marching in Rows* (2017).

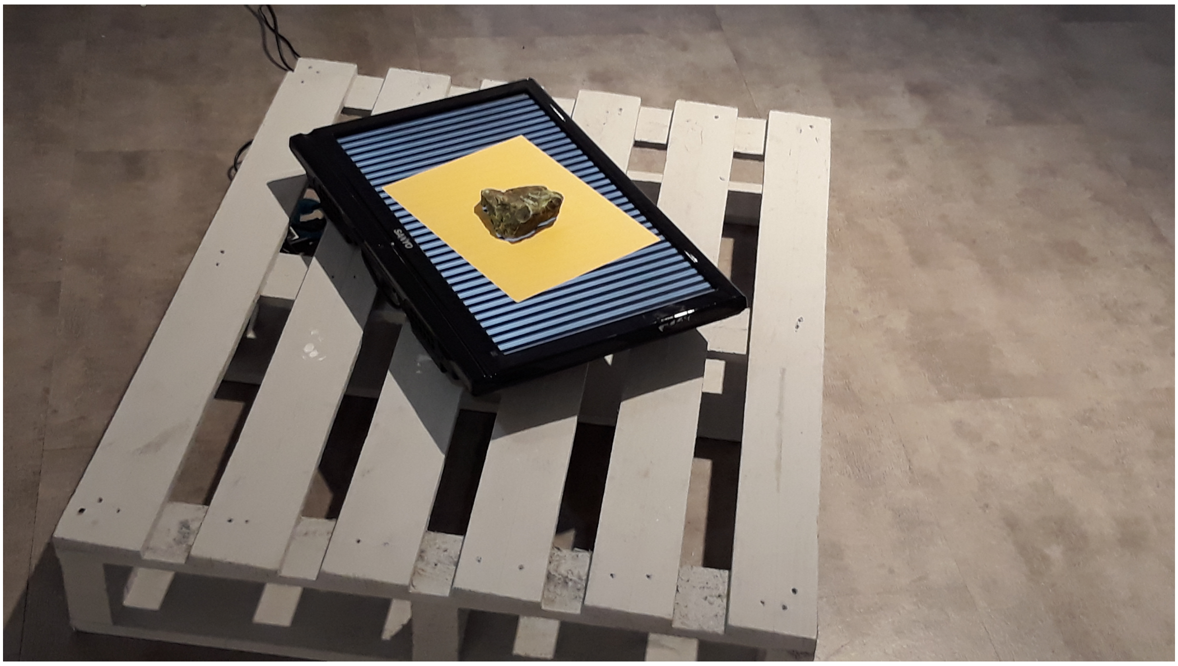


Figure 15 *Marching Ants Marching in Rows* [mixed media], PhD Viva exhibition, The Winchester Gallery (2019).

Figure 16 *Marching Ants Marching in Rows* [mixed media], L4 Gallery, Hartley Library, Southampton (2017). Original photograph courtesy of Jane Birkin.

Plantation 2. *Marching Ants Marching in Rows*

2017. Mixed media. Screen, paper, rock. Variable dimensions

Marching Ants Marching in Rows is a process where a media archaeological approach meets a DIY type of diagram. It deals with a software entity that is present in every image editing application: the marching ants effect — or marquee selection — that highlights, for instance, the clipping paths of the region of an image that is going to be altered. That is, it is the visible sign of a potentially immediate transformation within the surface of the screened image.

The animated movement of the lines is the product of a re-elaboration of an old technique used within the continuous scrolling panoramas, adapted to the surface of digital screens. As chronicled by Andy Hertzfeld (1983), in the early stages of Apple's *MacPaint*, computer engineer Bill Atkinson needed to depict the selection rectangle tool in a clear way so as not to be confused with the underlying image. Hertzfeld explains how Atkinson noticed a Hamm's beer sign in a pub. "The sign featured an impressive animated waterfall, with the water seeming to flow down the waterfall into the lake. Bill figured out the animation was accomplished by a mask layer moving beneath the surface of the sign that varied which portion of the image was visible below it" (1983). And Hertzfeld's story continues, with the engineer racing back home to implement the animation by using an alternating sequence of patterns that produced the illusion of continuous motion — the mechanism that today produces the marching ants on every screen.

In *Marching Ants Marching in Rows*, Atkinson's mechanism out of the beer sign with the flowing water is performed and displayed as a process of stacking separate layers. The silhouette of a stone is profiled on the surface of a piece of thick paper. It is then cut, resulting in a paper mask with the shape of the stone, which is placed on a screen with a looped animation of scrolling bars — the animation that underlies all marching ants after Bill Atkinson's algorithm. The paper mask is then used to envelop the rock. A thin line between the paper and the stone will appear, resulting from the thickness of the cut. This line parallels the one-pixel-thick transparent line that Atkinson's algorithm uses to display the ants. Through these slits, the background animation seeps into the foreground. In both cases — the original algorithm and its material reconstruction – the animated ants appear.

Figure 17 Image of the waterfall and the flowing waters of the lake scrolled in Hamm's beer panorama.

1.3 Visual agriculture: landscapes of production

1.3.1 The visual cultures of Precision Farming

Thus far, I have signalled and located the role and scope of aerial photogrammetry in the design and communication of the Spanish *Inner Colonisation*. Before continuing with more details of the case, it is worth observing that the development of visual-based soil operations has evolved to become a multi-scale practice today, in a much more dense and intensive way. Since the 1990s, and as a consequence of the availability of satellite imagery, the umbrella term *Precision Farming* names the use of remote sensing in agricultural contexts. In particular, it embraces an expansive set of practices where aerial vehicles track and guide the actuations executed on the ground. For instance, devices on tractors are programmed to control the dispersion of water and chemicals at each point of the plot upon information gained from satellite or aircraft-based sensors that measure the wavelengths of radiant energy absorbed and reflected from the surface of land. Infrared light reflected by the Earth informs of its biological activity. When contrasted to averaged models and statistics, this information can be used to detect whether it needs water, fertilizers, pesticides and even seeds. The resulting diagnosis, obtained from the air, is sent by sensing devices — drones, airplanes or satellites — back to the ground as images called *prescription maps*. Tractors that are provided with so-called variable rate applicators — which are digitally controlled irrigators — receive these prescriptive images. Soil moisture, surface temperature, photosynthetic activity, and weed or pest infestations are addressable with a resolution smaller than a square metre, almost exactly the size of the irrigation system actuator. In the midst of this circulation of images, agriculture is practiced, and, remarkably, the material flows in the circuit — water, pesticides, fertilizers or seeds — are embedded inside the tractors, out of view, enhancing the agency of these entities, the operative images and the system that sustains them. Within this circuit, the ground becomes a sort of screen, read as a stream of images that specify the doses to be applied at each point.

At a different scale, this is the same circuit that we are witnessing in the case of the Spanish *Inner Colonisation*. As a large-scale programme that needed to recognise the unproductive lands to be transformed — identifying existing plots, evaluating their character and crop figures and addressing the owners to be expropriated — aerial imagery and photogrammetry became a prescription tool used to shape the Zones to be affected. These, in turn, became the subject of the operations of machinery in a centralised unit, the INC, which mobilised the tractors, excavated the water streams and set up the workforce. As in the case of Precision Farming, it was a visual circuit. A circuit meant to activate unproductive soil.

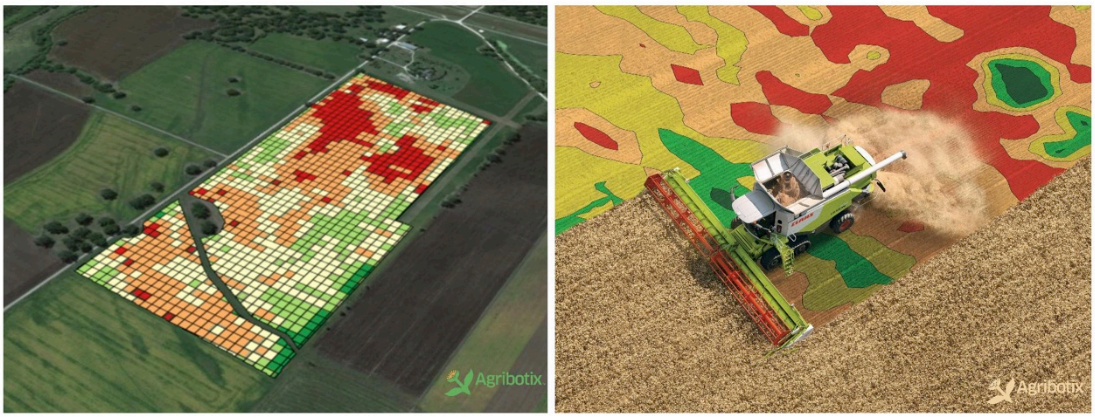
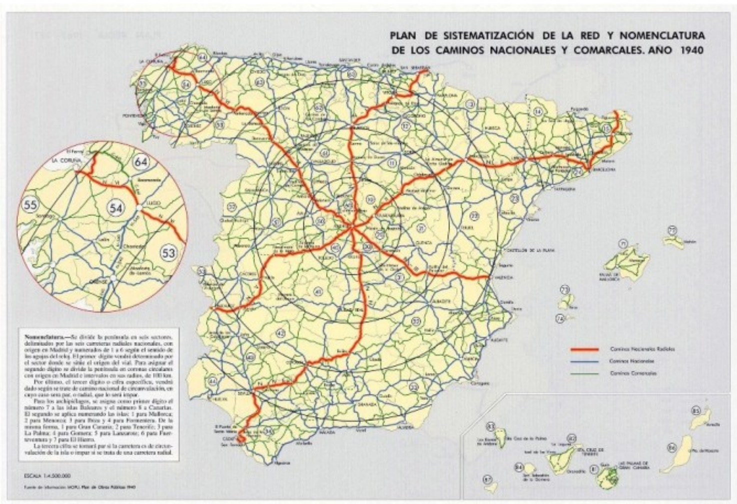


Figure 18 Images from the website of Agribotix, a company that sells Precision Farming products.

1.3.2 An infrastructure space

As already mentioned, after an initial autarchic period of confidence in private initiatives, the INC became more interventionist, particularly after their technicians visited the integral management programmes carried out in the United States (Delgado, 2013, p. 80). Subsequently, the Institute started to generate agricultural landscapes as sequences of easily recognisable patterns, networks of small towns, reached by irrigation channels and protected by a slim forest outline surrounding them. Through this "soupy matrix of details and repeatable formulas" (Easterling, 2014, p. 19), the infrastructure space of the Zones deployed, as "spatial software" (Easterling, 2014, p. 22), the model guidelines.



Pizarro.—En la subzona C, término de El Campo, a unos cinco kilómetros al Sur de este pueblo, contados sobre la carretera L-cuatrocientos veinte y a trescientos metros al Oeste de la misma.

Cijara.—En la subzona C, término de Villar de Rena, a unos cien metros al Norte del río Ruecas y a unos ochocientos al Oeste del camino del Polvillo a Zorita.

Puebla de Alcollarín.—En la subzona C, término de Villar de Rena, a trescientos metros al Este del río Alcollarín, sobre el camino de Piedra Hincada.

Casar de Miajadas.—En la subzona D, término de Miajadas, a un kilómetro al Oeste del camino vecinal de Miajadas a Don Benito, a unos mil setecientos metros al Sur del cordel de Trujillo.

Vivares.—En la subzona E, término de Don Benito, al Oeste del camino del Molino Nuevo a Arenillas, a unos cinco mil quinientos metros al Norte del río Ruecas.

Hernán Cortés.—En la subzona E, término de Don Benito, al Norte e inmediato a la variante de la carretera N-cuatrocientos treinta en el tramo de Santa Amalia a Valdivia a la altura del puente que se construirá sobre el río Ruecas.

Valdehornillo.—En la subzona E, término de Santa Amalia, en el camino de Santa Amalia a Miajadas, a trescientos metros antes de su cruce con el del Cebollero.

Yelbes.—En la subzona E, término de Santa Amalia, a cuatro mil doscientos metros al Este del río Búrdalo por el cordel de San Pedro y a cuatrocientos metros al Sur del mismo.

Alonso de Ojeda.—En la subzona G, término de Don Benito, en las proximidades del cruce del camino del Cuadrado de Almoharín a Santa Amalia con la línea divisoria de las provincias de Cáceres y Badajoz.

Conquista del Guadiana.—En la subzona G, término de Don Benito, a quinientos metros a la izquierda de la carretera N-V, a la altura del hito kilométrico trescientos cinco.

Figure 19 Left: map displaying the road network naming system, drawn up in 1940. Right: announcements of new towns in the Boletín Oficial del Estado (BOE), in 1955.

Part of these guidelines was the protocol used to address the positions of the newly built towns. As a state-driven programme, most of the relevant actions of the *Inner Colonisation* plans were logged and published in the Official State Gazette, the *Boletín Oficial del Estado* (BOE). There, remarkably, we find the announcements of new settlement towns, together with their proposed locations. In order to address their positions, a system based on the road network was used. Since 1940, roads and motorways were distinguishably numbered following a procedural nomenclature system (Figure 19).[40] Given this organised platform of road names, it served as a reference for the position of the new towns to be created inside idle lands. Thus, their locations were written down as distances to the nearest roads,[41] with the specification of the kilometric milestones concerned. The location of Pizarro, Hernán Cortés or Alonso de Ojeda, for instance — tiny towns significantly named after the *conquistadores* sent to America[42] — were specified (Figure 19, right) in the following way:

Pizarro	Subzone C, within the boundaries of the municipality of El Campo, 5Km south of this town, counted on the road L-420, and 300m west of this road.
Hernán Cortés	Subzone E, within the boundaries of the municipality of Don Benito, to the north and next to the turnoff of the road N-430, in the stretch between Santa Amalia and Valdivia, next to the bridge that will be built over the Ruecas river.
Alonso de Ojeda	Subzone G, within the boundaries of the municipality of Don Benito, in the vicinities of the crossing of the road from Cuadrado de Almoharín to Santa Amalia with the borderline between the provinces of Cáceres and Badajoz.

Figure 20 Locations of new settler towns as specified in the BOE of 5 July, 1955.

As an address system based on the calculation of distances to an infrastructure in the background, this ephemeris information signifies what social anthropologist Penelope Harvey (2012) has pointed out as the topological quality of infrastructural spaces, or, in her analysis of the national road network in Peru, as the operational transformation of territories after the impact of transport infrastructures. Here, as Harvey emphasises (Harvey, 2012, p. 78), geographical surfaces are conceived and designed after a new kind of spatial awareness. Space is apprehended in relation to the effects of a calculating background. As Nigel Thrift (2004) explains, it is a

[40] The new naming system was drawn up in the *Plan General de Obras Públicas* (1940), and referenced each road with a number that depended on 1) its angular location in relation to the six main radial motorways and 2) its distance to the *Puerta del Sol* square in Madrid. This nomenclature protocol is still in operation today.
[41] Other geographical references were also used, such as the course of rivers or borderlines between provinces.
[42] Many towns received names linked to the colonisation of America, to recall an infamous "glorious national past" (Delgado, 2013, p. 21).

"movement-space" (ibid., p. 597) that is linked to the experience of the gridding of time and space, the invention of filling and listing systems, and the invention of logistics (ibid., p. 587). Surfaces of land are intertwined within a new spatiotemporal continuity that emerges in the practices of sorting, numbering and calculating, where "it is relationality that is important… turning space and time from 'a priori' into 'a posteriori' categories" (Thrift, cited in Lury, Parisi and Terranova, 2012, p. 5). The nodes of the networks of settlements were thus announced in the official gazette through messages that point to the projective logic that reshaped the colonised territories.[43]

Figure 21 Settlement towns of Miralrío (Jaén) and Esquivel (Seville), part of *Inner Colonisation*. Source: (Delgado, 2013).

1.3.3 The cart-module. The footprint of a broadcast agriculture

As Michel Serres (2007) explains, early large-scale agriculture entailed the expertise of geometry. Where the flooding of the Nile erased the parcelled banks, the land surveyors — the *harpedonapts* — with their ability to calculate areas from their measurements, were the ones who could bring back the agricultural order within that fluctuating stability: "They had the cord, the unit, the measure, writing, and prestige" (Serres, 2007, p. 179). The equilibrium between landowners was articulated by the size of the plots, which came out as the critical magnitude.

In the case of the agricultural programme I am presenting, property and size were not the problem. Firstly, expropriated land was considered to be areas of national interest and belonged to the State. Secondly, following the procedures put into work in the referential case of the US Columbia Basin Project, the shape of the family units and the sizes of the plots were prescribed as part of the colonisation plans (Tordesillas, 2010, p. 192). In other words, the Zones were

[43] Interestingly, the design decision of positioning settlement towns in the nearby road system has been discussed by Scott as the control and monitoring disposition of authoritarian States (Scott, p. 237). In this sense, the INC programme has been criticised for its pervasive practices of surveillance on the settlers (Gaviria, Naredo and Serna, p. 356).

partitioned in a homogeneous way. The main problem of the plans, however, resided in the spatial distribution of the houses of the settlers and the allocation of their plots within the Irrigation Zones, where nothing existed but wasteland or previous dry exploitations. A spatial distribution was sought that, taking into account the productive spirit of the whole project, filled the entire space with agrarian units — house plus plot — so much so that no idle soil could be found within the Zones.

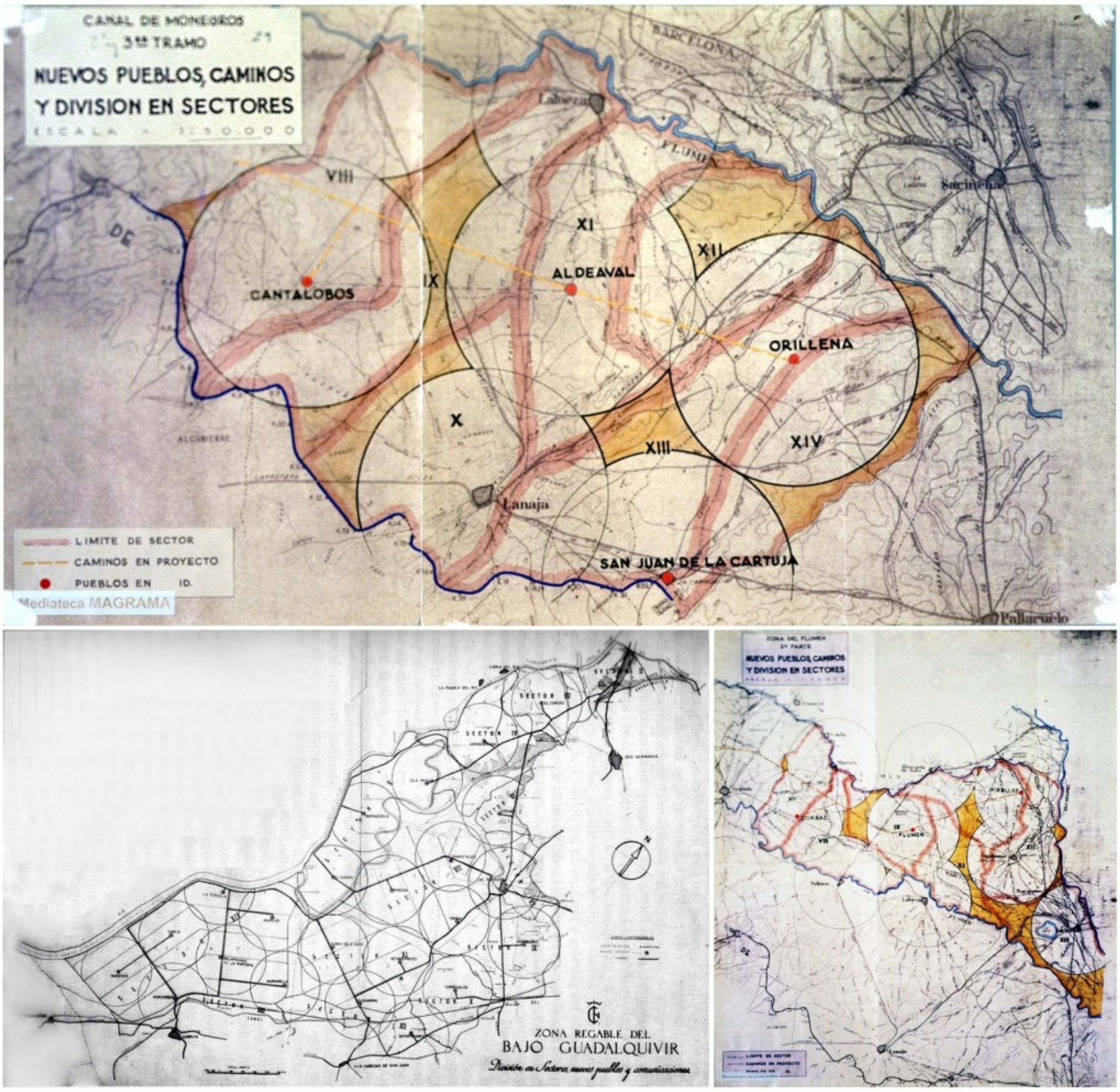


Figure 22 Cart-modules in different Irrigation Zones. Sources: (Villanueva and Leal, 1990) and Mediateca del Ministerio de Agricultura y Pesca, Alimentación y Medio Ambiente.

After analysing the failure of a model based on disseminated farms authored by Mussolini (Alagón, 2015, p. 7), the INC decided to distribute settlers among constellations of towns scattered as networks inside the large Irrigation Zones. Therefore, the problem was transformed into a question about the spatial distribution of the nodes of a network, and, additionally, each network of settlements had to be linked to the irrigation system, as the settlers needed to be placed in the vicinity of their irrigated plots. This problem was solved with one of the most salient features of the Spanish plans: the use of the so-called *cart-module*. The cart-module was a graphical planning tool used by the INC that was defined after the maximum operative distance covered by a settler with a cart; that is, the distance that would allow a farmer to go and return to a plot without losing much time (Alagón, 2015, p. 8). Estimated as 2.5 km, this distance was used as the radius of a circle around the town — the cart-module, or its area of spatial influence — where the plots were placed. Neighbour towns, as a consequence, should ideally be separated by 5 km, with their areas of influence drawn as tangent circles. The cart-module therefore allowed the graphical exploration of different combinations able to fill the available space. Once one of these visual arrangements was chosen, the circles were transformed into the canals, the water and the humans that would farm the Zones.

This drawing technique allowed INC technicians to position the settler towns, and to deploy the needed infrastructure — water canals, in particular. A singular case of mapping infrastructures, the central role of the cart-module highlights a significant dimension of the agriculture put into play: agriculture was being broadcast over these extensions. Following the work of Lisa Parks (2005; 2009; 2013), broadcasting can be understood as a technologised practice that results in the establishment of signal territories; that is, territories that are both culturally and materially transformed by the presence of specific signals. Within this *inner colonisation*, the design of the cart-modules abstracted the daily flows of farmers and water streams as periodic signals whose extent was calculated beforehand. On the maps of the infrastructure, workers and water are replaced by circular signals broadcast by the settlement nodes of the network. The Zones became signal territories, where each single settler town assumed its own footprint – the cart-module – as the territorial boundary in which its emissions could be received.

The arable space emerged after the expropriations as a signal space. Lands were connected lands. In addition to the space-filling character of the cart-module circles, it is important to highlight their time-based nature. As I have explained, their radius was linked to the workers' displacement time considered in relation to their workday. It was an averaged everyday measurement of human activity that turned out to shape the vast Zones. If water had to reach the plots through the circuits of the network, farmers had to access them too, by their own means.[44] The ordering of space was subsumed to this temporal constraint.

[44] The "cart" in the cart-module accounts for the main transportation means in rural Spain at the time, a cart pulled by a donkey, horse or farmer. As explained, the plans clearly took this into account. To such an extent that, as repeatedly argued (Alagón, 2015, p. 8; Tordesillas, 2010, p. 199), this has also been one of the most salient failures of the model, as the design became immediately obsolete when mechanised vehicles filled the lands (once the international blockade to Franco's Spain ended).

1.3.4 Surfaces for the averaged sedimentations of time

Once in the plot, another temporal window comes into play with the watering of the yields. These plans were designed to promote surface irrigation, which was the standard system of distributing water at the time. Practised for millennia, surface irrigation can be executed through several methods that guide and spread the water: parallel furrows, contour ditches, bench terraces, basin flooding, etc. Each of these methods irrigates differently, and it is recommended for different cultivations and characteristics of the terrain. As a general rule, water reaches one side of the plots through a canal, but enters the ditches and furrows only if the corresponding floodgate is opened.

Figure 23 Training and irrigation practices in one of the colonised areas. Source: *Mediateca del Ministerio de Agricultura y Pesca, Alimentación y Medio Ambiente*.

These famers only had access to a stipulated maximum daily quantity of water, which they needed to manage and distribute within their fields through the use of different gates and irrigation methods, and making the most of that water depended on the expertise of the farmer. The *First Aid for the Irrigator*, for instance, was a 1947 manual by the US Department of Agriculture distributed during the execution of the American irrigation programmes. It detailed the characteristics of the different methods and the importance of coupling them together, as for instance how the excess water after an irrigated surface can be drained and used in another, how to avoid water erosion, over-irrigation, etc. Inside the booklet, 'flow' is the most repeated word, and it might be read as a manual for the "accurate control of flow of irrigation water" (US FHA, 1947: 2), with sections devoted to the different types of gates, check boxes to limit the flows, measuring devices and more.

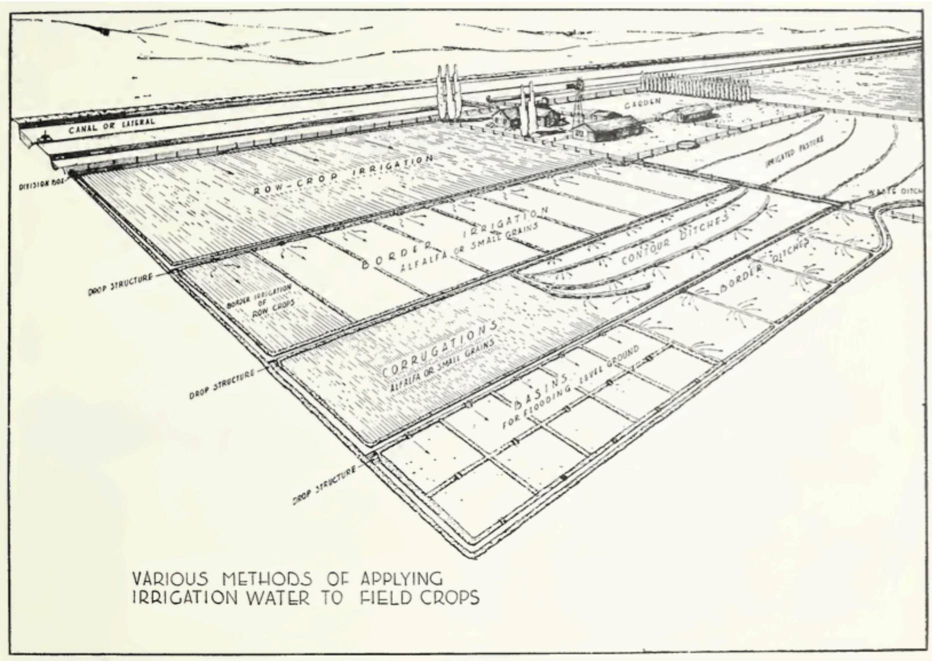


Figure 24 *First Aid for the Irrigator* manual (1947, p. 3).

In the case of Spanish *Inner Colonisation*, it must be taken into account that in order to keep the big land tenants happy, most of the plots offered to settlers had low-quality soils.[45] In addition, numerous settlers had never worked before with irrigation crops (Gaviria, Naredo & Serna, 1979, p. 278). Initially, during the first decade or so, these limitations resulted in very low figures, which in turn forced a redesign of the plan. After a new colonisation law,[46] each of the settler towns, for instance, received an agricultural engineer from the Institute, and each of the Zones was under the responsibility of a chief engineer. Thus, the INC assumed control of the irrigation design, types of cultivations, timings, fertilizers and pesticides. The *Inner colonisation* thus became a programme of supervised agriculture, with settlers receiving specific training and monitored over a two-year testing period. The watering machine, then, was put into operation, with controlled and periodic flows of water. No idle soil, no idle water.

[45] To keep the big landowners happy, the State assigned the worst lands to the settlers. The rest of the plots — still private property — were connected to the irrigation system. This way, the owners multiplied their benefits, despite the lands having been expropriated (Gaviria, Naredo & Serna, 1979, p. 262).
[46] The new colonisation law was introduced in 1949 (Gómez Benito, 2004, p. 75).

Figure 25 Satellite image and map of the colonised Zone of the Bajo Guadalquivir, the main producer of rice today in Spain. Source: *Google Maps/Digital Globe*.

At this point, in the context of the large-scale spreading of these levelled soils with calculated slopes, of the terraced benches, the floodgates opened and closed for amounts of time specified by engineers, it is enlightening to recall the chapter devoted to the surface of the digital image in Sean Cubitt's *The Practice of Light* (2014). In it Cubitt describes different episodes in the regulation of the flow of light that give rise to the production of the technological image. Episodes in the history of photography such as the Zone System by Ansel Adams, for instance, where light is systematically measured in the portrayed scene in order to obtain a spatial arrangement of numerical parameters — the zones — that subsequently guide the exposure times and the development times. As Cubitt observes, within these techniques the eye of the photograph was displaced in favour of an averaging sequence of calculations and technological operations. This sequence, in turn, ended up being embedded inside the lattice and the structure of gates and channels that compound the CCD sensor[47], whereby each cell of the gridded sensor accumulates the energy of the incoming photons over a short interval of time: the latency time that it takes to

[47] The research and work by artist Stephen Cornford on the CCD sensor is particularly illuminating. See for instance his series *Saturation Trails* (2017).

transform accumulated charges into valid voltages. The cells are then flushed, and the process repeated again. In the CCD, as in the time architecture of the Zone System, Cubitt unveils the technical definition of images nowadays: they are averaged transformations of time into space, controlled cuts, in time and space, of surface accumulations of light.

The industrial nature of the colonising agriculture analysed here also involved a controlled cut in the time and space of the sedimentation of light on infrastructured surfaces of soil. Light was commodified by means of the spatial control of flows, such as water and pesticides, through gates and exposure times, as well as through the estimation and numerical averaging of their productivity. In these circuits, agriculture becomes an averaging activity that seeks the control of production, guaranteeing the needs of the markets as well as preventing the generation of surplus. Embedded inside visual circuits and broadcast over Irrigation Zones conceived as signal territories, the streams of water, chemicals and human workforce converge in these agricultural programmes as a systematic practice of slicing surfaces of commodified light. Agriculture becomes a circuit of light: it is commodified, on the one hand, seen from the air and projected back to the ground.

Figure 26 *A Mechanical GIF* [kinectic sculpture], installed at *In-Sonora 9*, CRUCE Arte y Pensamiento, Madrid (2016).

Figure 27 Detail of the tin hands used in *A Mechanical GIF*.

Figure 28 Detail of one hand and the cylinder that holds it to the rotating axis. Inside the cylinder, a piece of rubber ensures the transmission of the rotation.

Plantation 3. *A Mechanical GIF*

2015. Kinectic sculpture. Wood, methacrylate, tin, stepper motors and electronics.

Digital images circulate on the top of multiple layers of materiality and labour. In *A Mechanical GIF*, a weaving flag is created out of the synchronised rotation of a collection of tin hands, cut after the famous icon of the social network. The hands are distributed on a grid in such a way that each one is slightly rotated in relation to its neighbouring hands. Connected to the motors, they all spin at the same time, resulting in the kinetic optical illusion of a coherent waving.

As a visual device, the piece displays the convergence of different scales and layers that operate within the stacked architectures of contemporary social networks. Taken individually, each hand performs repeatedly the well-known gesture of approval and rejection; when seen at a distance, each individual movement fades out against the motion of the flag, whose oscillation emerges from their collective, involuntary action.

In this regard, the piece recalls the looped gifs that are continuously shared through social networks. On its back[48], with the aid of transparent materials, the mechanism that generates the movement of the ensemble is made visible. Explicitly, then, the set of motors and rotating devices emphasize the moment of a material transfer: the one where a characteristic behaviour of the digital, the endless loop, becomes physical in the analogue world.

[48] Originally, the back displayed also a hand-written text about an episode occurred during the Belgian colonisation of the Congo, which involved the mutilation of slaves. This text has been permanently removed from the piece, due to the non-justified use of a colonial violent past only as an addendum on a work that addresses essentially digital animations, social networks and materiality.

Figure 29 *A Mechanical GIF* [kinetic sculpture], installed at *In-Sonora 9*, CRUCE Arte y Pensamiento, Madrid (2016). View of the backside[49].

[49] The hand-written text visible in the picture has been permanently removed. See note 48.

Chapter 2 The Plant-Image

2.1 Introduction. The greenness of plants

In the previous chapter, the irrigation and land settlement programme of the Spanish National Institute of Colonisation was presented as a case that displays how the practices devoted to setting up a modernised agriculture during the middle decades of the 20th century were tightly interweaved with the space of media operations opened by the spread of aerial photography. In particular, it has demonstrated how the distinction between productive and unproductive lands gave rise to a set of surveying, partitioning and managing techniques meant to identify and transform areas of uncultivated terrain. The notion of idle soil was developed in terms of Michel Serres' conceptualisation of the parasite and the media operations that gave rise to such a distinction as cultural techniques, primarily following the work of Bernhard Siegert. If ploughing is presented in Cornelia Vismann's and Winthrop-Young's texts as a practice that grounds both the notions of agriculture and property, then the media operations practiced after the civilian uses of aerial photography were considered in the previous chapter as founders of a second iteration of the agricultural distinction. The industrialised agriculture of the *inner colonisation*, defined against landforms and agricultures categorised and rendered as unproductive, was presented as the production of a particular type of cut: the one performed by the cultural techniques of measuring, addressing and averaging on the surface of the aerial photograph.

In this chapter the focus rests on the vegetal surfaces of plants rather than the agricultural extensions of land. The object of inquiry this time is a series of experimental practices that took place in the contexts of plant physiology at the turn of the 20th century, and characterised by the use of specific camera-less photographic techniques used to measure and describe the growth and shape of plants. In this vein, the work of the Austrian plant physiologist Julius Wiesner will be examined in detail. His use of cultural techniques of photographic measurement such as the *Insolator*, the *Lichtflache* or colour charts will be put in relation to contemporary discourses on photographic theory, as well as media theory developments such as Giuliana Bruno's notion of the surface. This analysis will, therefore, present his work as a series of operations where the photographic is transferred to the growth of plants, and vice versa. Additionally, the work of other distinguished plant physiologists will be addressed and also put in relation to other previous photochemical experiments. In short, this chapter presents a rich set of experimental practices that signal, in the context of plant physiology, a mutual re-operationalisation of vegetable matter and photographic technique.

2.1.1 Vegetable *Anordungs*. A material culture of visual media and the living

Any research on the interweaving between agriculture and operational images would be incomplete if it didn't take into account the fact that plants are themselves visually characterised by the green surfaces of their leaves and stems. The green colour distinguishes plants. It flags the presence of chlorophyll and as such, it emerges on their surface as a signature of their singular and fundamental ability among living beings; that is, to transform light into chemical energy. The green colour of leaves and stems is a visual index, a trace that does not only account for the activity of chlorophyll, but also for certain parameters of the plant such as its health or its state of development. Incidentally, the first chapter has already shown how contemporary precision farming systems exploit the fact that plants feature not only their characteristic green colour, but a more complex electromagnetic footprint of frequencies that transform them into emissive objects particularly apt for the analytic capabilities of contemporary imaging techniques. Beyond its role as part of current circuits of machine vision, however, this visual dimension of plants needs to be analysed further.[50]

The fluctuating relation between leaves, their colour and their exposure to sunlight is already accounted in texts devoted to them from Antiquity, such as Theophrastus' *Enquiry into Plants* or Aristotle's *De Plantis*. Of particular relevance for this chapter is, however, the modern experimental observation that the green colour of plants is itself a leftover, an after-effect of photosynthesis. Plants are green because of their inability to process the green rays of the electromagnetic spectrum. While they absorb most of the frequencies of light, the green ones are reflected back. In other words, plants filter light for it to be made operative and transformed into vegetative growth. This pre-processing of light will ground the main topics addressed in this chapter, bringing in a different scale of visual agriculture hybridisation, that of the individual plant.

Interestingly, greenness accounts for a particular form of vegetal sensitivity that is related to the contemporary notion of plant sentience discussed, among others, by Plant Studies scholar Michael Marder (2015), philosopher Elaine Miller (2002) and anthropologist Eduardo Kohn (2013). This notion of the sensitivity of plants to the environment will be traced back in this chapter to a set of scientific practices of the end of the 19th century; specifically, to the experiments measuring their movements carried out by botanists and plant physiologists. The last quarter of that century

[50] The emphasis in the chapter will be put on the green surfaces of leaves. Other visually notorious organs of plants, such as flowers, will not be considered here. Taking this into account, the green colour is presented here as a case of the broader spectrum of colour-encoded processes of exchange of matter and energy in the planet, which goes, in Jeffrey J. Cohen's words, "beyond green" (Cohen, 2013).

witnessed how these disciplines struggled to overcome the traditional distinction between *anima sensitiva* and *anima nutritiva* that had differentiated, since its introduction by Aristotle, between the behaviours of animals and plants. The study of the growth of plants and its relation to external stimuli gave rise to a set of concepts and experiments where plants were observed as if they were animal-like creatures (Chadarevian, 2011). This chapter, in particular, will focus on one of the definitions that addressed this form of vegetal sensitivity, which was meant in addition to measure it quantitatively: the notion of *Lichtgenuss* (the enjoyment of light) coined and systematically explored by Austrian botanist and plant physiologist Julius Wiesner (1838–1916).

In order to analyse it, in this chapter I will focus on the experimental work carried out by Wiesner during the last decades of the 19th and the early 20th century. In his laboratory, as well as in others that will be referred to, plant growth was scrutinised by measuring and intervening the surfaces of leaves and their surrounding light conditions. Remarkably, the tools put into play were photographic techniques: sensitised surfaces, the development process and the control of light. In the experiments reviewed below, photographic environments will be connected to living processes, in a series of different arrangements. These, for the sake of brevity, will be addressed with the name of *Anordungs*, incorporating the term proposed by German physiologist and pharmacologist Carl Jacobj (1857–1944).[51] *Anordungs* were "rather complex assemblages of organic and mechanical parts, electrical current and light rays, lenses, carbon rods and mirrors, frogs, wooden boards, and water jars" (Schmidgen 2012, p. 99). The vegetable *Anordungs* analysed here were devoted to measuring the behaviour of plants and were performed by scientists with great expertise in the material culture of the photographic image.

As I will show, the photographic techniques were used not only to quantify lighting conditions but also to characterise and classify plant behaviours. Echoing the description by Bernhard Siegert of Leonardo da Vinci's observations and drawings of natural phenomena (Siegert 2015, p. 125), in these *Anordungs* photographic technique and cultural technique will be shown to coincide: instead of being mere instruments that register the behaviour of plants photographically, they were the sites where a specific form of plant behaviour was defined. In these set-ups, then, the formation of the photographic image and the formation of vegetable organic tissue concurred. Not by chance, Russian plant physiologist Kliment A. Timiryazev (1843–1923) — whose work on

[51] While differing from the projection apparatuses meant to create movement images of the living that proliferated in the visual instruction of life sciences, such as the ones analysed by Henning Schmidgen, the experiments in this chapter are, nevertheless, contemporary to these set-ups. They include, for instance, the "Universal Projection Apparatus" by Leitz; the "Epidiascope" by Zeiss in Jena and the "Universal Projectoscope" by Stoelting in Chicago; episcopic projections of Salomon Stricker (1834–1898) in Vienna and Carl Kaiserling (1869–1942) in Berlin; Johann Nepomuk Czermak, Spectatorium, Leipzig. For more details, see (Schmidgen, 2012).

spectroscopy will also be examined in the last part of the chapter — acknowledged that, regarding the interweaving of plants with light, "the life of a plant is like a phantasmagoria, a successive series of changing magic-lantern pictures" (Timiryazev 1958, p. 68). In other words, photographic media gave rise to plants of a photographic nature.

2.1.2 Transfer operations

In the first chapter, the use of aerial photography during a large-scale development programme of irrigation agriculture was studied following the media theory notion of cultural techniques. Lands were partitioned with the aid of visual media in a process where territories were projected to become green surfaces. The resulting account of the chains of operations that brought media into the lands and that transformed them back into media has been contextualised as part of the becoming visual of agriculture. In this chapter, moreover, the notion of cultural techniques will be pivotal, as a new interweaving between imaging techniques and vegetable growth is considered. On this occasion the context of this interweaving will be the experimental practices of plant physiology that paralleled the industrialisation of agriculture.

Before continuing with the research that dealt with the action of light on the surfaces of plants, two related experiments conducted by Wilhelm Pfeffer will be referred to next in order to highlight some aspects of the analysis followed in this chapter. Between 1898 and 1900, this German plant physiologist produced a series of well-known photographic time-lapses of vegetable growth, the first photographic time-lapses to be produced (Gaycken, 2012, p. 56).[52] These were speeded-up sequences of photographs that allowed researchers to easily see and recognise different types of plant movement. While innovative, this media work was devoted mainly to teaching purposes, seeking to provide students with a "correct and plastic image", in Pfeffer's words (ibid., p. 58), of the otherwise difficult-to-attain sense of plant movement. Indeed, the behaviours that the films pictured had already been accounted and measured a decade earlier thanks to a material culture of automatic self-registering instruments (Gaycken, 2012). Pfeffer's time-lapses, nevertheless, exceeded the scientific domain[53] and helped to popularise the view of plants as sentient and dynamic beings (Janzen, 2016, p. 2).

Let's consider next one of these time-lapses, the acceleration of the growth of an exemplar of *Impatiens glandulifera* (Figure 30). The time-lapse consists of a minute of footage compressing 35

[52] As film scholar Oliver Gaycken has observed, there was an important tradition of time-lapse media in plant sciences before the photographic ones. The Darwins, for instance, used systematically smoked glass-plates and drawings to register periodic movements (Gaycken, 2012).
[53] The German film pioneer Oskar Messner contributed to popularising them by showing them at film evenings before main features (Janzen, 2016, p. 2).

hours of what is known as geotropic curving; that is, the ability of the plant to sense gravity and to grow vertically against it. The initial scene shows the plant lying in a horizontal position, with its rotated pot resting on a second supporting pot. When the film starts, the tip of the stem begins an upward movement, gently curving the whole plant. The wandering tip oscillates then towards verticality until finally the stalk acquires an L-shaped form.

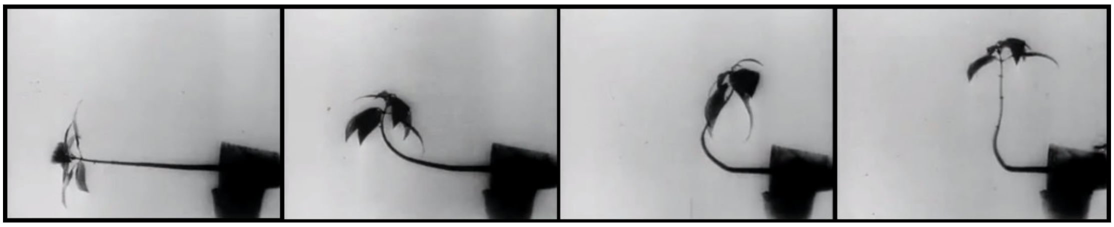


Figure 30 Stills from Wilhelm Pfeffer's film on geotropic curving of the *Impatiens glandulifera*. *Kinematographische Studien an Impatiens, Vicia, Tulipa, Mimosa und Desmodium von W. Pfeffer (1898–1900). Dir. Wilhelm Pfeffer.* 1900.

In the film, the plant seems to seek the vertical position itself instead of being pulled by light or any other agent. This, as media theorist Janet Janzen has remarked, illustrates a growing current of thought in the late 19th century where plants were represented "as manifestations of nature's creative dynamic force as opposed to the reductionist perspective of materialism and naturalism" (Jansen, 2016, p. 3). In addition to this, it is necessary to take into account a characteristic of the context were these shots were taking place; that is, life science laboratories and educational institutions. In these places visual media were part of a programme based on "the gaze as a means of power to control the organisms", as historian of science and media Henning Schmidgen has remarked in relation to the use of projection apparatuses mixed with living organisms in the context of Austrian and German physiology (Schmidgen, 2012, p. 114). Noticeably, this control practiced by the gaze can be observed in Pfeffer's time-lapse too, whereby the plant in movement seems to be shaped neither by light nor gravity, but rather by the framing of the photographs instead. In this vein, the images in the time-lapse seem to recall one of the main ideas proposed by artist and cultural theorist Joanna Zylinska regarding the relation between photography and life: "photography is a formative practice of life not only because it represents our lives in various ways but also because it actually shapes life" (Zylinska, 2017, p. 17). This, in the case of Pfeffer's time-lapse, occurs in the eyes of the audience; the limits of the framing constrain the image as well as the depicted growth. In the end, growth happens in the image, and it is shaped by it.

Instead of delving deeper into the visual analysis of the images produced by the time-lapses, my research now seeks to emphasise a space of material relations between the techniques of imaging and those with regard to observing the growth of the plant. In the specific example of Pfeffer's time-lapses, for instance, this means that the imaging process needs to be put in relation to the broader material culture of his laboratory. In this case, the time-lapse on geotropic curving, specifically, can be related to a particular experimental device, the clinostat,[54] designed by the well-known plant physiologist Julius von Sachs (1832–1897)[55] and improved and extensively used by Pfeffer later on (Chadarevian, 1996, p. 39). The clinostat is a mechanical instrument that allows physiologists to hold a pot horizontally in such a way that it can be rotated manually or automatically (Figure 31). The aim of the apparatus is to cancel the effects of gravity and light on the growth of the plant. The slow rotation of the pot — one revolution per minute, for instance, achieved with the aid of a clockwork mechanism (Pfeffer, 1897, p. 569) — makes the plant sense gravity and light sources all around, with no privileged direction. As a consequence, the plant grows counter-intuitively along a horizontal line, parallel to the ground and to the sky.

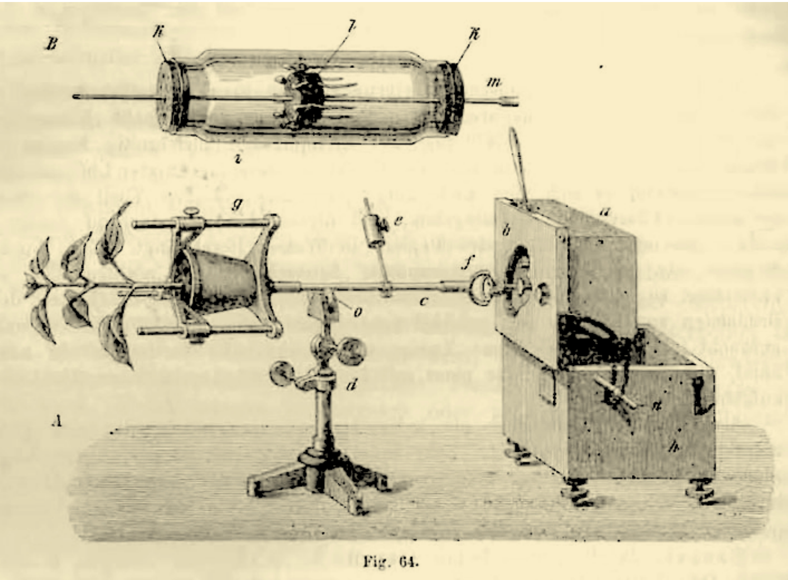


Figure 31 Clinostat, as depicted in Pfeffer's *Pflanzenphysiologie* (Pfeffer, 1897, p. 570).

The clinostat relies on the particular sensitivity of plants to their environment. "Their absence of movement is nothing but the reverse of their complete adhesion to what happens to them and their environment", writes philosopher Emanuele Coccia in his *The Life of Plants: A Metaphysics of Mixture* (Coccia, 2018, p. 5). Plants are so deeply entwined with their surroundings that the changes around them leave an impression on their shape; that is, they can be transformed by intentionally altering their milieus. From this point of view, the rotating disk of the clinostat can be seen as an intervention in the environment that moulds the plant, forcing it to grow horizontally instead of vertically.

[54] Sometimes spelled klinostat.
[55] Sachs had also been Pfeffer's mentor.

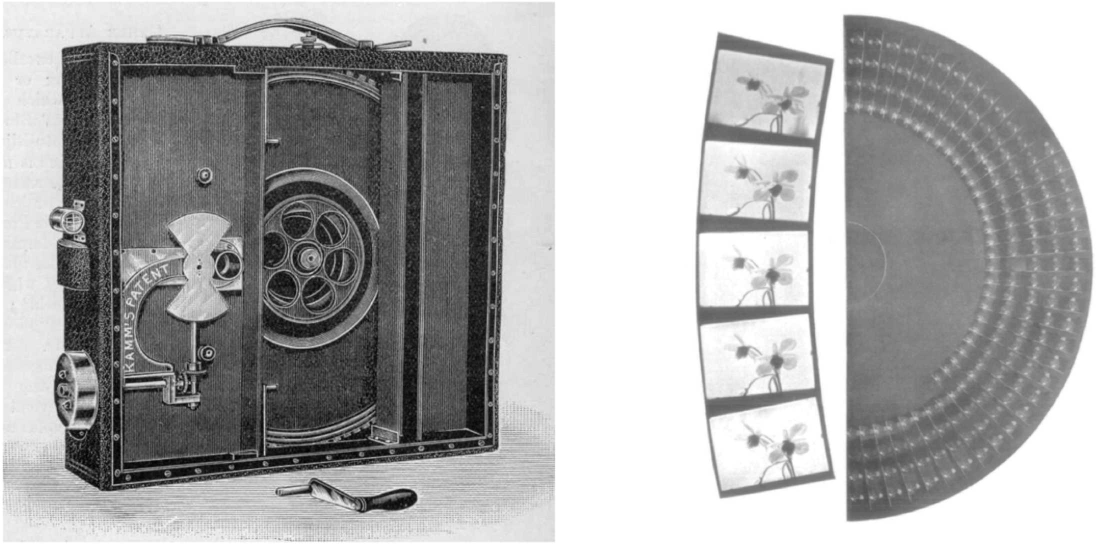


Figure 32 A rotating disk plate (right) with the inflorescence of the *Sparmannia Africana* registered by Henderina V. Scott (1903), obtained with a modified kammatograph (left).

To understand the rotating conditions of the plant as an altered environment enables this technique to be linked to Pfeffer's time-lapse. In order to do this, it is necessary to observe that the German physiologist's sequences of images rely on a very similar set of techniques. In his case, the production over 35 hours of a series of photographs to be used in an accelerated animation required the set-up of a careful synchronisation of lighting conditions and rotational devices (Pfeffer, 1900). As botanist Henderina V. Scott remarked when describing her process of building a cheaper version of Pfeffer's invention, uniform exposure and absolute rigidity of the apparatus were among "the very great practical difficulties" the set-up needed to solve (Scott, 1903, p. 773). Although the experiments that led her to obtain the first time-lapse registered outdoors involved greater challenges than Pfeffer's — such as the varying light conditions of a greenhouse instead of indoor photography — most of the practical difficulties she documents also characterise the original set-up. The production of the time-lapse needs, on the one hand, a mechanism able to shoot a photograph first and then to replace the sensitive film without moving the camera in order for the framing to be kept. Pfeffer made use of a kinematograph (Scott 1903, p. 772) that involved the rotation of a roll of celluloid film; as this option was too expensive for Scott, she produced her sequences of photographs with a kammatograph[56] instead, where the negatives were printed on a rotating glass disk instead of on a film (**Error! Reference source not found.**). On the other hand, the control of exposure, i.e. the light received both by the photographic surface and the plant, was of course an additional factor involving the careful

[56] The kammatograph, invented by Leonard Kamm, was one of the early predecessors of the cinema camcorder (*The Kammatograph*, 1952, p. 3)

arrangement and measurement of artificial lights, for the night photographs, in particular (Scott 1903, p. 773).

Interestingly, the same techniques that constrain the growth of a plant to a specific direction appear within the mechanism that accurately registers a sequence of free vegetable growth in a sensitive surface. Moreover, the movements prevented by the rotation of the clinostat are precisely the ones registered in the sequence of images. It is as if the growth of the plant that was confined in the first experiment had been transferred to the imaging process in the second. Or, vice versa, as if the mechanisms able to register growth inside the frames of the image had also been able to shape and constrain the growth of the plant in a controlled environment. This transfer operation between visual media and measuring set-ups will characterise the experiments that follow in this chapter. In particular, a context of camera-less photographic practices will be presented, where photographic papers, light measurements and colour charts contributed to building up the material culture where these experimental life sciences took place. The work of the botanist and plant physiologist Julius Wiesner, of particular relevance to this research, will be highlighted next.

Figure 33 *The Quivering of the Reed*, studio installation (2019)

Figure 34 *The Quivering of the Reed*, PhD Viva exhibition, The Winchester Gallery (2019)

Defoliation 1. *The Quivering of the Reed*

2019. Installation. Plant, beamer, DC motor, spot light and paper screen. Variable dimensions.

The *Quivering of the Reed* is an installation conceptualised as a media archaeological arrangement of operations that merges together experimental scientific practices with early moving image devices. A pot of cat-grass — a fast-growing assemblage of grass, soil nutrients and water, designed as a scaled down and domestic form of pasture — is placed on top of a rotating platform in between a source of light and a projection screen made of millimetric paper. The shadows produced by the rotating plants on the screen create an endless stream of ever-changing images.

This material form of vegetal filmmaking — using media theorist Peter Uhlin's words (Uhlin, 2015) — is complemented by a sequence of subtitles. These take a sentence by Andrei Tarkovsky as a starting point: "Just as from the quivering of a reed you can tell what sort of current, what pressure there is in a river, in the same way we know the movement of time from the flow of the life-process reproduced in the shot" (Tarkovsky cited in Uhlin, 2015). The projected text inverts, however, the filmmaker's statement: the movement of time in media shapes and transforms the living by measuring and creating new conditions of manipulation.

The plant occupies the position of the film reel. It registers light as well as it produces images. Devised as the encounter of three surfaces — the leaves of the plant, the millimetric paper and the projected subtitles — the installation exposes a very particular form of synchronisation: moving images with vegetal growth. In rotation, this camera-less and film-less cinema resembles a planetary diagram. Seen from the deep times of the Earth, it speaks for the vegetal nature of stock.

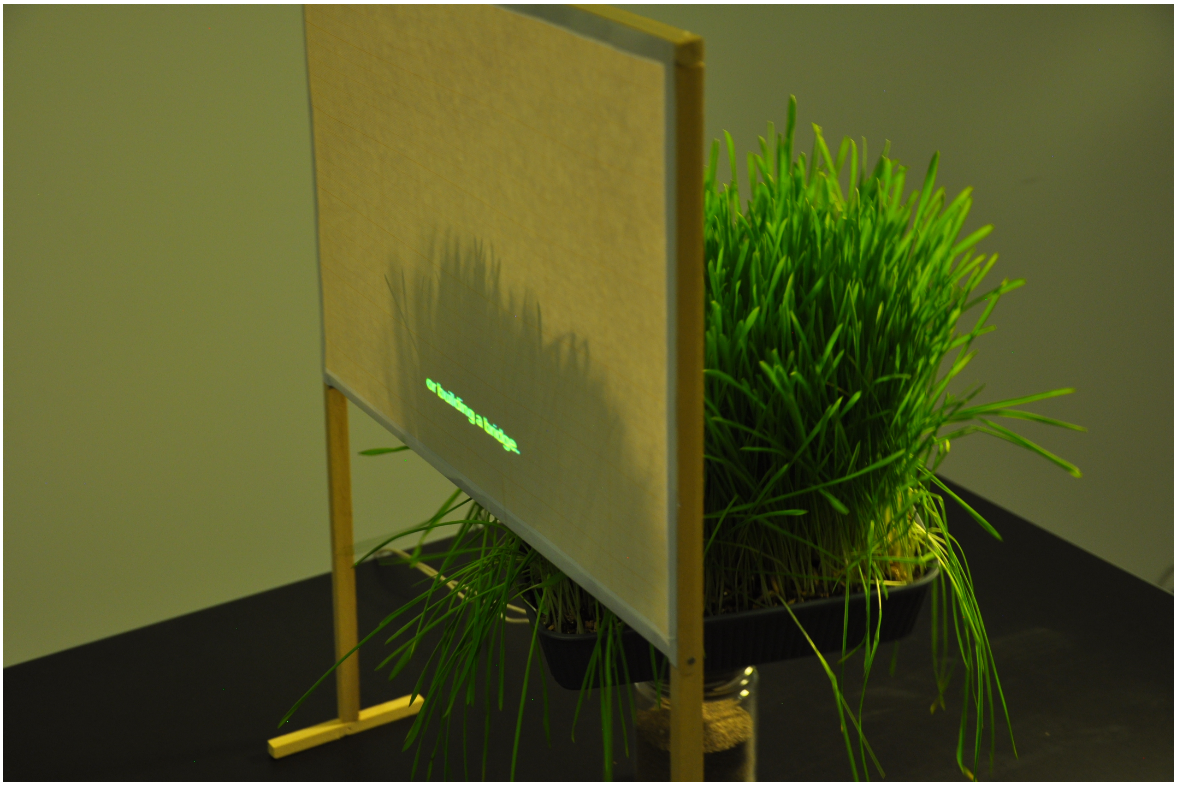


Figure 35 *The Quivering of the Reed*, studio installation, detail (2019).

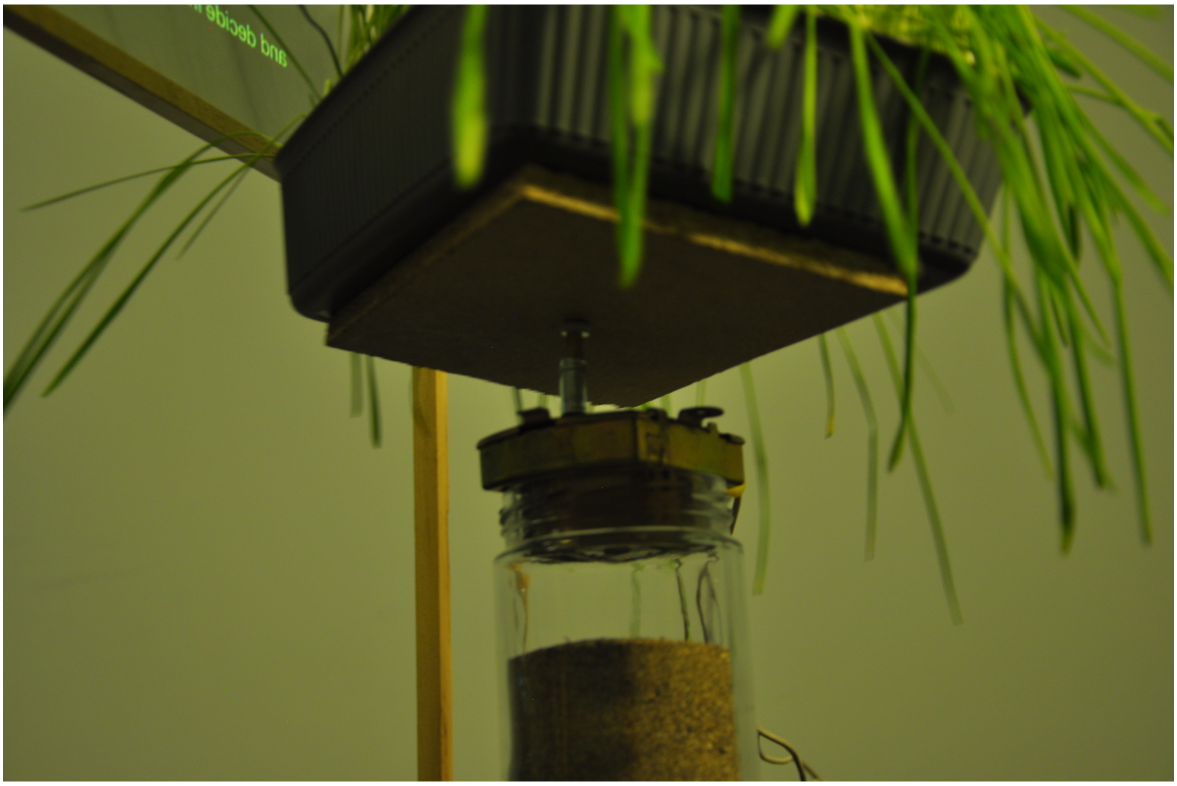


Figure 36 *The Quivering of the Reed*, studio installation, detail (2019).

Figure 37 *The Quivering of the Reed*, PhD Viva exhibition, The Winchester Gallery (2019).

2.2 Surfaces of measured light. Plant physiology and photography

This chapter is focused on a specific set of experimental *Anordungs*, where certain techniques imported from photography were employed to characterise the interaction between light and the surfaces of plants. It will explore, for instance, how the incidence of radiation on plants was measured through the use of photosensitive papers or how vegetable leaves were employed as photographic surfaces upon which to fix a light imprint. To do this, the chapter will deal specifically with a series of experiments on the relation between the growth of plants and the incidence of light carried out by chemists, plant physiologists and botanists at the turn of the 20th century.

The work of the aforementioned plant physiologist Julius Wiesner on the notion of *Lichtgenuss* will conduct the following pages, and will also be a means to review other remarkable experiments put into practice by his contemporaries. As illustrated below, his research on the interaction of plants with light is of particular interest, given that he proceeded to investigate it through a systematic and extensive gathering of photometric data (Eder, p. 417). In addition, Wiesner, an international reference point in the plant science community (Chadarevian, 1996) and director of the Research Institute of Plant Physiology in Vienna, stood out as an expert in technical microscopy[57] and a recognised authority on applied physiology[58], with links to the paper industry, in particular (Rischel, 2014). Anecdotally, featuring the characteristic Viennese *fin-de-siècle* disposition to conjointly cultivate the arts and sciences,[59] he was also a remarkable practitioner of natural photography: a cyanotype attributed to him is part of the collection of the Metropolitan Museum of Art (Figure 38**Error! Reference source not found.**).

Of course, photographic practices in scientific laboratories like Wiesner's had been put in operation since the first daguerreotypes. Photography was integrated into scientific material cultures through its gradual connection to other instruments such as the telescope,[60] the microscope[61] and spectrometers,[62] and also in textbooks and other teaching media (Curtis, 2012, pp. 76–78). Writing about the historical and material transformations of the role of imaging in scientific contexts, historians of science Lorraine Daston and Peter Galison highlight the importance of the entrance of photography in the experimental spaces of the mid-19th century.

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[57] See, for instance, his publication of technical microscopy (Wiesner, 1867).
[58] On the many relations he kept with the industry and the domain of applied physiology see (Wiesner 1898).
[59] On Wiesner as a promoter of universal knowledge, see Coen (pp. 164–165)
[60] John Adams Whipple, *The Moon*, c. 1840 (McKenzie, p. 25)
[61] See, for instance, the early experiments with microscope daguerrotypes published in 1844 by Alfred Donné and Leon Foucault (Daston and Galison, p. 134)
[62] Already in 1842 John William Draper made daguaerrotypes of solar spectra (Hentschel, p. 197)

For them, in particular, it triggered the development of a "mechanical objectivity", meaning a redefined and re-operationalised notion of objectivity: a "new configuration of epistemological convictions, image-making practices, and moral comportment that aimed to quiet the observer so nature could be heard" (Daston and Galison, 2007, p. 120). Following their work, after the invention of photography, scientists started to consider themselves as self-registering instruments, or "photographers of phenomena", in the words of French physiologist Claude Bernard (Curtis, 2012, p. 68). Not a temporary trend — continue Daston and Galison — this assemblage of ethos, practices and technologies dominated scientific production during the whole 19th century (Daston and Galison, 2007, p. 195).

Figure 38 Microscopic cyanotype by Julius Wiesner displaying an arrangement of diatoms (Wiesner, 1870). Source: Metropolitan Museum of Art.

Parallel to the spreading of this particular form of objectivity, however, the essentially camera-less experiments practiced in the context of plant physiology are linked to a different type of approach to photography. Wiesner — as well as his colleagues — operated photographic techniques not to picture plants, but to analyse their assimilation of light. In their experiments, plants were wrapped up with photographic techniques for the control of light, in *Anordungs* meant to produce measurements instead of images. In this vein, these assemblages expand upon an alternative tradition in early natural photography that cultural historian John Tresch has described in relation to the experiments carried out by French physicist François Arago (1786–1853) (Tresch, 2012, pp. 89–122). Arago, who used daguerreotypes to measure the intensity of starlight, "was not interested in the objects depicted on the silver plate, but rather in what the process and rate of its development revealed… Rather than reproducing what the perfect, unbiased human eye would see, in this instance the daguerreotype registered invisible phenomena unfolding over time" (Tresch, 2012, p. 115). This association of early photography with the unfolding, over time, of phenomena endorses the thesis held by art historian Vered Maimon in which these practices of imaging are related to an underlying focus on motion and temporality rather than on "substances and matter" (Maimon, 2011, p. 963). This would explain, in her words, why "early photography, both in its mode of formation and imagery, no longer represents the static 'order of things', but registers an evolving visual map in which vital forces mark themselves as they unfold in time" (Maimon, 2011, p. 967). Rather than a replacement of the eye with a mechanism, then, some of these early practices would seek instead to expand the possibilities of vision in its interweaving with temporal phenomena. Significantly, as I will show next, these different approaches are related to the clash between mechanical and vitalist world views that characterised the discussion context in life sciences, where photographic practices by Wiesner took place. This coincidence is particularly helpful in order to understand the operational role played by his imaging apparatus in relation to the formation of knowledge on plant growth and, more importantly, the consequences of its application to the ongoing industrialisation of agriculture.

2.2.1 The *Vivarium* and plant-light interaction

The interaction between plants and light was the main object of study for most of Julius Wiesner's career. During his time, nature and the characteristics of the movement of plants in relation to their surrounding conditions were contentious topics among botanists, polarised between two very different positions: the one defended by Julius von Sachs, who argued for a mechanical explanation of these movements,[63] and the one postulated by Charles Darwin and further elaborated by his son Francis, where plants had the ability to respond to stimuli due to the circulation of signals inside them (Chadarevian, 1996).[64] While critical of Darwin's analysis of the movements of plants (ibid., p. 38), Julius Wiesner maintained a subtle position that argued for their sensitivity: "shouldn't we speak of a sensation of the plant when one sees that it absorbs light, gravity and other external influences as stimulus?" he wrote (Wiesner, 1898, p. 67). At the same time, however, he acknowledged the modelling effect on plants operated by the

[63] Where the movements of roots would be explained as a mere action of the gravity, for instance.
[64] As a sort of proto nervous system.

environmental conditions around them, those of light in particular: in his words, “one could say that light moulded their shape as though they were a plastic material” (Wiesner, quoted in Vernadsky, 1998, p. 59). Wiesner understood that the shape of plants was the result of the encounter of these two agencies: environmental light, on the one hand, and plants’ active leaves, on the other.

This adaptive relation between active organisms and their fluctuating environment is related to a specific scientific culture that characterised the Viennese complex of institutions around Life Sciences that hosted Wiesner’s research, the Viennese *Biologische Versuchsanstalt* complex, also called the *Vivarium*. A very particular approach to the experimental practices in quantitative biology has been highlighted there (Coen, 2006; 2007; Müller 2017) and described as “a ‘third way’ between mechanical determinism and pure spontaneity” (Coen, 2006, p. 496). In the *Vivarium*, the ‘‘mastery of environmental conditions” — as its director Hans Przibram termed it (Coen, 2006, p. 498) — was the experimental motto, and the notion of “plasticity”, a transversal trait that all separate experimental disciplines shared when addressing the interaction between individuals and their milieu (Coen, 2006, pp. 508–511).

As Wiesner’s above-mentioned quote reveals — “one could say that light moulded their shape as though they were a plastic material” — his work can be framed easily in this cultural background. Yet this research seeks to understand the plant-image hybridisation beyond Wiesner and the Viennese context, through the analysis, in particular, of the material cultures and practices where plant physiology was taking place. Consequently, the tension between the sensitive surface of the plant and the active environments of light will not be scrutinised through the culturally situated notion of plasticity, but through the cultural technical analysis of the practice of camera-less photography that is closely related to this research, as outlined below. Remarkably, the tension between the chemical activity of light and the sensitivity of paper is resolved in the photographic formation of the image. Recalling again the work of the already mentioned François Arago, images emerge, in his words, as the encounter of both the “action of light” and a “sensing substance” (Tresch, 2012, p. 116). As I will show, the continuously self-regenerating surface of plants will be similarly considered: modelled after an ever-changing image in perpetual formation.

2.2.2 *Lichtgenuss* and its measurement: the *Insolator*

Devised to work on the two-way relation between the environment and the plant, the notion of *Lichtgenuss* became Wiesner’s main research problem at the end of his career. This study, gathered in his 1907 book *Der Lichtgenuss der Pflanzen* (The *Lichtgenuss* of Plants), broadly aimed “to show how the plant as a whole behaves in relation to the luminous intensity offered to it”

(Wiesner, 1907, p. 251). That is, it was a project that sought to build a holistic approach to the plant in relation to light, instead of dealing with the specific microscopic or chemical dimensions of it, as his previous works on the formation of vegetable matter or on plant transpiration had done, for instance.[65] To understand this way of light-plant interaction, he relied instead on a careful and systematic practice of measurements of light received by the plant surfaces at different points of their body and at different times of the year. He addressed each of these measurements as a value of the plant's *Lichtgenuss*, with this magnitude being a characteristic of the species that varies with the seasons and time of day. In other words — as I will emphasise in these paragraphs — the notion of *Lichtgenuss*, understood as an intrinsic characteristic of a plant at a certain point it space and time, was quantified in terms of light measurements.

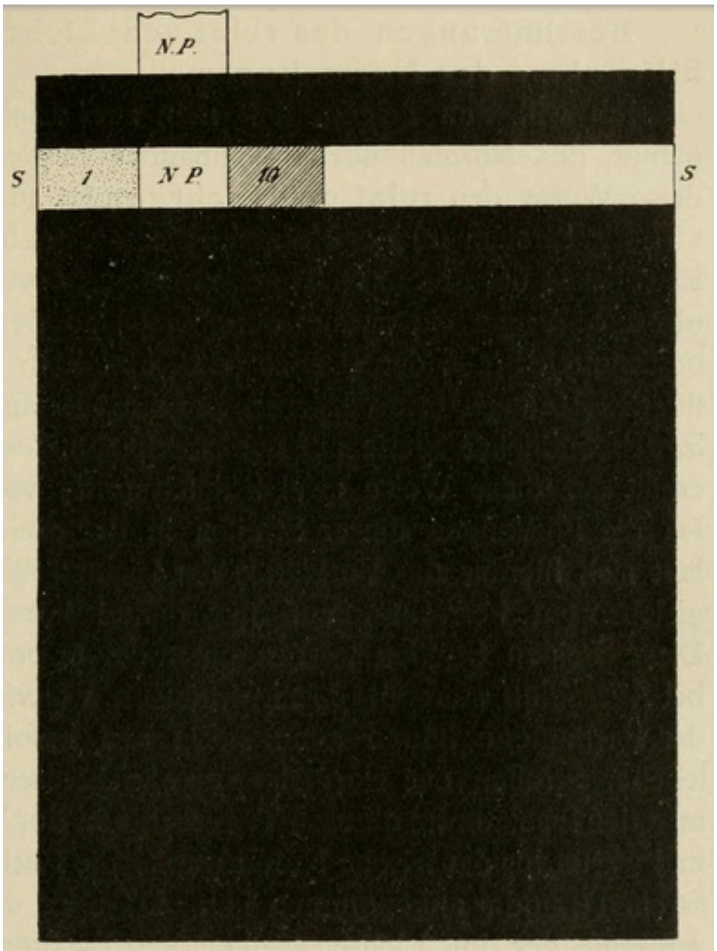

Fig. 1. Insolator in natürlicher Größe. *ss* Schlitz, in welchem Normalton und Normalpapier unbedeckt liegen, im übrigen durch fest anliegendes, schwarzes Papier gedeckt sind. *N. P.* Normalpapier. 1 Normalton (Einserton). 10 Skalenton (Zehnerton).

Figure 39 *Insolator* (Wiesner, 1907, p. 15)

[65] His work on the growth of plants at a microscopic scale is gathered in (Wiesner, 1892), where he proposed his theory of the plasoms, the particles that made up vegetable matter.

To carry on his research, Wiesner needed to be able to measure the intensity of light accurately, or, in his words, “to proceed photometrically" (ibid, p. 68), and to do so he redesigned a well-known photometer developed[66] by chemists Robert W. Bunsen (1811–1899) and Henry Roscoe (1833–1915) based on the sensitivity of photographic paper. His *Insolator* consisted of a hand-sized rectangular piece of wood where sheets of photographic paper could be slipped in under a black cover that shielded them from the action of light (Figure 39**Error! Reference source not found.**). The experimenter could then pull the paper out and observe the blackening due to its photosensitivity. In order to be able to easily compare this blackening to a reference value, a strip of paper with two so-called normal tones was attached to the border of the black cover. Thus, with this elemental device the intensity of light could be calculated with the aid of a chronograph (ibid., p. 14) by simply measuring the time needed for the photographic paper to reach the reference tone. A more advanced use of the *Insolator* allowed him to work with several sheets of photographic paper at the same time, which could even be laid directly on top of leaves, trunk and other inaccessible parts of the plants.[67] The size of a smartphone, the *Insolator* was the portable photometer that Wiesner needed to measure the intensity of light anywhere, anytime. "The 30 of March 1893 at 10h45m I observed in the Wiener Augarten a total daylight intensity=0.427", he wrote (Wiesner, 1907, p. 69), displaying in his words the characteristic attitude prone to measuring the everyday that years later Robert Musil would describe in *The Man Without Qualities*. With this device he obtained reference daylight curves (Figure 40) and measurements of the *Lichtgenuss* of all kinds of Central European plants, and, moreover, undertook several expeditions all over the world geared towards analysing the behaviour of plants in extreme weather, light and height conditions, such as the ones in the Artic, the Sahara, the tropics or the Alps.

What the experimental practice of Wiesner evidences in particular is how photography brought a new cultural technique to life sciences that transformed the understanding and operationalisation of the formation and growth of plants. To understand this, Wiesner’s *Lichtgenuss* and the *Insolator* need to be analysed as a form and practice of inverted photography. In order to do this, it is first worth recalling that Wiesner’s modification of the photometer invented by Bunsen and Roscoe was anything but original; in the context of photography, similar commercial devices also relying on photographic paper, measurements of time and normal tones — such as actinometers

[66] In his work on the history of photography, Eder tracks the development of this invention, and explains how the design by Bunsen and Roscoe improved the one by F. J. Malaguti in 1839 (Eder, 1905, p. 415).
[67] This was achieved through the notion of the relative *Lichtgenuss*: with the aid of assistants, several papers were exposed to light during the same amount of time. One by one, the blackened papers were introduced in the *Insolator*, and pulled out together with the measuring photographic paper, in order to measure the time the test paper needed to acquire each of the colours. These relative times could then be easily recalculated to become absolute figures.

and exposure meters — were already common.[68] This means that the *Insolator* was a regular photographic exposure meter introduced and explained to the plant science community. However, while the main function of these devices was to estimate the amount of time needed for an image to form on the sensitive plate, Wiesner used them differently — in a reversed way, in fact.

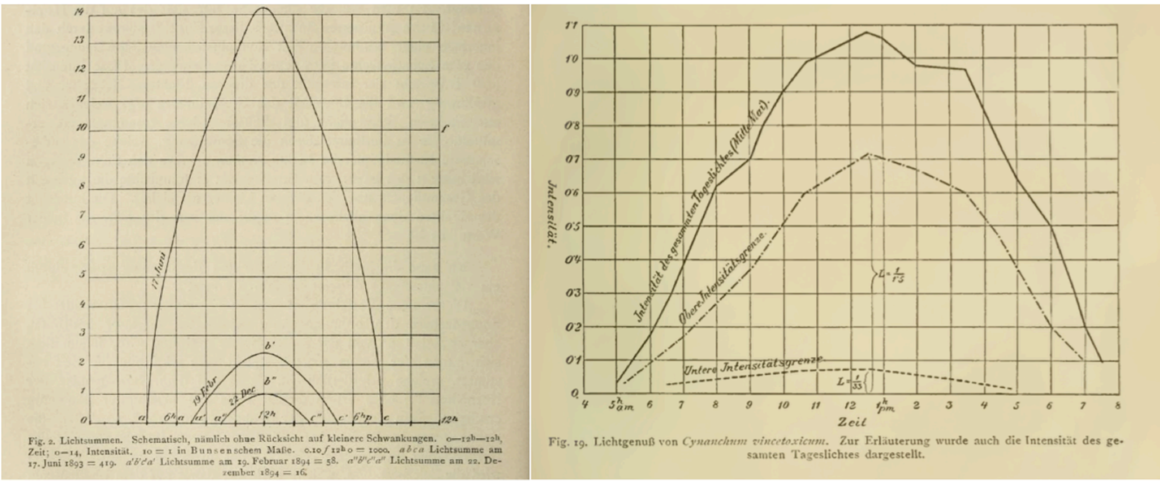

Figure 40 Samples of daylight measurements by Wiesner, printed originally in (Wiesner, 1907, pp. 20, 131).

Wiesner addressed singular exemplars of trees and plants, already formed and grown, and measured the intensity of light where they had grown; that is, where their leaves were placed. For him, their shape was the expression of their ability to adapt to their surrounding conditions: the plant as a whole was able to place each leaf in the right place following its *Lichtgenuss*. As Emanuele Coccia remarks, “plants coincide with the form they invent” (Coccia, 2018, p. 12). In Wiesner’s case, this commentary would translate into the assumption that the measured light on the surface of the leaf coincides with the amount of light that the plant needs, as the plant is supposed to be adapted to its environment through its shape. Hence, Wiesner’s particular use of the *Insolator* relates this concordance to the development of images on sensitive paper in the context of camera-less photography. Instead of measuring the exposure time needed for a correct picture to be formed, he measured the exposure time where the surface of the leaf had been formed. That is: implicitly, the forms of the plant were treated as if they had a photographic character. In this vein, he proposed a classification of plant leaves following their affinity to the exposure to light: leaves could be *photometric*, *aphotometric*, *euphotometric* or *oligophotometric*

[68] As Eder puts it, “exposure meters with silver salt papers and normal gray tints with tables were introduced by Stanley (1886), Wynne (1893), Alfred Watkins (‘Standard Exposure Meter’) 1890, (W. G.) Watkins (‘Beemeter’), and others” (Eder, 1905, p. 449). For more details see (Pritchard, 2013).

(Wiesner, 1907, pp. 70–74).[69] In Wiesner's account, leaves developed light – in photographic terms – yielding vegetable matter as a result.

This parallelism between the photographic formation of an image and the form of vegetation encompassed in Wiesner's works had already been perceived by a notable contemporary. Charles Darwin, in a letter sent to a Canadian fellow about an earlier experiment by Wiesner,[70] observed how the Austrian had borrowed a term from photochemistry to explain the continuing movements of plants when lights had been turned off.[71] The term in question was photochemical induction, a chemical interaction between light and matter introduced by Roscoe and Bunsen that succeeded at explaining most of the photographic processes of the time.[72] Wiesner, in the early work referred to by Darwin, indeed relied on this photochemical process (Whippo and Hangarter, 2006, p. 1,111). That is to say, according to that paper, the plant response to light was stated to display an inductive nature. In other words, and taking into account Wiesner's acquaintance both with photochemistry and the practice of photography: the interaction of plants with light was explained again as a photographic response.

To sum up, Wiesner understood plants as sensitive beings sculpted by light. They didn't grow merely as accumulations of vegetable matter reacting mechanically to external forces, however, nor as free organisms with the ability to experiment with their own form. They were moulded by light as if they were photographic developments. From this point of view, the *Insolator* allowed him to collect *Lichtgenuss* tables with minimum and maximum values of different species at different times of the day and year, not so different from the exposure tables published by chemists and photographic manufacturers ().[73] With the aid of these, one could roughly foresee the adaptive reaction of a plant if its surrounding light conditions changed: it would grow and evolve until the exposure times corresponding to its species, its *Lichtgenuss*, could be met. *Lichtgenuss*, or the measurement of the intensity of light where the plant had formed, was the

[69] Whether their growth occurred in the direction of incident light rays, against them or independent from them.

[70] Wiesner's experiment took place in 1878. "The inductive nature of the response was finally confirmed when Julius von Wiesner (1838–1919) showed that plants continue to bend towards a light source even after the light is turned off." (Whippo and Hangarter, 2006, p. 1,111)

[71] Darwin, *From C. Darwin, Esq., to G. J. Romanes. April 18, 1881:* "Wiesner and Tieghem seem to think that this is explained by calling the whole process 'induction,' borrowing a term used by some physico-chemists (of whom I believe Roscoe is one), and implying an agency which does not produce any effect for some time, and continues its effect for some time after the cause has ceased. I believe (?) that photographic paper is an instance. I must ask Leonard [his son] whether an interrupted light acts on it in the same manner as on a plant."

[72] "The laws of photo-chemical induction, which we have developed in this Part, explain most completely many of the singular phenomena which lie at the foundation of the photographic processes." (Bunsen, Roscoe, 1857, p. 400)

[73] In relation to exposure tables see (Pritchard, 2013).

measurement of the exposure time that kept the form of the plant alive — a living photograph of its own species.

Lichtgenuß einiger mitteleuropäischer Bäume und Sträucher [1]).

(Nach in Wien und Umgebung angestellten Beobachtungen.)

	L (min)	Intensitäts-maximum	
Buxus sempervirens	$\frac{1}{108}$? [2])	0.012	Freistehender Gartenstrauch.
Fagus silvatica	$\frac{1}{85}$? [2])	0.015	Freistehender Baum, Gartenform.
Aesculus hippocastanum . .	$\frac{1}{83}$? [2])	0.015	Freistehender Baum, Gartenform.
Fagus silvatica	$\frac{1}{60}$ [3])	0.021	Geschlossener Bestand.
Aesculus hippocastanum . .	$\frac{1}{37}$	0.023	,, ,,
Carpinus Betulus	$\frac{1}{36}$	0.023	,, ,,
Acer platanoides	$\frac{1}{35}$	0.023	,, ,,
Acer campestre	$\frac{1}{43}$	0.030	Freistehender Baum.
A. Negundo	$\frac{1}{28}$	0.046	Geschlossene Baumgruppe.
Quercus pedunculata . . .	$\frac{1}{26}$	0.050	,, ,,
Ailanthus glandulosa . . .	$\frac{1}{22}$	0.063	Freistehender Baum.
Thuja occidentalis	$\frac{1}{20}$	0.070	,, ,,
Populus alba	$\frac{1}{15}$	0.086	,, ,,
P. nigra	$\frac{1}{11}$	0.118	,, ,,
Pinus Laricio	$\frac{1}{11}$	0.118	Kleiner, nicht dichter Bestand.
Betula verrucosa	$\frac{1}{9}$	0.144	Üppig entwickelter Gartenbaum.
Liriodendron tulipifera . .	$\frac{1}{7.5}$	0.186	Einzeln stehender Gartenbaum.

Figure 41 A vegetal exposure table: the minimum and maximum values of *Lichtgenuss* in some Central European trees and shrubs, measured by Wiesner (Wiesner, 1907, p. 153)

2.2.3 Surfaces of measured light

Endless movement characterises plants: "their body is a morphogenetic industry that knows no interruption" (Coccia, 2018, p. 13). They sense the environment and grow and adapt their vegetable organs as a response. Plants move and change their shape, seeking "an ecological optimum with respect to the light", as Wilhelm Pfeffer put it in relation to Wiesner's work (Pfeffer, 1897, p. 109). Regarding these movements, the notion of *Lichtgenuss* addressed the existence of a disposition spread in the vegetal realm, a proneness to stabilising forms in continuous interaction with light. As I have shown in the previous discussion on the *Insolator*, with this notion and its technical implementation Julius Wiesner was able to apprehend the formation of vegetable surfaces in photographic terms. That is, with the aid of a material culture linked to the practice of photography, the plants' metamorphic inclination was conceptualised as a photographic disposition.

So far, my analysis of Wiesner's research displays a case where the already mentioned work on nonhuman photography by artist and theorist Joanna Zylinska is particularly fitting. In her "relational ontology of mediation" (Zylinska, 2017, p. 84), photography and life are interweaved in such a way that life can be considered "a creation of images in the most radical sense, a way of temporarily stabilizing matter into forms" (Zylinska, 2017, p. 75). In this manner, as it has been argued, Wiesner's case evidences how photography entered the plant physiologist's practice to literally shape and give form to the living. Yet, as the use of aerial images in large-scale agriculture indicates, this research on the growth of plants had an impact on a very particular context of application: the improvement of yields. "These investigations open a comparatively new field", commented a reviewer of Wiesner's work (Hus, 1906, p. 602) in a similar vein, "of both scientific and practical value, being applicable to physiological and horticultural problems alike". Thus, in order to understand these practices, there is a need to consider the fact that the physiologist's work was about the growth of plants as well as the growth of crops. In Wiesner's words: "Under the influence of plant physiology, agricultural chemistry has transformed itself into an agrarian physiology, which today has to be counted among the most important disciplines in the practice of life." (Wiesner 1898, p. 73)

Therefore, in the context of this research I understand the Austrian physiologist's work as one of the sites where a distinction was being produced in the relation between images and the surfaces of the world. The practice of imaging was being re-operationalised. Following my arguments above in relation to Pfeffer's and Scott's time-lapses, it is not that plant growth was understood in terms of the image only, but also that the practice of imaging was being synchronised to the formation of surfaces that belonged to different material contexts. The *Insolator*, as a photometer applied to non-standard photographic formations, can be understood as a device that produces this synchronisation. In Wiesner's work plants were not understood as images but operationally replaced by them. This entanglement of the photographic surface with the vegetable one turns Wiesner's photographic practices into a set of cultural techniques linked to the operational image. Here, then, I am not vindicating the immanence of the philosophical notion of the imaging cut, but a context of practices where the operational mode of the image was produced. As I will emphasise next, his work on the notion of *Lichtgenuss* can be analysed as the production of a set of techniques that gave rise to a new epistemic configuration of the approach to the vegetable surface. A close inspection of these techniques will be addressed, for they reveal two additional significant media dimensions that need further analysis: their surface character, on the one hand, and their reliance on measurements, on the other.

2.2.4 *Lichtflache* and the *Farbenskala* colour chart

Wiesner's technique of the *Insulator* highlights the importance of the interfacial surface where light and vegetable matter meet, in particular when it is considered in relation to his previous interest in microscopic research on tissues – such as vegetable surfaces, papers and textiles.[74] Together with the colour green, surfaces are one of the most salient features of vegetal structures. "The plant's body is all skin", writes plant scholar Michael Marder (Marder, 2013, p. 81), as "it is for the sake of adhering as much as possible to the world that they develop a body that privileges surface to volume", continues Coccia (Coccia, 2018, p. 5). In relation to what comes next, and seen from a media theory point of view, surfaces are spatial enablers, arrangements with a disposition, for instance, for time to become material space. Following Giuliana Bruno (2014), surfaces should be understood as operative relational layers that mediate material spaces as if they were a form of media on their own. This, in the case of this cultural technique approach, can be related to how vegetal formations were refashioned once their photographic condition was assumed. Along the same lines, I will show how plants and trees were addressed as visual spaces of operations when considered as a whole, and to do this I will review two other surfaces defined by Wiesner in his book on the *Lichtgenuss* of plants.

The first of these was the notion he proposed of the *Lichtflache* (the surface of light), defining it as the tangential surface that would wrap the entire tree or plant (Wiesner, 1907, p. 96). This surface was then an abstract entity, akin to a mathematical concept, detached from any actual physical surface of the vegetal exemplar. If the *Insolator* addressed the leaf of the plant, then this new notion of the *Lichtflache* was devised to deal with objects of a bigger scale, such as the crowns of trees or the extensions of grass. The notion of *Lichtflache* was thus a tool that allowed him to arrive to a surface object defined mainly in relation to its interaction with light. In other words, it allowed him to assimilate alike a shrub, an ivy or a rainforest palm. It was a mathematical coat, to use Georges Bataille's wording (1985, p. 31), which reduced complex assemblages of vegetable matter to a visual shape — where, significantly, the vegetable was not even present in the name of the concept: surfaces of light.

[74] He wrote extensively about the microscopic form and growth of vegetable surfaces (Wiesner, 1892), and extended his practice to the analysis of paper (Rischel, 2014) — including texts on old manuscripts — and textiles (Heim, Sachse and Walker, 2009, p. 207).

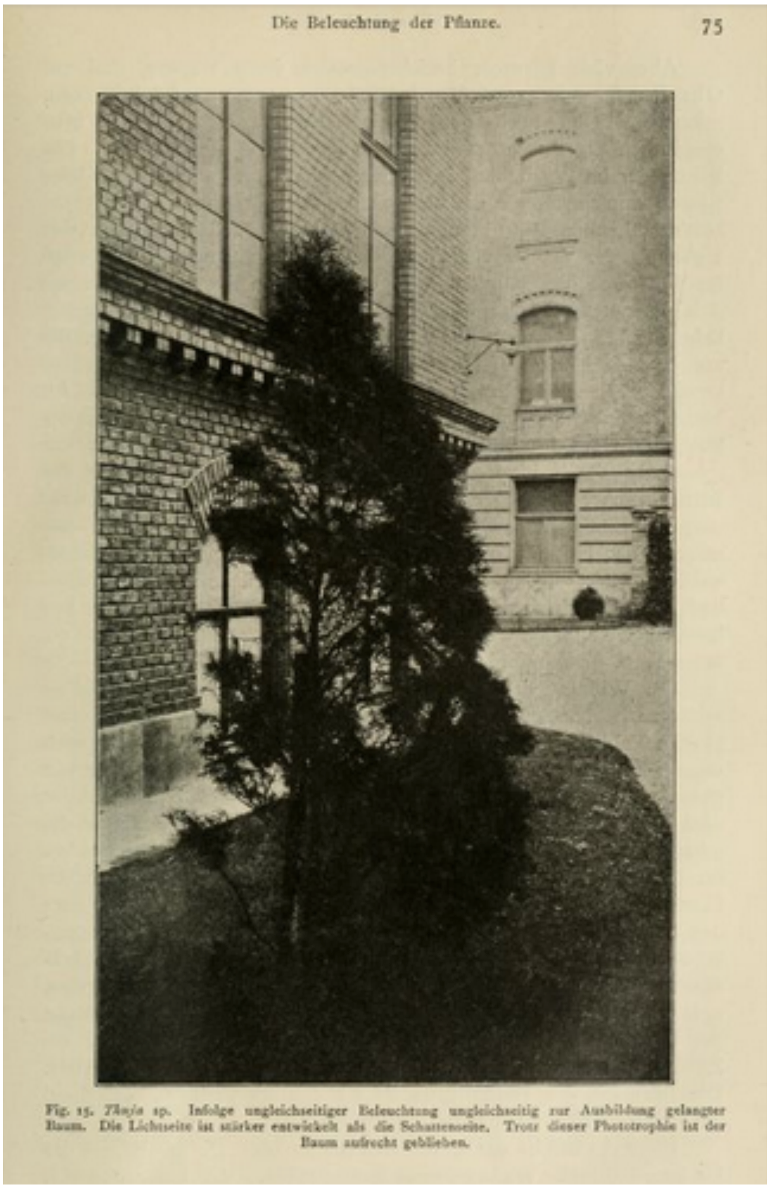

Figure 42 Photograph by Wiesner of a tree crown adapted to the lighting conditions due to its position near a building (Wiesner, 1907, p. 75).

Seen from the point of view of the above-mentioned work of Giuliana Bruno, this transfer to the surface involves a new space of operations. Indeed, Wiesner devised it to calculate the green density of canopies, considering it as a geometrical area that could be compared with the sum of the individual areas of the leaves in the plant. The ratio of these two extensions allowed him to calculate a measurement of the density of the foliage and its porosity in relation to light. This is a significant contribution as it is directly linked with the current notion of *Leaf Area Index* (LAI),[75] widely used in environmental research. The utility of this definition, in fact, was already detected in the 1920s by Russian biogeochemist Vladimir I. Vernadsky, who used it to calculate the density

[75] The calculation of the LAI index is slightly different however: the sum of the one-sided areas of leaves in relation to the area of the ground.

of what he called living matter in vegetal formations such as forests or prairies in order to compare them to the lower values of agricultural fields (Vernadsky, 1998, p. 78).[76]

In addition to this *Lichtflache*, a second significant example of surface can be found in his use of a standard colour chart available at the time, the so-called Otto Radde's *Farbenskala* (), used as a means of colour communication in scientific and trade applications (Kuehni, 2008, p. 86). This colour metric scale allowed him to classify the different greens observed in plants, and with the aid of it he systematically measured and compared all the different shades of green present in plants and trees. He then explicitly addressed the plant leaf as a visual object, equipped with the tool that the industry used to protocol the correct circulation of coloured commodities, allowing him to achieve a greater resolution than the naked eye. He thus measured the fluctuations of the green of the leaves, their relation to the amount of chlorophyll, the effects of different lighting conditions and many other phenomena. Notably, this colorimetric approach to the plant allowed him to perceive otherwise indiscernible variations, many among them —following Wiesner — unknown until his measurements.

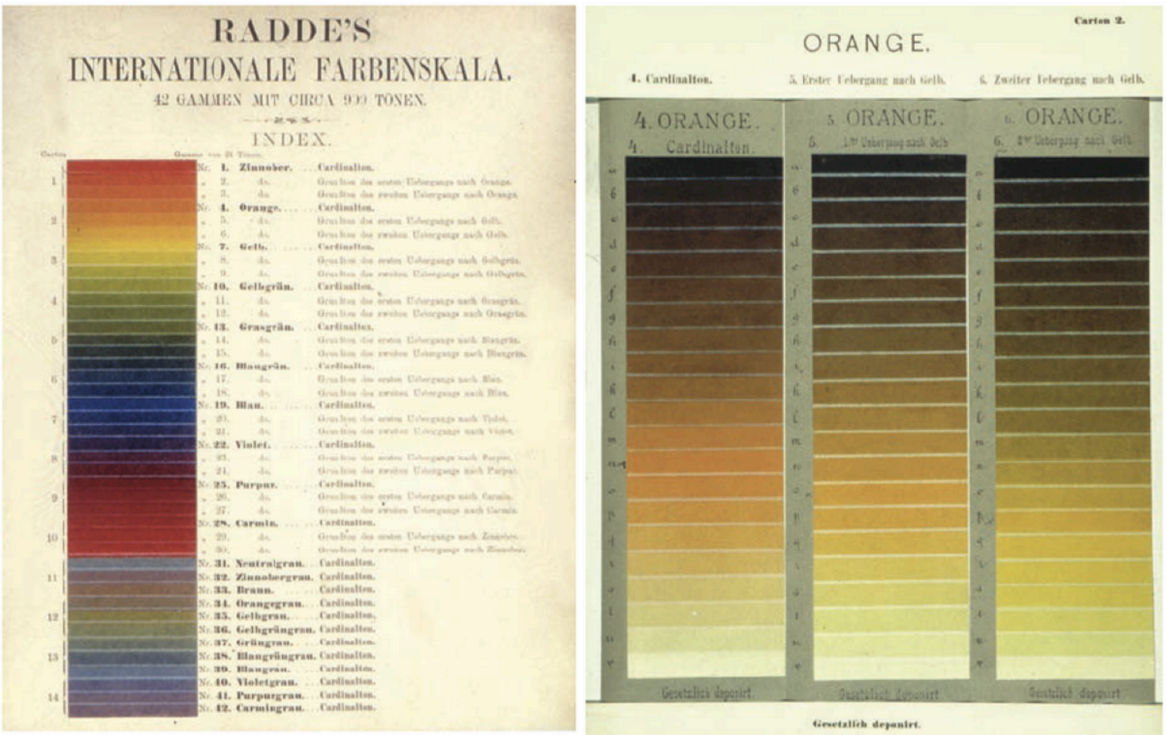

Figure 43 Reproductions of Otto Radde's *Farbenskala*. Source: (Koehni, 2008).

[76] As the next chapter considers Vernadsky's work in detail, I will emphasise the extent of the influence of Wiesner's ideas.

The *Insolator*, the *Lichtflache* and the use of colour charts involve the presence of devices that belong to what Wolfgang Ernst names as "measuring media" (Ernst, 2012, p. 178). With the aid of these, the photographic disposition of plants that stemmed from his methods permitted the distinction of otherwise unperceived natural phenomena, and his image-plants could be seen beyond the visual thresholds of the naked eye, in a similar way to what was happening in the chronophotographic experiments continued by Eadweard Muybridge, Ottomar Anschütz, Étienne-Jules Marey and others.[77] In other words, after their assimilation by the techniques of the image, plants became augmented plants; not only in relation to their size — which they did, too () — but also in relation to the notion of an improved nature able to be brought into new circulations that characterised the techno-scientific complex around life sciences.[78]

Fig. 25. *Lepidium sativum.* Aussaat am 9. Mai. Aufnahme am 20. Juni. *a* bei L = 1, *b* bei L = $\frac{1}{4}$ (im ausschließlich diffusen Tageslichte), *c* bei L = $\frac{1}{10}$ (im gemischten Lichte). Samenreife bei *a* am 20. Juli, bei *b* am 13. August, bei *c* am 20 August. $\frac{1}{10}$: untere Grenze des (normalen) Lichtgenusses.

Figure 44 Plants grown under different values of controlled *Lichtgenuss*. Source: (Wiesner, 1907, p. 254).

These tools, then, entailed a common surface condition, a refashioning of the vegetable surface that characterises Wiesner's research as a whole. They explicitly laid the operational surface where the image-plant hybridisation would spread. Of course, this operational surface is the one that I addressed in the first chapter, when describing the large-scale episodes of visual agriculture.[79] Brought to the present day, it can also be observed in relation to the contemporary ubiquity of aerial policing. That is, this operational surface can be linked to the research by

[77] See for instance (McKenzie, 2014, p. 32–33).
[78] For a broader view on this complex, see for instance (Elina, Helm and Roll-Hansen, 2005).
[79] *Lichtflache* are, for instance, also linked to the contemporary circuits of computer vision as when crown-detection algorithms are used in plantation inventories. See (Ke and Quackenbush, 2018).

architect and researcher Hannah Meszaros on “how new methods of imaging and data production have informed eradication policies” practiced through the fumigation of green canopies in the Amazon (Meszaros, 2018, p. 242). Once replaced by the image, the greenness of plants becomes a colour. It can be spread, layered, and also cleared.

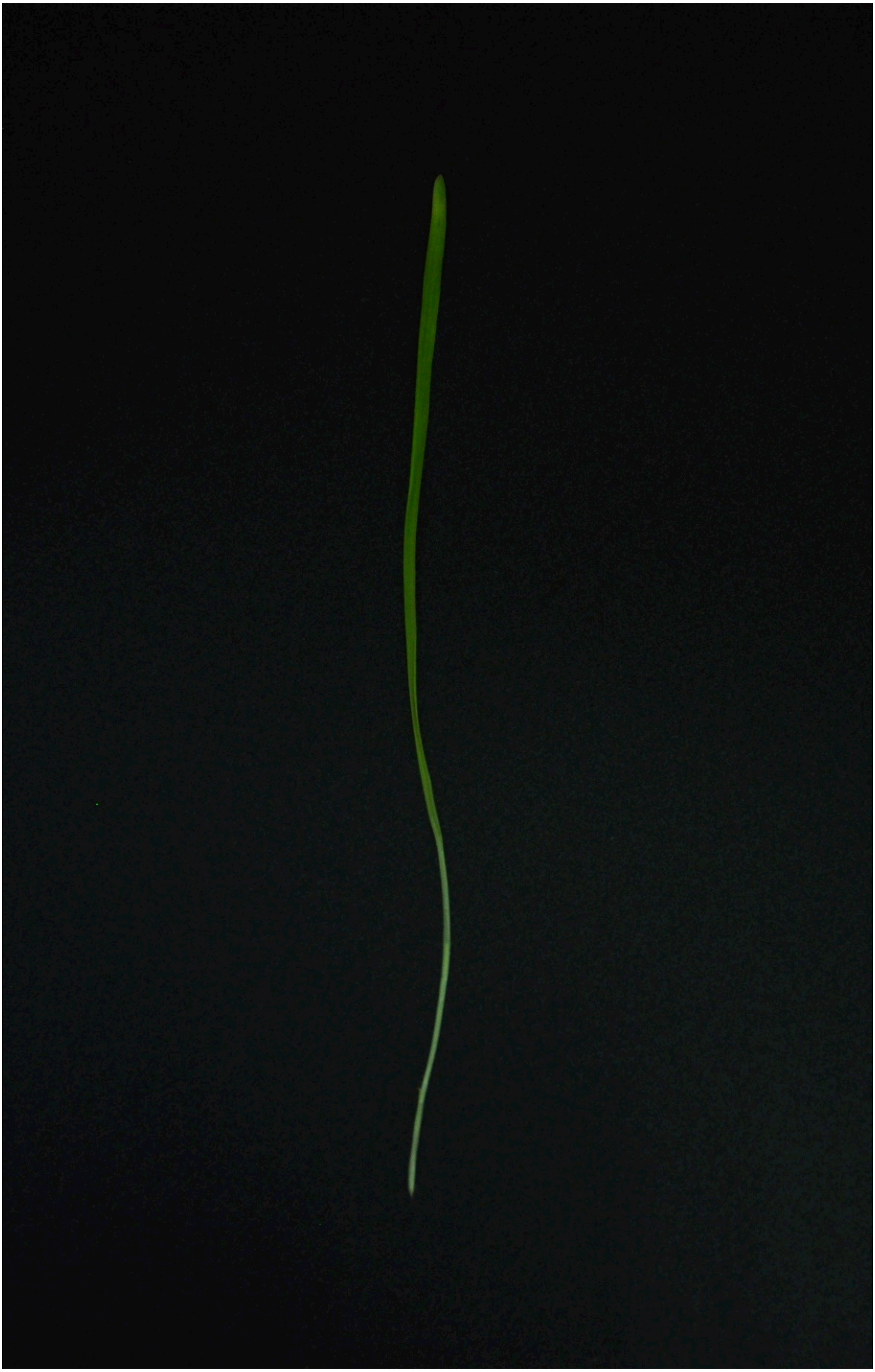

Figure 45 *The Growth of the Eye* [single channel video loop] *(2019)*, detail of a still of the video.

Defoliation 2. *The Growth of the Eye*

2019. Single channel video loop

The Growth of the Eye presents an animation of the growth of a blade of grass. The sequence of the growth is repeated twice. Before each of the repetitions, two placards explain the process followed to build the sequence. First, each of the leaves of a pot full of grass were cut, and individually photographed. Then, all the resulting photographs were ordered following their length and shape[80]. The ordered sequence of images was used finally to produce the animation. The resulting video, with the two placards, is reproduced in loop.

The process deals with two different circumstances at the same time: the impossibility of the existence of a grass of a single blade, on the one hand, and the mowing of the complete pot of grass to build the film of an individual leaf, on the other.

The work, then, addresses the genre of the time-lapse of growing plants in order to establish a relation between two different formations: first, the amplification of the domain of the eye thanks to the chronotechnical space of manipulations permitted by visual media; second, the notion of the individual subject implicit in the anthropomorphic accelerated vision of the growth of a plant. These two coalesce critically in the process of cutting the blades. In this regard, the work emphasises the moment of the physical cut. As the leaf grows in the image, the grass is reduced in the pot. Imaging is blended with its material counterpart.

[80] To do this, I wrote a software program that with the aid of computer vision tools recognised the form of the leaves against the background and ordered them. This could have been done manually, however.

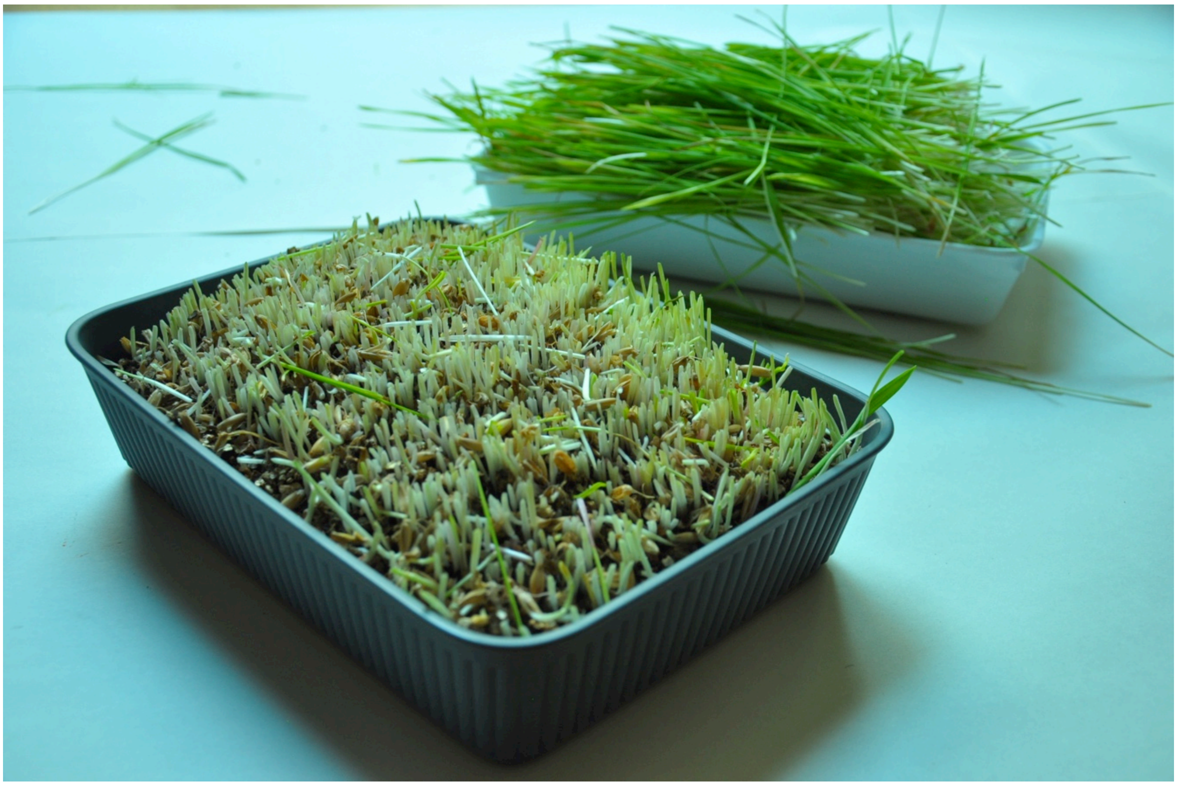

Figure 46 *The Growth of the Eye* (2019). Defoliation process.

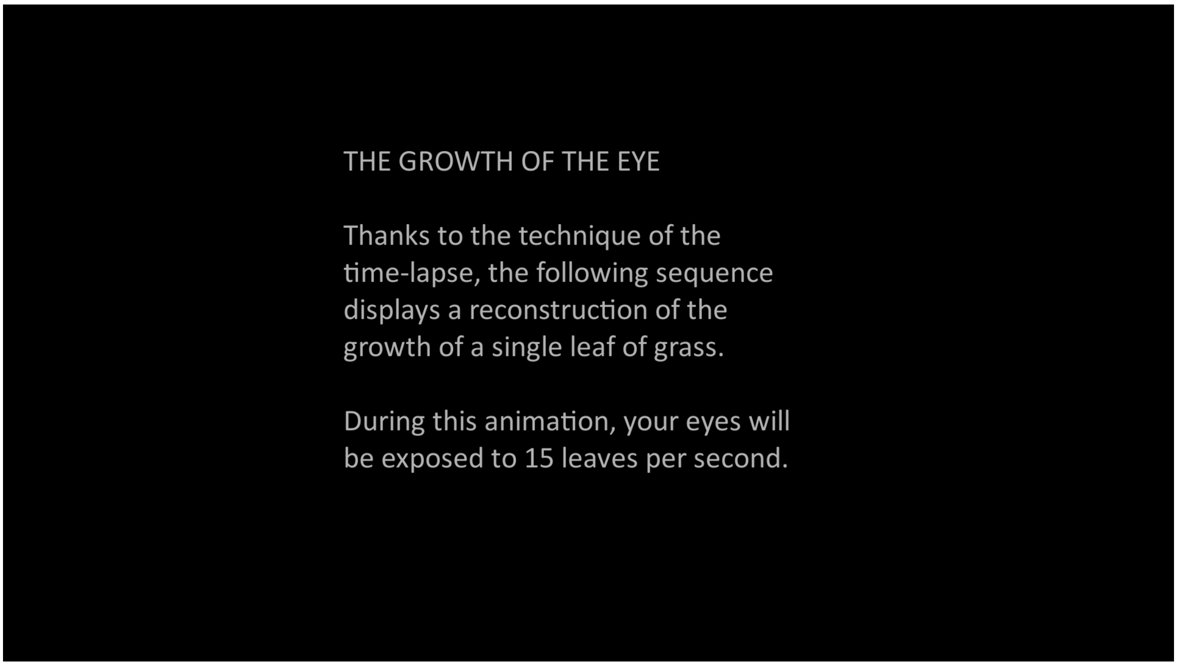

Figure 47 *The Growth of the Eye* [single channel video loop] (2019). Still of the video.

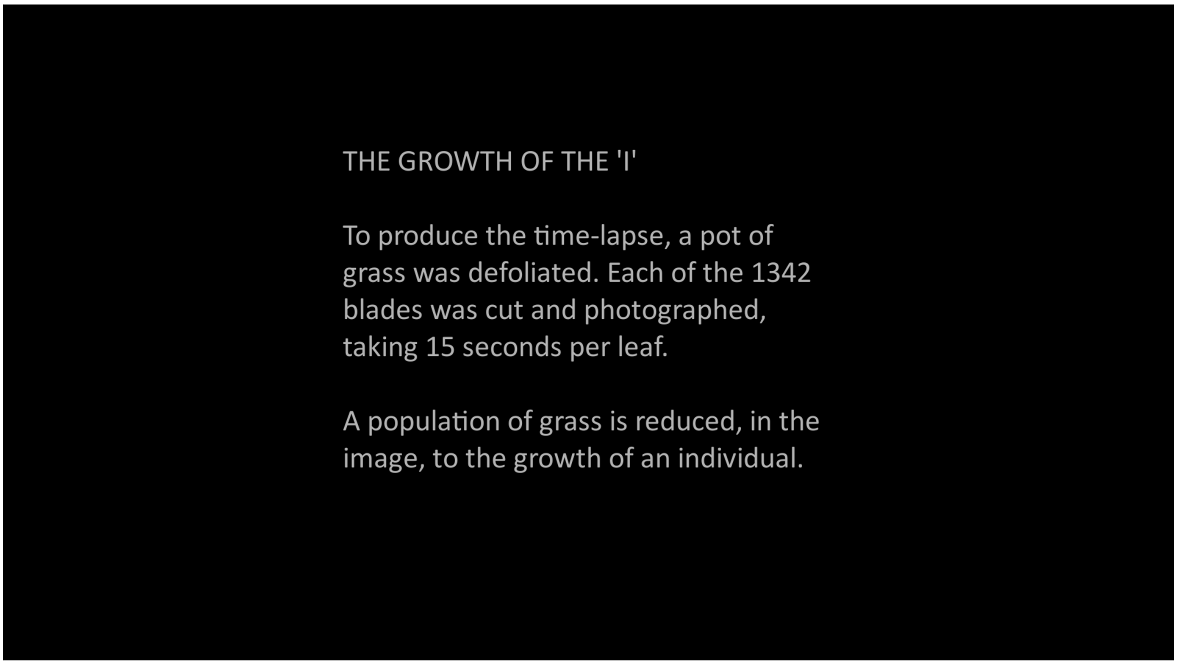

Figure 48 *The Growth of the Eye* [single channel video loop] (2019). Still of the video.

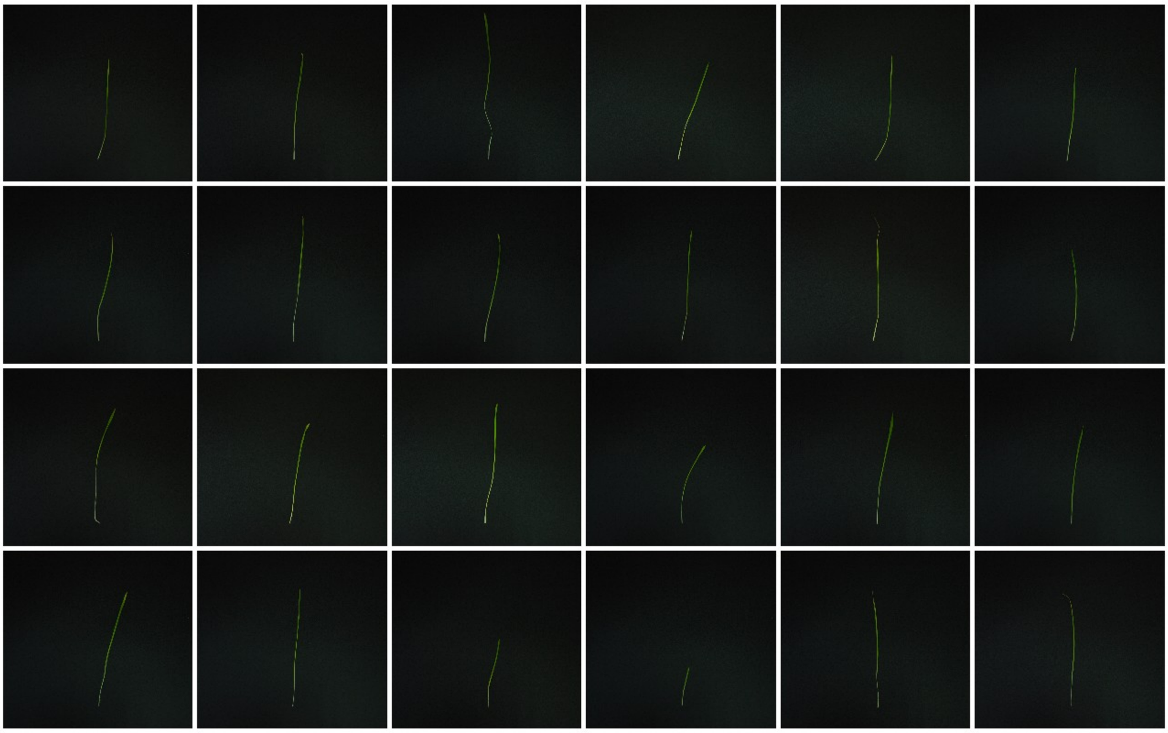

Figure 49 *The Growth of the Eye* (2019). Samples of the leaves of grass.

2.3 The leaf image

Despite Wiesner's systematic and careful work being lauded by his contemporaries, his notion of *Lichtgenuss* and his later observations on the effects of plant light barely outlived him in scientific contexts. Already in 1905 his colleague, the chemist Josef Maria Eder (1855–1944) – well-known for his large volume on the history of photography (Eder, 1905) — stressed a particular limitation of Wiesner's method: it was not able to deal with longer measurements of light, such as the accumulated sunlight received during a day, for instance.[81] Nevertheless, Wiesner's project was focused on the correlation between lighting patterns and the forms and shapes of plants and trees. In the context of this chapter, the interest of his work relies not on the long-term impact of his research, but rather on its value as a cultural marker in the historical and materially contingent understanding of the relation between plants and light. His conscientious practice of linking direct measurements of light with the surfaces of the plant through the notion of *Lichtgenuss* signals a perception of its sculpting power in relation to the formation of plants that pervaded the decades around the turn of the century and which was later, as discussed in the next chapter, up-scaled to the planetary surface.

So far, the experimental relation between plants and light has been observed through a series of photographic techniques related to the measurement of the sensitivity to light. I have shown how Wiesner's notion of *Lichtgenuss* allowed him to unfold a series of experiments practiced on the surfaces of plants. Photography involves sensitive papers as well as the careful control of the surrounding conditions. As I will show next, plants were also introduced in darkened spaces, immersed in liquids and exposed to precisely tuned frequencies of light for their reactions to be observed in photographical terms. Thus, in the experiments that will be reviewed, the implicit operationalisation of plant behaviour in terms of photographic development will be unveiled once again. In addition to the practices of Julius Wiesner, the spectroscopic ones by Russian physiologist Kliment A. Timiryazev will also be scrutinised — in both cases, the practices reviewed will be analysed in relation to crucial experiments in the domain of 18^{th}-century photochemistry. Light became a material enabler due to the photochemical space of interactions with matter. In the next series of experiments in the domains of photochemistry and plant physiology photographic techniques will play a crucial role once more.

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[81] As Wiesner himself recognised in the introduction to the compilation of his *Lichtgenuss* studies, he only focused on the chemical intensity of light (Wiesner, 1907, p. iii), thereby leaving aside other factors at play, such as its duration. He missed out important phenomena, such as photoperiodism, or the influence of the length of daily light periods upon the growth of plants (Kellerman, 1926).

2.3.1 Environments of controlled light

One of Julius Wiesner's contemporaries, the already mentioned Russian plant physiologist Kliment A. Timiryazev, proposed to the British audience gathered for the occasion of his Croonian Lecture to think of his lifelong work in terms of one of the open questions formulated by Newton in his *Optics* book: "why may not Nature change bodies into light and light into bodies?" (Timiryazev 1904, p. 461). The question alluded to the discipline of Photochemistry, whose methodologies Timiryazev had worked with in relation to the study of the assimilation of light by plants. Photochemistry names the practices and theories on the chemical transformations of matter due to the action of light. Notably, in its laboratories, even before the establishment of modern chemistry by Lavoisier,[82] experiments were pursued either with photosensitive materials or with the living surfaces of plants. A material space of surfaces reactive to light gathered together applications and practitioners from a wide variety of fields. While their projects differed, they all shared a similar stance on the active abilities of light. "Light acts chemically on bodies", Nicéphore Niépce explained in a letter, "it is absorbed, it combines with them and communicates new properties to them" (Niépce quoted in Mckenzie, 2014, p. 16).

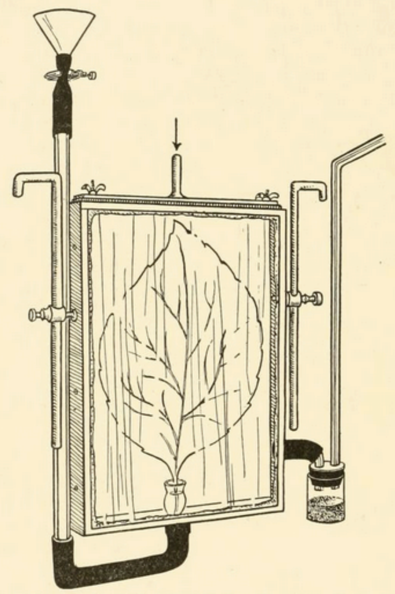

FIG. 16.—Container for excised leaf used in experiments on photosynthesis and respiration. The petiole of the leaf is in a nutrient solution the level of which can be adjusted. The air-stream enters at the top, leaves at the lower edge of the frame, and is dried over P_2O_5 before passing to the absorption tubes.

Figure 50 Bottled sunshine: a container designed to measure the exchange of gases during photosynthesis (Spoehr, 1926, p. 250).

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[82] The laboratory of Swiss Jean Senebier is an example of these, as he systematically examined the effects of the incidence of light on a variety of surfaces such as plant leaves, fruits, flowers, wood, minerals and other substances.

Incidentally, Louis Daguerre, the recipient of Niépce's missive, went further and proclaimed to have "seized the light" with his daguerreotype (Daguerre quoted in Mckenzie, 2014, p. 15). The arresting of light was one of the topics that Timiryazev's lecture dealt with, specifically regarding the measurements of the efficiency of plants when extracting energy from them. As a matter of fact, in the opening of his speech, he described himself as "staring at a green leaf in a glass tube, and breaking [his] head in vain endeavours to clear up the mystery of 'bottled sunshine'" (Timiryazev, 1904, p. 424).

Beyond the energetic dimension of the plant-light interaction, which will be commented on in the next chapter, Timiryazev's image of the physiologist observing the reactions of a leaf inside a glass tube addresses a space of experimental practices where plants were not explicitly manipulated but their surroundings were. Interestingly, before the plant physiologists, chemists had profusely explored this space; the same chemists, in fact, that had contributed to the developments of photochemistry in relation to photography, as the above-mentioned Josef Maria Eder had put it in his *History of Photography* (1905). As I will show next, this space of practices did not involve the manipulation of plants or substances, but the arrangement of carefully controlled environments of light.

For this purpose, an illustrative case by a renowned Swiss natural philosopher, Charles Bonnet (1720–1793), will be addressed next, due to its explicit photographic nature. In 1779, Bonnet analysed the movements of plants with a device distinctly akin to a *camera obscura* (Figure 51). Inside a closed box with a shutter built into one of its walls, he introduced a vase filled with water with two bean seedlings placed oppositely and tied downwards. He observed that when the shutter was closed, each seedling reoriented upward towards the nearest wall. When the shutter was raised, however, both seedlings reoriented toward the opening, as if they had sensed the light (Whippo, Hangarter, 2006, p. 1,111).[83]

[83] Or in Bonnet's interpretation, the warmth of the sunlight (Whippo, Hangarter, 2006, p. 1,111).

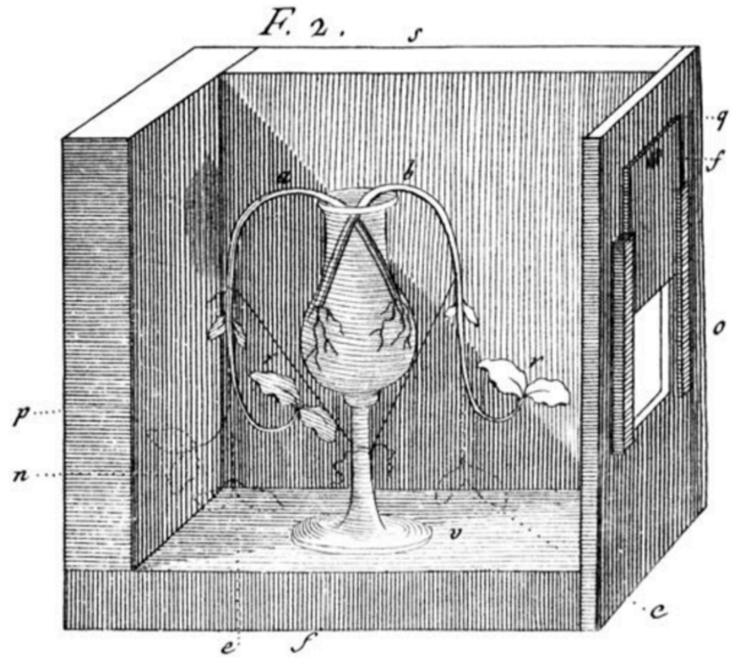

Figure 51 An experiment by Charles Bonnet on tropism, in 1779 (Whippo, 2006, p. 1,111).

Remarkably, more than one hundred years later, Julius Wiesner repeated a similar experiment on phototropism, albeit on a different scale. He placed a ten-year-old lime tree inside a corridor with high ceilings in his research institute in Vienna, covering the windows by the tree and, over several years, observed its growth in the darkened environment which was only affected by the light of nearby windows that the bright floor and walls reflected back. In contrast to Bonnet's, Wiesner's experiment did not make use of a shutter, although his set-up did involve precise control of the environmental light as it inverted the usual lighting conditions: in the darkened space, light came mainly from below, instead of above. As he observed and pictured (Figure 52), the new branches that had developed grew downwards (Wiesner 1907, p. 106); following Wiesner's design, light sculpted the tree. Like in Pfeffer's experiment with the clinostat, this resulted in an utterly unnatural growth, as the tree grew downwards. While Pfeffer's clinostat can be read in relation to the mechanism of the time-lapse, Wiesner's darkened corridor appears clearly as a large-scale *camera obscura*. Wiesner scaled-up Charles Bonnet's experiment, and kept a corridor closed for several years, and, during this time, as a slowly sculpted photograph of vegetable matter, light developed the tree. In some respects, he produced a photograph: he prepared the image of the tree downwards, and let the light develop it.

Figure 52 A photograph of a photograph. The picture taken by Julius Wiesner displays a tree, inside a light-isolated corridor in the *Vivarium*, whose branches grow downwards because of the absence of zenithal stimuli (Wiesner 1907, p. 106).

2.3.2 The living image

The final experiments that I will consider next will take into account the important role the media practice of spectroscopic research also played in the plant physiology of Wiesner's time. Through spectroscopic research I am addressing those experiments where the central instrument is a prism which, when interrupting the linear path of a ray of light, is able to visually separate the different frequencies contained by it. By means of this, the rays of light can be observed as a compound whose signature is precisely the spectrum that results from this technique. Since the

1860s, spectroscopy became an essential tool in chemistry as well as in other disciplines (Hentschel, 2002). Materials of different chemical composition were observed to reflect light or to emit it — when hot enough — with distinct spectral lines. These lines thus became the signature of the presence of certain elements, turning spectroscopy into a sort of visual prospective technique.

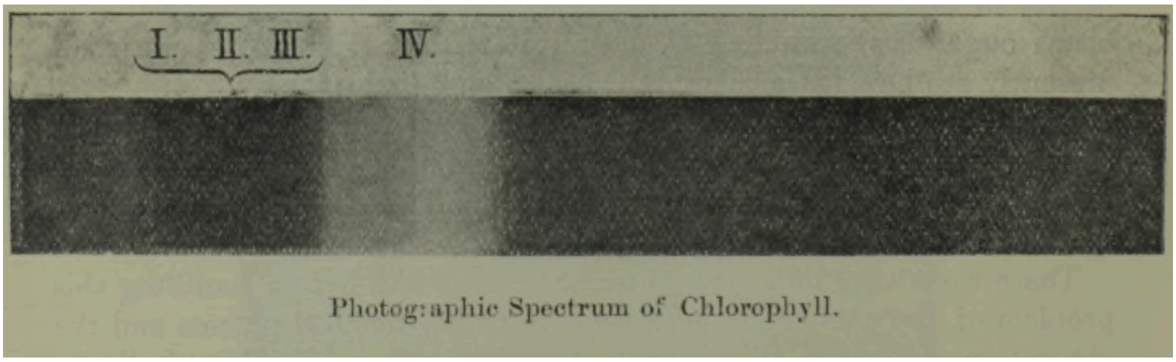

Figure 53 Photograph of the spectrum of chlorophyll obtained by Timiryazev in 1892 (Timiryazev, 1904, p. 430)

If Wiesner can be deemed an expert in technical microscopy, in the domain of spectroscopy the above-mentioned Kliment A. Timiryazev was recognised as one of the leading figures — for instance, he was the first to obtain a photograph of the spectrum of chlorophyll (Figure 53). Leaves were shown to reflect light rays that contained frequencies in two distinct bands: the green one, as expected, and a fainter one, in the red zone — close to the left border (Figure 53). This was already known: plants are not only green, but rather the colour composition of the light they reflect is a mixture of green and red. By using photographic techniques to register their spectra, however, Timiryazev sought to obtain more precise measurements of these two bands. Interestingly, in parallel to the standard camera-less registering of the spectral lines, he also carried out a series of different experiments where plant leaves were used directly as photographic surfaces.

To do so, he first remade a classic experimental set-up proposed initially by the chemist Jean Senebier[84] (1742–1809), contemporary of the aforementioned Charles Bonnet. The Swiss experimentalist immersed a plant leaf in a glass filled with water and observed how the green areas became gradually covered with small bubbles, thereby visualising the emission of oxygen by the plant. Timiryazev repeated this set-up in a dark room, projecting the rainbow colours of the

[84] Highly influential in the maturing of both photochemistry and plant physiology (Eder, 1905, p. 124), Senebier's practice can be described as the careful installation of leaves and chlorophyll solutions in altered environments from which to observe and measure the effects on their reactivity to light. In this vein, leaves were submerged in liquids such as water, alcohol and tints and then exposed to light (Senebier, 1782).

full spectrum of sunlight to the surface of the leaf. Oxygen bubbles were only produced in the red and green regions where the colour was able to activate the photosynthesis. That is, the bubbles formed a picture of the spectrum of chlorophyll.

Next, the leaf and the photographic surface were merged together in a more explicit way in a second experiment, where the spectrum was printed on the leaf directly. To do this, instead of immersing a leaf in water, he enclosed it in a dark box for a whole day. Leaves generate a thin layer of starch where photosynthesis is produced, which the plant uses as a reserve. By keeping a leaf in the dark he guaranteed that all the starch would be consumed and cleared from its surface. He then projected the spectrum of the sunlight on the leaf. Photosynthesis occurred, but only in the bands with the appropriate frequency, and starch was produced, as a consequence, only over those bands. He then 'developed' the latent starch image on the leaf with an iodine solution, known to colourise the areas with starch only. After the iodine bath, the leaf displayed its own spectrum, as if the sun had photosynthetically printed it on its surface (Figure 54).

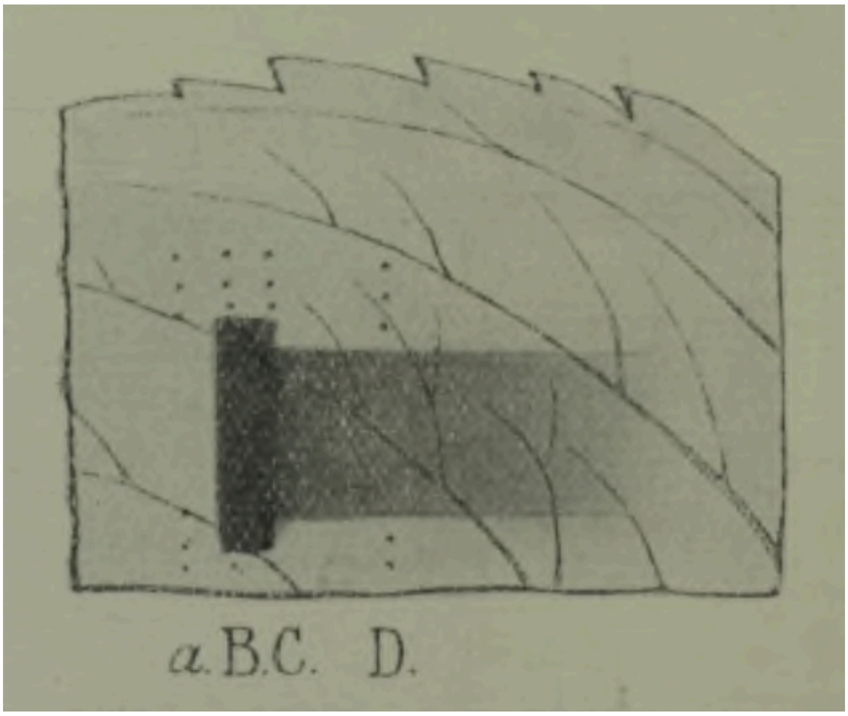

Figure 54 "In other words, a spectrum of sufficient intensity, projected on a living leaf previously depleted of its starch, will impress in this leaf an invisible image of the chlorophyll absorption spectrum formed of starch grains. This latent image may be developed by the iodine test." (Timiryazev 1958, p. 434).

Literally, the leaf had become the photographic surface in this experiment. Interestingly, Timiryazev printed the spectrum of chlorophyll on it.[85] Thus, the picture, in some sense, conjured up the idea of self-portrait, or, in a broader sense, the concept of reflexivity as it is addressed by N. Katherine Hayles, that is, as recursion: “Reflexivity is the movement whereby that which has been used to generate a system is made, through a changed perspective, to become part of the system it generates” (Hayles, 1999, p. 8). This turns the leaf-image into a second-order, a self-referential process, such as the ones media theorist Thomas Macho demands for a cultural technique to be defined as such: “Cultural techniques differ from all other techniques through their potential self-referentiality, a pragmatics of recursion” (Macho, 2013, p. 31). As emphasised continuously in the chapter, the photographic approach to plant phenomena carried out by these plant physiologists did not only seek to observe vegetable growth, but to refashion it in photographic terms. In this vein, this last experiment by Timiryazev needs to be understood not in terms of a probationary inquiry, but as a demonstration. A phatic demonstration of a viewpoint shared by an experimental community of plant physiologists that merged together two different photochemical sensitivities to light: one of vegetable matter and one of chemical-sensitive surfaces in photography.

In this chapter I have shown the relation established by a community of plant physiologists at the turn of the 20th century between the photographic formation of images and the vegetal formation of matter. It has been made clear that this was proposed as an experimental context of practices that operationalised this interweaving beyond mere comparative parallelism. As a result of these experiments, as it will be shown in the next chapter, plants as living images were ready to be circuited to the up-scaled planetary circulations of image flows that have characterised global economies since the early decades of the 20th century. Photomedia entered laboratories and the instruments of early plant physiologists to give rise to notions and categories that belong to a techno-scientific corpus that has shaped and regulated, since then, the production and growth of most of the planet’s vegetable cover.

[85] Vegetable surfaces could be used to develop any image. As a matter of fact, a British botanist and contemporary of Timiryazev performed the same experiment but developed a negative instead (Gardiner, 1889, p. 163). Remarkably, the picture did not display any human — or animal — subject again: the botanist chose instead to develop a negative that had captured a swarm of flagellated zoospores of an alga; that is, vegetal seeds with locomotive power.

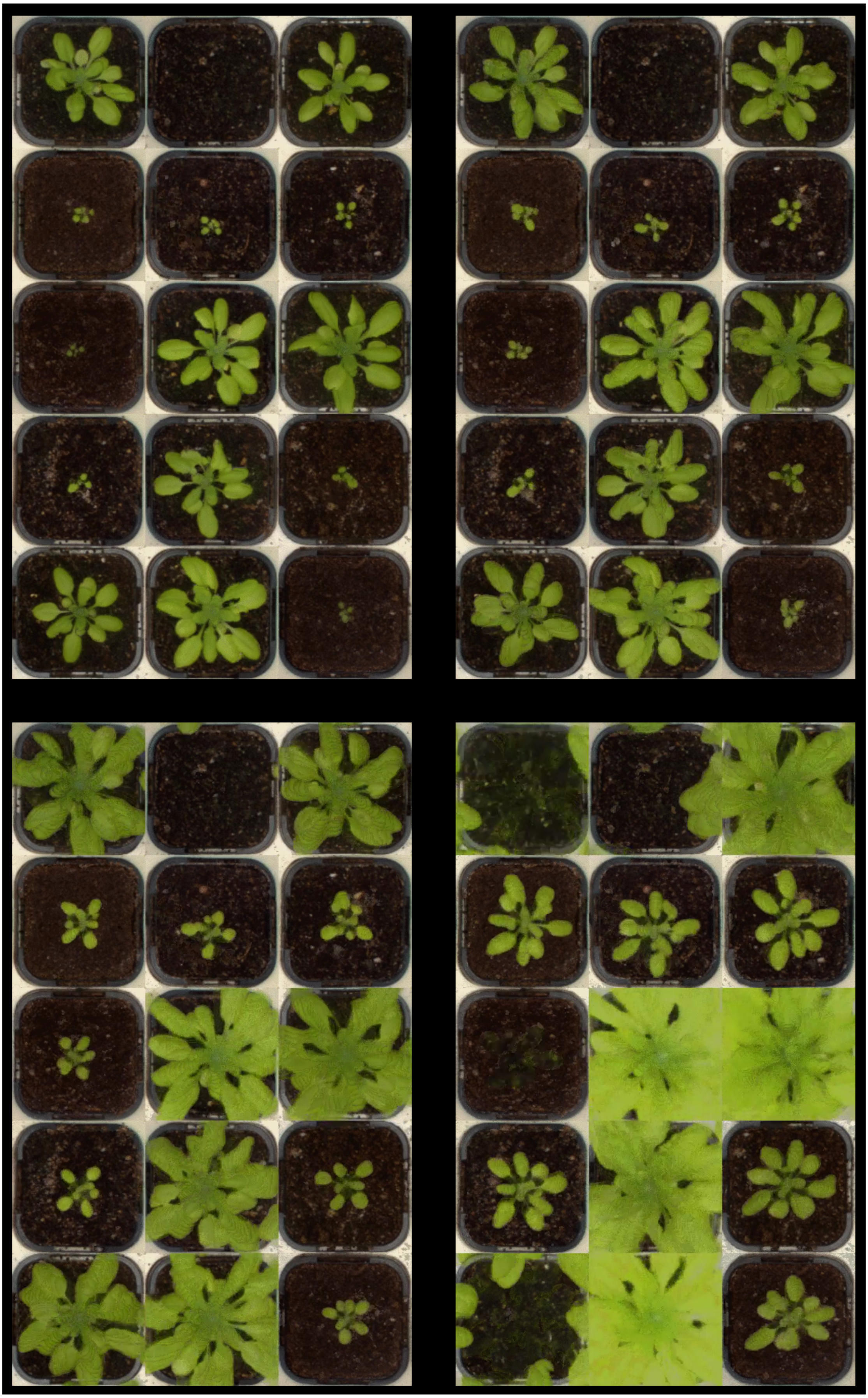

Figure 55 *An Earthology of Moving Landforms.* Machine learning based video prediction of the growth of plants.

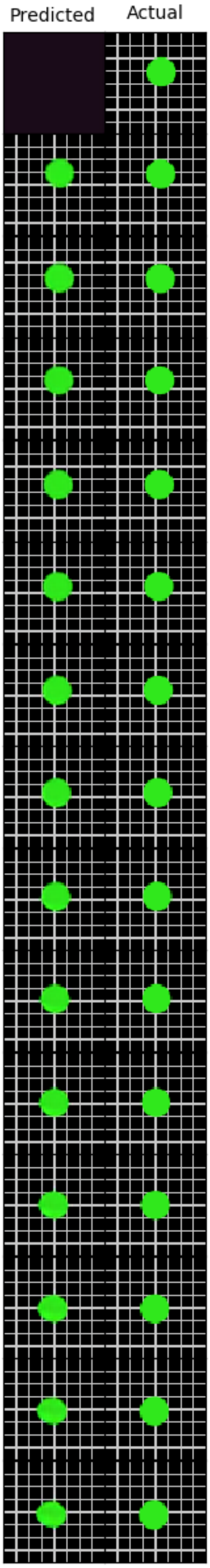

Figure 56 *An Earthology of Moving Landforms.* Demonstration of machine learning based video prediction of a simple animation.

Defoliation 3. *An Earthology of Moving Landforms*

2018-2019. Workshop series

The third project presented in this chapter is not an installative piece but a workshop held first in *Transmediale* in Berlin[86] and then repeated in the Linz festival *Art Meets Radical Openness*. The workshop proposed to examine the use of video prediction techniques based on machine learning to analyse time-lapses of archived satellite imagery in order to speculatively generate future images of the surfaces of the Earth.

The technique employed was the so-called Next Frame Prediction, that is, the experimental set of machine learning techniques aimed to algorithmically produce the frames that follow a given video sequence. This approach to video-prediction makes use of convolutional neural networks that, relying on large databases of images and videos, are able to identify temporal patterns and behaviours within a sequence of frames. This analysis provides them with the capacity of predicting the continuation of movements in the image and, consequently, of extending videos with plausible futures.

The project was devised to make participants face the large amount of visual material needed for these models to be operative. In order to predict for instance the evolution of an on-going deforestation, a collection of thousands of sequences of previous deforestations needs to be gathered first. The workshop evidenced in this regard the scale of the visual greed of these systems, where a particularly extractive gaze is at play. Moving landforms needed to be identified first, and then gathered in datasets. The surfaces of the world thus were classified in cinematic terms: rapid oscillating river meanders, drifting glaciers, crawling dunes or growing cities, for instance, are examples of these.

In order to demonstrate the ability of these models to predict surface movements, I generated videos displaying the predicted growth of plants (Figure 55), waves in a beach or walking pedestrians in a street. To achieve similar results at the environmental scale, however, involves a vast infrastructure. The object of the workshop was precisely to get a sense of the scales of this visual geo-engineering.

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[86] In Transmediale, this workshop was presented as the practice-based part of a longer one, *Surface Value, Landscape Prediction: An AMT Workshop* proposed and conducted by Jussi Parikka, Michaela Brebenel, Ryan Bishop and myself.

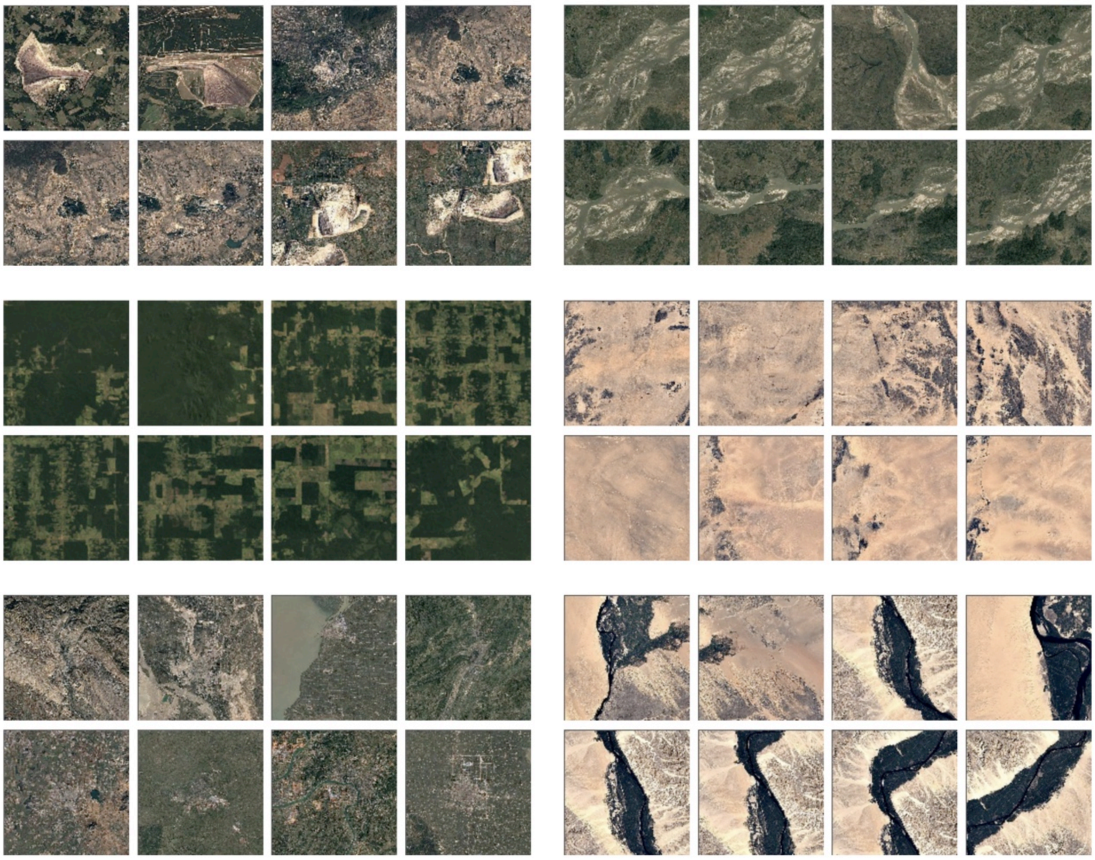

Figure 57 A collection of samples of some of the datasets of planetary surface behaviours used in the workshops. Clockwise, starting top left, they show: brown-coal mines, meanders of the Ganges river, dunes in the Sahara desert, the agricultural lands by the Nile riverside, cities in China and deforestation in the Amazon.

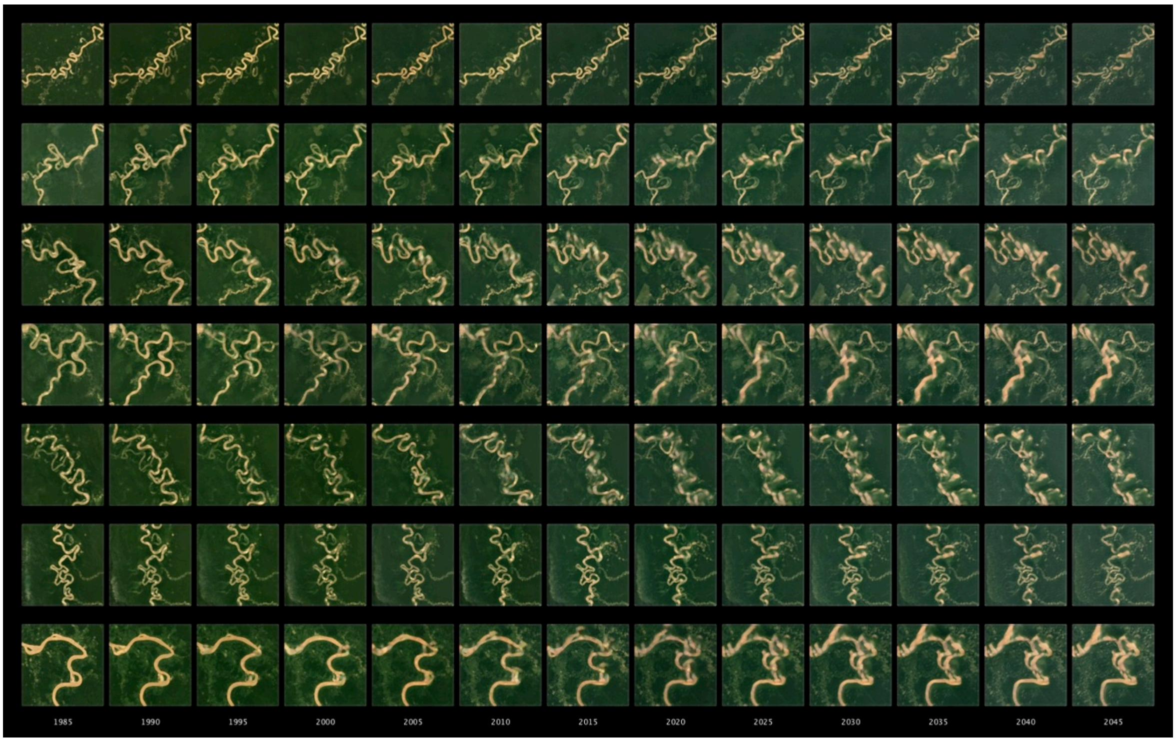

Figure 58 A series of predictions of the movements of the fast meandering Ucayali river in Perú. Some of these sequences display predictions that clearly "fail", as the river seems to dissolve itself and loose its continuity. This is related to the relatively small size of the datasets. The failure, however, is visually interesting: a visual accident becomes a reminder of aerial images of floodings and rivers out of control.

Chapter 3 The Planetary Living Image

3.1 Introduction. Scaling up

The first chapter of this research demonstrated how an episode of large-scale agriculture in Spain during the second half of the 20th century can be understood in terms of operations due to aerial photography, as if vegetable production had been managed from above as a photographic development. The second chapter narrowed the spatial scales and focused instead on a series of experiments in the last decades of the 19th century to show how this photographic condition also characterised scientific developments in plant physiology. In these inquiries, plant growth was measured and categorised through a series of experimental photographic processes. Plants were described as surfaces photographically sensitive to light and thus addressed, experimentally.

In this chapter the transfer between the photographic and the photochemical assimilation of light will be considered from the point of view of the planet contemplated as a whole. The chapter will look at the geochemical notion of the biosphere as Russian biogeochemist Vladimir I. Vernadsky elaborated it. Through the analysis of his work, I will show how his model can be read as an up-scaled form of plant physiology. That is, the biosphere will be presented as a physiology of the Earth's uppermost crust, an interfacial layer around the planet rendered biochemically sensitive as a living film. Therefore, the notions of movement and growth will be escalations of the ones put into play in the photographic relation between plants and light. As a consequence, taking into account the conclusions of the last chapter, the biosphere will concur with the visual in another hybridisation.

In addition, this scaling of the photographic mediated vegetable matter will be analysed as a media theory subject. First, the interaction of the living and the inert at a planetary scale in Vernadsky's approach will be related to the concept of infrastructure as a notion that has acquired a relevant position in media studies.[87] Second, different cultural and material contexts of his research will be brought in to relate this scaling-up to other material approaches to media, such as Giuliana Bruno's notion of the surface (Bruno, 2014) and Jennifer Gabrys' notion of becoming environmental (Gabrys, 2016). Moreover, Vernadsky's subtle analysis of the movements of life at a planetary scale will be related to the power that chemistry had in the industrial complex of his time, as Esther Leslie has expounded (2006). I will show how his upscaling can be read in terms of the refashioning that agriculture was experiencing after its

[87] See for instance (Edwards, 2003; Parks, 2005; Peters, 2015; Mattern, 2015; Rossiter, 2016; Svensson, 2016; Starosielski and Walker, 2016)

assimilation by the chemical industries. Finally, I will relate these vegetal upscalings — Vernadsky's as well as the agricultural — to the advancement brought about by this chemical complex to visual media, as addressed by Michelle Henning (2018). The chemistry of the planet and the chemistry of technical media will be thus presented in a double bind: a chemical interweaving that transported, at the same time, the vegetable covers of the world, as well as the images that measured them.

In this third chapter, then, the photographic nature of vegetable matter as it was outlined in the experimental practices reviewed in the last chapter will be brought up to a larger scale. By addressing the work of Vernadsky, I will show how in this plant-image relation many different contexts coalesced, outside the plant physiologists' practices and spaces. A colonial background of plantations as well as a material culture related to the notion of the globe, for instance, will be considered and linked to this agricultural genealogy of the operational image. As it will be shown, the plant-image, cultivated later in programmes such as the Spanish *Inner Colonisation* and in contemporary practices of precision farming, found in the early 20th century, parallel to the advancement of the chemical industry, a resonant milieu.

3.1.1 Vernadsky's biosphere

In 1926, Russian biogeochemist Vladimir I. Vernadsky (1886–1943) published the book *The Biosphere*, one of the first attempts to describe the ensemble of living processes on the Earth as a whole. Scientific domains such as geology, physics or chemistry[88] had already probed into the problem of creating models of the entire planet. *The Biosphere* was Vernadsky's proposition to analyse, similarly, the phenomenon of life at that scale. To do so, the book relied on the previously defined notion of the biosphere, introduced in 1875 by Austrian geologist Eduard Suess (1831-1914). While the geologist understood it as the planetary envelope that encompasses all life on Earth, Vernadsky added to this definition an interfacial character operating between the Earth and the universe: it became "the envelope of life where the planet meets the cosmic milieu" (Vernadsky, 1998, p. 39). In relation to Suess' one, his definition entailed an organised approach to the activity of the whole, closer to views from the past where the Earth was seen as a living organism.[89] Immersed in a space filled with radiation, in this uppermost layer the planet meets

[88] Examples of these would be *The Theory of the Earth* (1788) by Scottish geologist James Hutton (1726–1797), the series of works on the estimation of the age of Earth by Lord Kelvin (1824–1907) or the dissemination book *Worlds in the Making* (1908) by Swedish chemist Svante Arrhenius (1859–1927), where the greenhouse effect is proposed (Jones, 1990). For other related references in the domains of meteorology and geography, see (Davis, 2016).
[89] As historian of science and expert in the figure of Vernadsky, Jacques Grinevald has observed that this wording is a specific reference to the work of French physiologist Claude Bernard, who characterised the

the incoming electromagnetic flows where they are transformed into free terrestrial energy. For the Russian biogeochemist, then, the biosphere was an active envelope, absent in other planets, which in the encounter with this surrounding "cosmic force" (Vernadsky, 1998, p. 44) gave rise to a differentiation in a variety of chemical, mechanical and molecular forms of work.

In the following pages, Vernadsky's work will be explored in relation to the research in plant physiology that was presented in the last chapter. As shown below, a close reading of his main book, *The Biosphere*, reveals the strong influence exerted by the view on the growth of plants that Kliment A. Timiryazev, Julius Wiesner and Wilhelm Pfeffer had presented before him. If these had dealt with the photochemical growth of the "living substance"[90] in the plant, then Vernadsky addressed instead the biogeochemical multiplication of "living matter"[91] on the Earth, and by doing this, he transferred to the surface of the planet the features and activities that singularised plants in physiologists' studies. In other words, the following sections will present *The Biosphere* as a turn-of-the-century plant physiology of the planet taken as a whole. It is important to emphasise the temporal and vegetal delineations of this physiology, in order not to confuse it with other approaches, such as the influence that the work of Claude Bernard also exerted on the Russian biogeochemist,[92] on the one hand, or the more complex metabolism of living forms that has inspired later models of the Earth,[93] on the other. Vernadsky's work will be presented as clearly related to the photochemical approach that characterised the Central European physiology of plants in the 1900s, even if it had started to become outdated after a set of crucial discoveries in the 1920s.[94]

Taking into account the main argument of the last chapter, *The Biosphere* thus appears as a planetary escalation of a form of living growth that had been measured through camera-less photographic techniques and modelled as such. This turns the biosphere into an interface akin to a biochemical sensitiser that sets up the conditions for the radiation of the Sun to be transformed into the living surface of the planet, as if it developed an ever-changing photographic film. Consequently, the living Earth could be pictured as an imaging planet, both perceived and formed as a constant flow of images, similar to the one sketched by art historian Kaja Silverman in

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living organism as an entity that kept a distinction between the internal and cosmic milieus (Grinevald, 1998, p. 29).

[90] One of Wiesner's books was in fact entitled *Die Elementarstructur und das Wachstum der lebenden Substanz*, or The Elementary Structure and Growth of the Living Substance (Wiesner, 1892).

[91] This concept will be explained and addressed in more detail below.

[92] See note 89.

[93] See, for instance, the notion of geophysiology by James Lovelock, in relation to the work on Gaia that he elaborated together with Lynn Margulis (Lovelock, 1989).

[94] Since the first decade of that century, the role of hormonal circuits as carriers of stimuli information in plants started to be clear. The definitive discovery was the auxin hormone in 1926. See (Whippo, 2006).

relation to Russian filmmaker Andrei Tarkovsky's work: "This oceanic planet [Solaris], however, is our world, and it is through photography –rather than hallucinations– that it speaks to us" (Silverman, 2015, p. 85). In other words, once it is considered as an upscaled elaboration of the photographic-like physiology that has been presented in chapter two, Vernadsky's *Biosphere* can be read as a planetary, camera-less study case of non-human photography, to use Zylinska's terms.

However, rather than pursuing this ontological approach to photography and its relation to the Earth surface's fabric, Vernadsky's escalation is linked in this chapter to what Sean Cubitt has addressed as the finiteness of media (Cubitt, 2017). That is, the consideration of living matter as a whole brings in the fact that when media meet the scale of the planet, they necessarily face its limited resources and temporal scales. This is articulated in Vernadsky's model as a deep interweaving of the living and inert matter in the biosphere. In this vein, and following Vernadsky's arguments, the escalation of the plant surface to the planetary will be described, together with the role played by the inert matter around it.

The Biosphere is a remarkable book in terms of its clarity, scientific erudition and the abundance of illuminating commentaries in it. In spite of this, at the time it wasn't fully appreciated outside the Soviet Union, and it was not until the 1970s that its powerful visions started to be understood and widely vindicated (Grinevald, 1998, p. 20). Among several other reasons that have been suggested for its relative invisibility, [95] the importance assigned in his argumentation to a notion of his own — living matter — has been signalled as an important cause (Khailov, 1994, p. 2). Vernadsky defined the living matter as the total of the living organisms present in the biosphere at a given moment. Unlike other disciplines, Vernadsky's research programme aspired to understand organisms and populations in quantitative relations with their environments: as numbers of atoms, measurements of the space occupied or estimations of the exchanges in energy. This concept was out of the scope of the work carried out by most of his contemporaries, for it understood life outside the standard biological categories of species and individuals. As he acknowledged years later, "a living organism thus acquires an aspect different from the one it has in biology" (Vernadsky, 2005, p. 39).

[95] In addition to the argument in the main text, he didn't succeed in finding the necessary institutional support in the West to carry on his particular holistic research, despite spending several periods in scientific institutions in Germany and France in his early career. As a consequence, most of his work was developed in the Academy of Sciences in Moscow, where he was respected as an international scientist; however, as historians of science Jacques Grinevald and Giulia Rispoli have recalled, his ideas had to face the repressing context of the Stalinist State (Grinevald and Rispoli, 2018).

3.1.2 The Glass Jar Experiment

The previous chapter showed how plants were introduced into the artificial environments of controlled luminosity that make up visual media to observe and measure their relation with light. Charles Bonnet's experiment in 1779, where a plant is put in a *camera obscura* (Figure 59), can be taken as an early example of these practices, which became prominent in the decades that closed out the 19th century. Rather than directly addressing the surface where the light encounters the plant, the theoretical and experimental work examined in this chapter focuses, however, on exploring the consequences of the fact that plants affect and transform their immediate surroundings while they interact with their surrounding radiation. The importance of this phenomenon was immediately coupled with the observation that the metabolisms of individual plants have an accumulative effect, transforming the whole atmosphere as a consequence. The scientific experiment addressed next took into consideration the simultaneity of the transformation of light into vegetable matter and the oxygenation of the planet. As shown below, it faced the fact that these two processes cannot be separated, and that they brought in, necessarily, the planetary scale.

The discovery of the role of plants in the oxygenation of the atmosphere is linked to a crucial experiment in the domain of early chemistry. Parallel to the one published by the aforementioned Charles Bonnet, the British chemist Joseph Priestley introduced plants into one of the most pre-eminent scientific places: the inverted glass jar. In the 17th century, natural philosopher Robert Boyle had performed a series of well-known demonstrations on the production of vacuum. He introduced candles and mice in inverted jars to display how combustion and respiration could be made impossible if an air pump was applied.[96] A century later, Priestley reproduced the same set-up, but adding a plant to it; he first put a candle in the jar, and waited for the combustion to stop due to the consumption of air. Guaranteeing that no gas entered the jar filled with the remaining "noxious air"[97] after the combustion, he then introduced a sprig of mint and observed how, in a matter of days, the plant "restored the air" (Priestley, 1775, p. 50). To wit, the plant was observed to regenerate the necessary gaseous composition so that it "would neither extinguish a candle, nor was it at all inconvenient for a mouse" (ibid).

[96] As the well-known book by the historians of science Steven Shapin and Simon Shaffer has shown in detail (Shapin and Shaffer, 1985), the inverted glass jar with candles inside or connected to an air-pump succeeded in the 17th century in becoming the model of legitimate production of science — based on the value of systematic experimental practices — after a public struggle between experimentalist Robert Boyle and natural philosopher Thomas Hobbes.

[97] Carbon dioxide, as it was addressed by Priestley (Priestley, 1775, p.89-90).

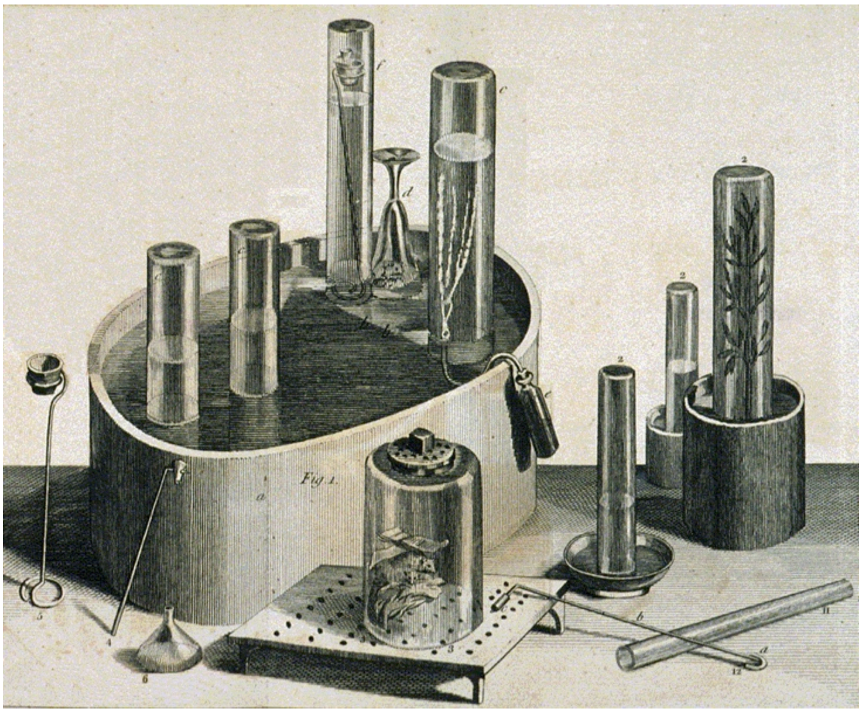

Figure 59 Cover image of Priestley's *Experiments and Observations on Different Kinds of Air* (1786), displaying plants and mice inside glass jars.

The air in the glass jar addresses a space that was not considered in the experiments reviewed in the last chapter, where the object of research was the interaction between the surfaces of leaves and light. Here, instead, it is the air surrounding the plant that appears in the foreground in Priestley's set-up. The photosynthetic activity of the plant is shown to rely on gaseous resources, which the air provides to the plant. The air, in this sense, appears as the elemental medium for the plant-light interaction, co-existing with the plant as a material enabler or, using Eva Horn's words when addressing the topic of air as medium, as its "condition of possibility, its 'infrastructure'" (Horn, 2018, p. 9). As the experiment shows, moreover, the plant does not only rely on it, but alters it and brings it into the gaseous equilibrium that best fits the plants themselves, as well as other forms of life. Seen from this point of view, the local composition of gases inside the vase can be understood as a microclimate, and this allows the experiment to be analysed in relation to the discussion that Horn undertakes on the feedback loops that characterise the coupling between climates and cultures. Following Horn, every microclimate instances the larger domain of possibilities of differentiation entailed by the planetary dimension of air. She then uses Ursula K. Heise's words to refer to the fact that the "sense of place" inside the jar would also be a "'sense of planet,' a medium of relations and differences" (Horn, 2018, p. 12). In other words, the air in the jar is produced as a link, built up as a locally elaborated reference to other jars and spaces, adding the planetary scale of the atmosphere to the material context of the experiment.

Interestingly, the ability of a plant to modify its surroundings locally, in such a way that other forms of life can benefit from it, was immediately understood by Priestley and his contemporaries as a phenomenon of global scale. In Priestley's words: "This observation led me to conclude, that plants, instead of affecting the air in the same manner with animal respiration, reverse the effects of breathing, and tend to keep the atmosphere sweet and wholesome" (Priestley, 1775, p. 86). Put another way, he took the inverted jar as a valid model for the atmosphere as a whole, and induced that plants exist in a mutual relationship with other forms of life, by cleansing and purifying the atmosphere. "In this the fragrant rose and deadly nightshade cooperate", commented one of his contemporaries,[98] acknowledging their accumulative effect (Timiryazev, 1956, p. 395). The enormous production of carbon dioxide by animal breathing and other sources could thus be counterweighted by a different planetary agency. Understood in relation to their interaction with the atmosphere, the ensemble of plants, "the immense production of vegetables upon the face of the earth" (Priestley, 1775, p. 93), could be considered responsible for the equilibrium in the atmosphere.

3.1.3 Planetary infrastructures

In Vernadsky's biosphere, like in Priestley's jar, a shell of inert matter — gases above, rocks below — encloses the living surface. The photosynthesis of the green component of living matter requires a gaseous background from which to absorb and secrete, as well its chemical sources and wastes. In Vernadsky's words, the movement of life can occur "only through a gaseous exchange between the moving matter and the medium in which it moves" (Vernadsky, 1998, p. 61). One could think, then, of this inert matter as a sort of infrastructure of the living. Its scale would initially recall Paul N. Edwards' words, "nature is thus in some sense the ultimate infrastructure" (Edwards, 1998, p. 196). In this case, however, the role played by the inert with respect to the animated can be related more precisely to the contemporary characterisation of soil as a bioinfrastructure that feminist science studies scholar Maria Puig de la Bellacasa has proposed. Indeed, as historians of science Jacques Grinevald and Giulia Rispoli have observed, Vernadsky's project was inspired by the analysis of soil as a "global natural object" that his mentor, geographer and mineralogist Vasily V. Dokuchaev, had elaborated (Grinevald and Rispoli, 2018). Dokuchaev understood soil as an entity affected, at the same time, by factors of different categories, including chemistry, climate, geology as well as biotic and anthropogenic factors. His pedology turned soil from a static physicochemical background into an active and evolving "natural body" (Dokuchaev, 1879, p. 46) whose agricultural fertility was in direct relation to the

[98] The president of the Royal Society, on the occasion of the Copley medal to Priestley.

"reciprocal activity of the living and dead agents" (ibid) that composed it. These agencies constitute what Puig de la Bellacasa names the "world of invisible labours" that maintain an infrastructure in operation.[99] That is, Dokuchaev's approach can be understood to entail the "infrastructural disposition" (Parks and Starosielski, 2015, p. 8) that unveils invisible enabling conditions which, when brought to the foreground, disclose underlying relations, contingencies and scales operating over ground.

Therefore, inert matter can be approached as the terrestrial infrastructure of Vernadsky's living surface. Yet this bioinfrastructure needs to be understood, in turn, as being reciprocally adapted, transformed and shaped by the living surface it hosts. As Priestley's experiment showed, green matter, for instance, is responsible for the oxygenation of the atmosphere; the fact that life needs to be protected from the otherwise excessive radiation of the Sun is another telling example. Unfiltered light, such as the one experienced in outer space, is a lethal agent: no form of life is able to survive the effects of certain ultraviolet components of its spectrum.[100] In the Earth, the ozone layer is responsible for this radiation not reaching the surface of the planet. Significantly, it was Vernadsky who proved, with geochemical data, the theory[101] that the totality of the ozone in the atmosphere had a biotic origin (Oparin, 1957, p. 157). That is, in the biogeochemist's model, it is not only that living matter keeps apt environmental conditions, but it creates its own shielding jar as well, the "ozone screen" (Vernadsky, 1998, p. 120).[102]

"Environments, like media", writes John D. Peters, "are delicate systems of contingent conditions for the organisms that live in them" (Peters, 2015, p. 47). They constrain and modulate the forms of life they enable, and are, recursively, transformed and even constructed by these same life forms. The ozone is an interesting case in relation to the double bind between living and inert matter that characterises Vernadsky's biosphere. It clearly shows that inert matter could be taken as the infrastructure of the living, but at the same time it reciprocally shows how the living could also be taken as an infrastructure of the processes of circulation and regulation of inert shells of matter in the planet. In other words, despite his insistence on differentiating inert from living matter, none of these two systems in *The Biosphere* is privileged. This substantiates what Bruno

[99] See in this vein (Star, 1999).
[100] This started to be acknowledged after a crucial experiment by French physicist Henry Becquerel in 1910, the consequences of which were particularly sound in the context of the discussions around the possibility of interstellar origin of life (Oparin 1957, pp. 59–69). In Vernadsky's words, "interplanetary space, where these rays are present, is inaccessible to all forms of life adapted to the biosphere" (Vernadsky 1998, p. 115).
[101] This idea was proposed in 1856 by Belgian chemist Corneille J. Koene (Oparin, 1957, p. 157).
[102] "The free oxygen necessary for the creation of ozone is formed in the biosphere solely through biochemical processes, and would disappear if life were to stop. Life creates both the free oxygen in the Earth's crust, and also the ozone that protects the biosphere from the harmful short-wavelength radiation of celestial bodies." (Vernadsky, 120).

Latour has emphasised in relation to the Gaia model: there is no prominence, priority or internal hierarchy among the systems in interaction (Latour, 2017, pp. 111–145). Thus, the biosphere is a compound of mutually enabling conditions. Living and inert matter are interweaved in such a way that, for Vernadsky, it is not even possible to state which came first.[103]

[103] On Vernadsky's relation with the hypothesis on the origin of life: "Throughout geological time, no azoic (Le., devoid of life) geological periods have ever been observed" (Vernadsky, 1998, p. 54).

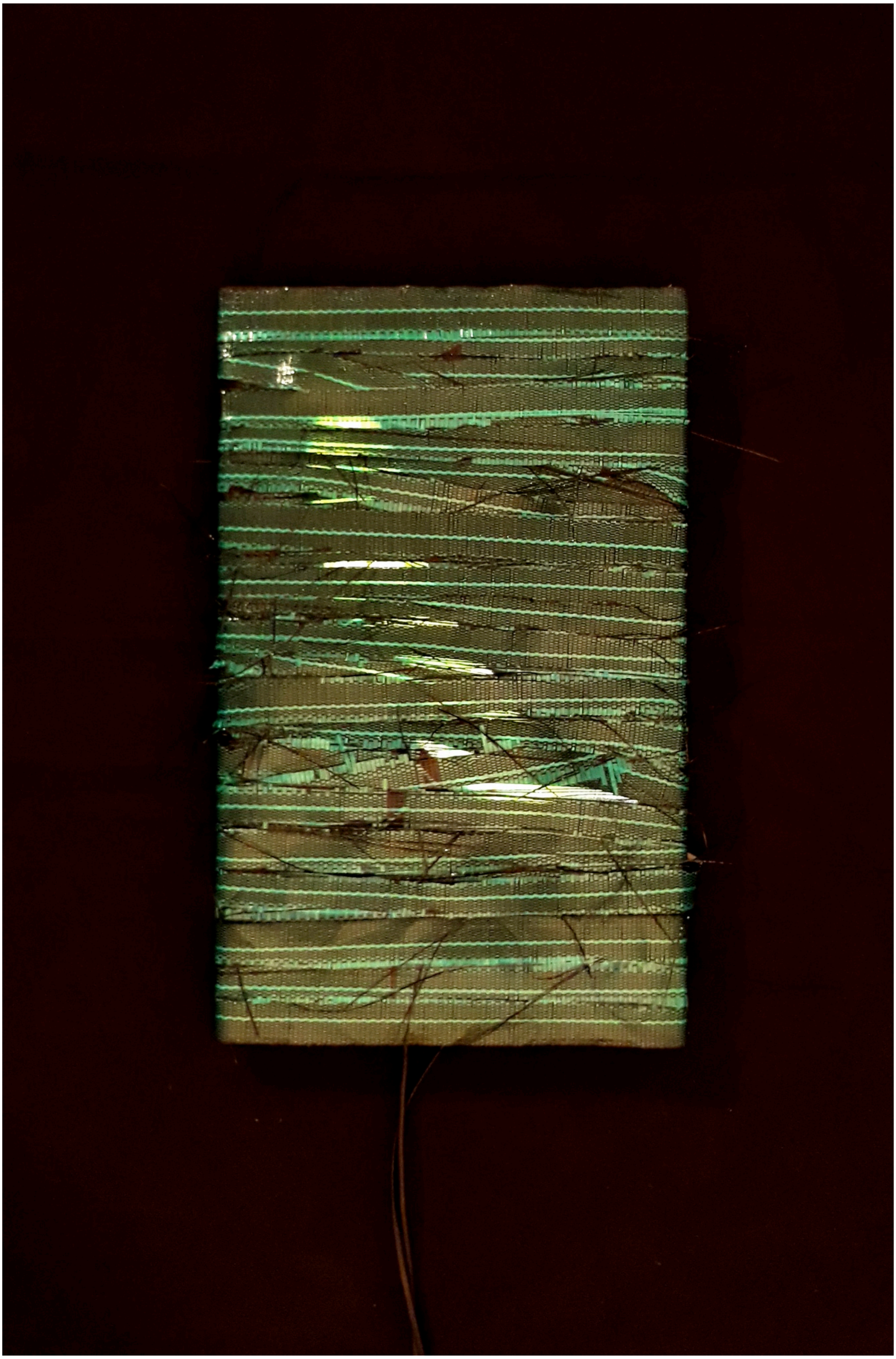

Figure 60 *Still Life with Screensavers and Landscape Fabric* [mixed media], studio installation, Madrid (2019)

Transplant 1. *Still Life with Screensavers and Landscape Fabric*

2019. Mixed media. Monitors, custom plastic wraps. Variable dimensions.

Agriculture is also a practice of enveloping. Beyond the greenhouse and its upscaling, the so-called sea of plastic that covers large-scale surfaces of land such as the Campo de Dalías in the South East of Spain[104], vast extensions of ground are also continuously wrapped with weed mats, geotextiles or harvesting nets. Landscape fabric, in particular, is used to prevent the growth of weed herbs by blocking the access of sunlight to the soil except in those places where a hole has been practised, for the cultivated plant to grow. In some cases these weed mats are sold with grids of holes already practiced on them (see for instance), in others they consist simply on rolls of plastic mesh with painted guidelines to easy connect each other ().

Still Life with Screensavers and Landscape Fabric is a work that consists on wrapping screens with landscape fabric, cut either in strips or in continuous films. They are presented as prepared monitors, completely covered with the plastic mesh, in such a way that, when turned on, light can go through the seeding holes or through the interstices between the strips.

Switched on, the monitors display a screensaver-like 3D model of a fruit orbiting and bouncing in the space of the screen. The fruits shown are bananas, pineapples and avocados, all of them consumed globally and linked to plantation agriculture. The effect of the wrapping of the screens with the plastic fabric is to make the fruits appear like spectral images[105], blurred with the fabric, in such a way that they seem to be emitted by the circumvallation of plastic instead of the surface below.

As a genre, the still life is a category of images deeply rooted in the colonial power of the modern pre-industrialised Europe, in plantationism and in the early circuits of international trade (Hochstrasser, 2007). Enveloped with the landscape fabric, the prepared screens of *Still Life with Screensavers and Landscape Fabric* bring then the spectre of colonialism to the plant-image phantasmagory created by the filtered light.

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[104] In the Campo de Dalías in Almería more than 20000 hectares are covered under an almost uninterrupted sequence of plastic greenhouses. See in this vein https://earthobservatory.nasa.gov/images/4508/greenhouses-of-the-campo-de-dalaas-almeraa-province-spain [Accessed 30 April 2019]

[105] In this regard, the work recalls Jim Campbell's Low Resolution Works, with LED screens stacked to translucent surfaces. See < http://www.jimcampbell.tv/portfolio/low_resolution_works/reconstructions/reconstruction_one/> [accessed 30 April 2019]

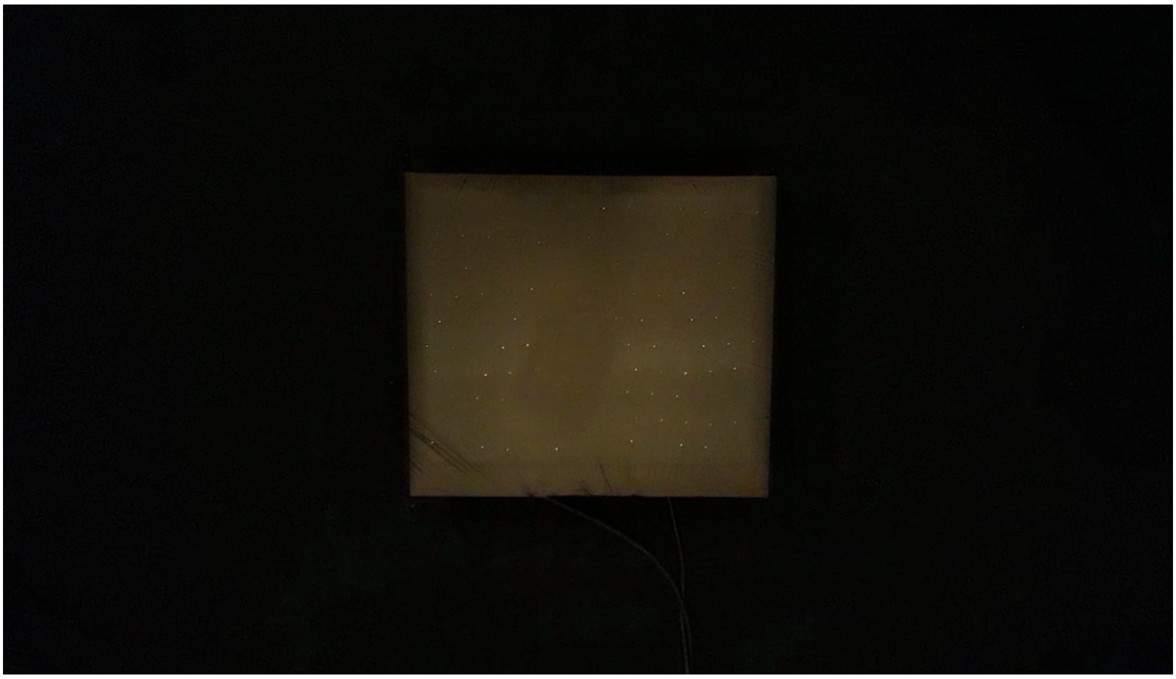

Figure 61 *Still Life with Screensavers and Landscape Fabric* [mixed media], studio installation, Madrid (2019). The shadow of a pineapple floats in the centre of the screen. The small dots of light correspond to the holes in the plastic film, designed initially as the places where the vegetal seeds should be located.

Figure 62 *Still Life with Screensavers and Landscape Fabric* [mixed media], studio installation, Madrid (2019)

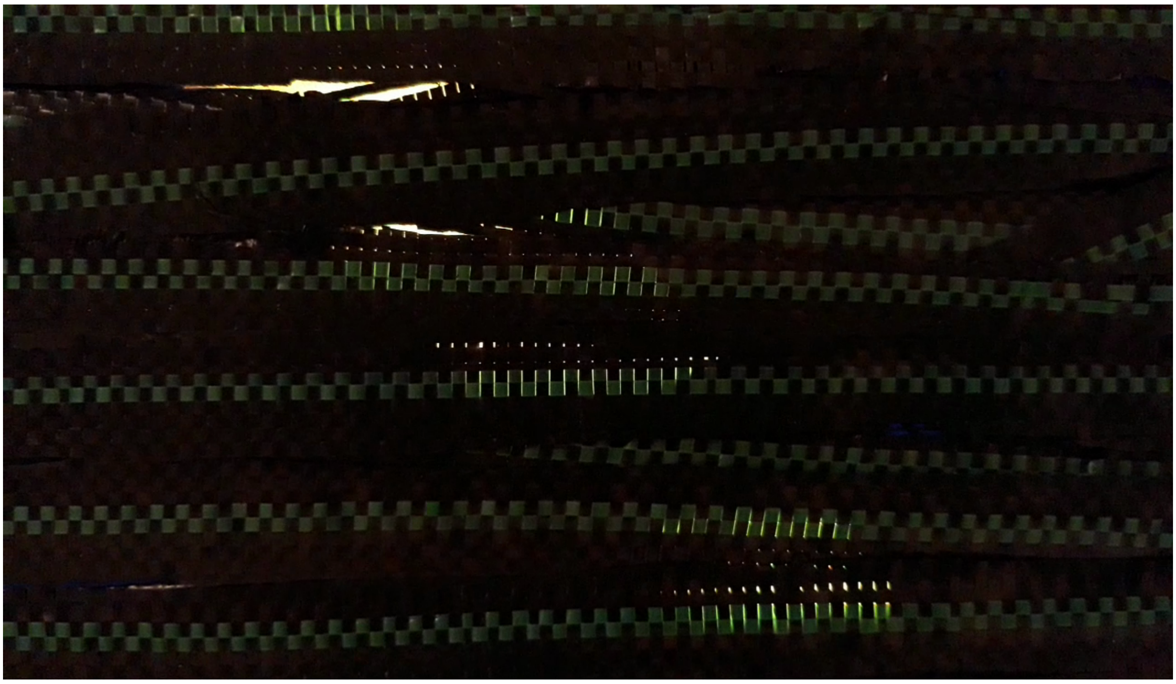

Figure 63 *Still Life with Screensavers and Landscape Fabric* [mixed media], studio installation, Madrid (2019). Detail.

3.2 The escalation of the photosensitive plant

3.2.1 The becoming environmental of experimental agriculture

From the second half of the 19th century onwards, experiments in chemical agriculture were being developed in greenhouses, experimental farms and laboratories. Historian Richard Drayton has shown how, in the last quarter of that century, these acquired a colonial character (Drayton, 2000, p. 238). As a consequence, networks of agricultural stations were built worldwide; in other words, not only in the interior of the Imperial main lands but also in their colonies. In the first decades of the 20th century, coinciding with the development of *The Biosphere*, the number of the agricultural stations exploded:[106] species were bred, tested and circulated from the West Indies to Indonesia, with major experimental centres in Sweden, Tunisia, Kenya and India, among others (Elina, Helm and Roll-Hansen 2005; Bonneuil 2006; Camprubí, 2017; Stull and Turpin, 2017).

These agricultural stations were enclosed environments designed to monitor the production of crops. In addition, and inspired by the new developments in botany and plant sciences, the efficiency of new techniques was evaluated. Reciprocally, as Timiryazev recalled, these also fuelled, in turn, demands for the development of these sciences, and plant physiology in particular (Timiryazev, 1958, p. 47). As a result of this exchange, new species and breeds were produced and tested in order to check if they grew efficiently in several parts of the globe at the same time. Those species with the ability to adapt to different zones were selected and spread globally;[107] in other words, the most efficient and resilient vegetable breeds were upscaled to the planetary. In this scientific and colonial context, before Vernadsky's work, planetary forms of the plant were already in practice, then.

In *Program Earth*, Jennifer Gabrys (2016) analyses the consequences of the contemporary spreading of networks of sensors that collect data about all sorts of terrestrial processes on a global scale. She articulates the notion of the becoming environmental of computation, which allows her to account for "the new entities and experiences that materialize through these processes" (ibid., p. 267). In Gabrys' view, this becoming does not only address the consequences of an upscaling of corporate control, but a broader context of possibilities of engaging with

[106] Even in poorer countries such as Spain (Camprubí, 2017, p. 136).

[107] In this sense, the stations instance, literally, what has been designated as Plantationocene: "the dynamics through which plants and animals are abstracted in order to become resources that can be used for investment" (Haraway et al., p. 557).

environments as a whole, which she finds in what she refers to as citizen-sensing practices (ibid., p. 271).

Interestingly, the turn of the 20th century also witnessed a global spreading of experimental stations linked to the domain of applied plant sciences. Following Drayton, these can be linked to the colonial "ideology of 'Improvement'" of nature (Drayton, 2000, p. xvi), yet they were also the background of theoretical undertakings in life sciences that started to consider the Earth as an active biological entity. The thermodynamic-based work of North American biophysicist Alfred Lotka, gathered in his *Elements of Physical Biology* (1925), is an example of this. In this book, on the one hand, "the entire body of all these species of organisms" was boldly addressed as a "World Engine" and characterised as "a vast unit, one great empire" (ibid., p. 360), yet, on the other, Lotka introduced the impact of human industries in his models, and ever since has been considered an acknowledged pioneer of ecological environmentalism (Grinevald, 1998, p. 28). Similarly, Vernadsky's *Biosphere* can be counted as another example of this becoming environmental of applied plant sciences. In the following pages, I will show how he scaled the surface of the individual plant up to the planetary. In some respects, this was already happening in the worldwide circulation of vegetable matter inside the networks of agricultural stations.

3.2.2 Environments of glass

Before continuing with Vernadsky's work, an additional dimension of his cultural and material context will be related to his proposition of the escalation of the green plant. In order to do this, I will consider first how the scaling-up of the above-mentioned glass jar is related to the work of historian of science Sabine Höhler on the elaboration of the notion of environment. In particular, Höhler has analysed the importance of this development in the use of miniature worlds inside laboratories, such as aquaria, vivaria or terraria. Interestingly, as she notes — and beyond the larger scope of her work —[108] "glass became crucial in the shaping of the notion of 'environment' by way of carving out and separating segments of nature from their surrounding spaces" (Höhler, 2018). Further, this observation on the role of glass has been emphasised by historian of science Kijan Espahangizi in relation to the elaboration of the proposition that the atmosphere functions like a giant glasshouse.[109] Following Espahangizi, this upscaling was also linked to the multiplication of glass containers — jars, bottles and test tubes — as part of the material culture of life sciences (Espahangizi, 2011).

[108] Höhler uses explicitly Peter Sloterdijk's terms to define her project as a genealogy of endospheres; that is, of self-sustained environments linked to the contemporary forms of dwelling and enclosure.
[109] A development that culminates in Svante Arrhenius' description of the greenhouse effect (Jones, 1990).

The observation of the containers from the outside immediately recalls the characteristic image of the globe and its associated scientific gaze from nowhere. Relatedly, as Matthew Fuller has observed, they are linked to the global logistic space of the freight container, that he locates in the imaginary modular architectures of Futurist Velimir Khlebnikov, which relied on personal standardised glass capsules in constant circulation (Fuller, 2005, p.93). The emphasis on the glass, moreover, brings the material space where these images of the global are produced to the foreground. As Giuliana Bruno has stressed, there's a "surface condition" that needs to be taken into account in the articulation of spaces and the images produced out of them (Bruno, 2014, p. 5). Following Bruno, a surface tension specifically characterises the inevitable coexistence of the different materialities that make the physical presence of visual media in a particular space possible. The movie theatre in relation to its surrounding architecture (ibid., pp. 56–59) or the fabric of the projection screen in relation to the chemical coating of the film (ibid., pp. 118–119) are examples of these surface encounters. Thus, the emphasis on surface tension as a relational materiality ultimately allows different dimensions of space and time to be considered in relation to the analysis of media.

In returning to the glass, the aforementioned studies resonate with an observation by media theorist Janet Janzen in her research on the interweaving between visual media and plant sciences (Janzen, 2016). In particular, she underlines the prominent role that glass had in the science fiction stories written by Paul Scheerbart (1863–1915), which featured gardens that contained, instead of plants, animated fragments of coloured glass. Following Janzen's observation, glass is featured as the materialisation of an extended utopic aspiration to transform nature and — coinciding with cultural theorist Esther Leslie —[110] to replace it, ultimately (Janzen, 2016, p. 92). This replacement of the vegetable with glass can be seen, however, from the point of view of a surface condition at play. In particular, it can be addressed in relation to the surface tension that occurs in the encounter of the greenhouse with the plants inside. Following Bruno (2014, p. 5), "surface tension can turn both façade and framed picture into something resembling a screen". The surface of the greenhouse and that of the plant coalesce in an entanglement when observed in visual terms. The glitter of glass and the inner movements of plants combine in a relational in-between, a surface condition, that can be understood as a refashioning of the actual materials.

From this point of view, Scheerbart's plant-glass rematerialisation can be addressed as part of a characteristic surface condition in the early decades of the 20th century in Central Europe, specifically analysed by Bruno. In her study, she recalls the writings of Siegfried Kracauer, where

[110] This same thesis is also supported by Esther Leslie (Leslie, 2006, p. 108).

the “shimmering light of the urban arcade” equalled the “flickering space of the movie theater”, as if they instanced the same surface condition (Bruno, 2014, p. 56). This “surface splendour” of the ornament in motion, continues Bruno (2014, p. 56), emerged not only in the texture of films or in urban façades, but as a material characteristic of their time. That is, the interweaving of the insides and the outsides of theatres were related to those of plants and greenhouses. A fleeting and phantasmagoric disposition to become light in motion rematerialised the world with its ornamental signature, and blended the glass greenhouse with the plant as a consequence. This surface tension, notably, was even scaled-up to the aerial. In a remarkable scene by Scheerbart, it is the whole skin of the planet what is rendered as a twinkling fairy-scape of animated light:

> “The surface of the earth would change immensely if everywhere brick architecture were replaced by glass architecture. / It would be as if the earth had clothed itself in jewellery of diamonds and enamel.” (Scheerbart quoted in Leslie, 2006, p. 109)

Bruno’s material analysis of visual media thus describes a surface tension linked to the interplay of light and movements in the cities of the early decades of the 20th century. This condition also spread to the vegetable, as I have shown following the cultural historical reading of Paul Scheerbart’s works by Janet Janzen and Esther Leslie. This transfer to the surface of plants, it has been shown, was mediated by the glass that enclosed the practices as well as the public display of life sciences.

It is in this context that Vernadsky proposed his own hybridisation of the green surface. As I will show next, his notion of living matter will be presented as a scaling-up of the vegetable plant, and characterised with movements intimately linked to its enveloping relation with the Earth’s crust: “Living matter clothes the whole terrestrial globe with a continuous envelope” (Vernadsky, 1998, p. 59). Emphasising its surface character, Vernadsky addressed the assemblages of vital matter that made it up as “living films.”[111] Following Vernadsky, while they grounded the oxygenation of the planet, at the same time they refashioned its uppermost geologic crust: “Seen from space, the land of the Earth should appear green” (Vernadsky, 1998, p. 59). And in addition to this, while the upscaling of the green plant allowed him to address the planetary, it also allowed its movements to be brought to the human sensorium:

> “The careful observer can witness this movement of life, and even sense its pressure, when defending his fields and open spaces against it. In the impact of a forest on the steppe, or in a mass of lichens moving up from the tundra to stifle a forest, we see the

[111] Such films were, for instance, the continuous layers of green life that cover the surface of oceans (Vernadsky, 1998, 126). In the case of land, “it contains only one *living film,* consisting of the *soil and its population of fauna and flora.*” (ibid., p. 142)

> actual movement of solar energy being transformed into the chemical energy of our planet." (ibid., p. 62)

3.2.3 The escalation of the photosensitive plant

Before continuing, it is worth observing that in the book Vernadsky enunciated a central methodological issue he had to face in relation to the notion of scale and its epistemic implications. In particular, when dealing with the biosphere as a whole, individual phenomena had to refer to the context of a larger scale.

> "Historically, geology has been viewed as a collection of events derived from insignificant causes, a string of accidents. This of course ignores the scientific idea that geological events are planetary phenomena, and that the laws governing these events are not peculiar to the Earth alone. As traditionally practiced, geology loses sight of the idea that the Earth's structure is a harmonious integration of parts that must be studied as an indivisible mechanism." (Vernadsky, 1998, p. 39)

From his perspective, the study of the planet required it to be addressed as a "holistic mechanism", with all the parts combined in an invisible whole (Vernadsky, 1998, p. 40). Despite the explicit reference to a "mechanism", his work should not be linked to a mechanistic representation of life, which he explicitly rejected (ibid., p. 51). It is instead an all-encompassing metaphor that describes a system of linked phenomena that, in opposition to a multiplicity of "essentially blind" accidents (ibid., p. 40), sense each other and constitute the presence of a different order of magnitude, as it occurred in the theories of complex systems in the second half of the 20th century (Grinevald, 1998, p. 30). Geological events, including the ones linked to life, were put forward to be connected to each other, giving rise to a dynamic system in equilibrium.

Remarkably, he eluded the question on the nature of this holistic mechanism: "I will not speculate here about the existence of the mechanism, but rather will observe that it corresponds to all the empirical facts and follows from scientific analysis" (Vernadsky, 1998, p. 40). That is, he postulated it as a fact in order to rely on it afterwards. In order to be able to advance his arguments, he needed to be able to formulate such statements. He named these principles "empirical generalisations" (ibid., p. 51–56), stating explicitly that these were not introduced as theoretical hypotheses. These were formulations grounded in induction, well established by the experience, which could not, however, be fully provable due to the scale and variety of their domain (ibid., p. 53). Throughout the book, he postulated a series of these; among them, for instance: the permanent difference between inert and living matter (ibid., p. 53), the presence of life during all geological periods (ibid., p. 54)[112] or the invariability of the chemical influence of living matter (ibid., p. 55).

One of these, “an empirical generalization of the first magnitude” (ibid., p. 59), is of particular interest for this research. Right after his initial description of living matter as a biogeochemical assemblage of entities and processes, the unique role of plants in the surface of the living is highlighted in the book. Plants, together with some autotrophic bacteria, are the only ones able to transform the incoming radiation into chemical energy. In his words, “all living matter can be regarded as a single entity in the mechanism of the biosphere, but only one part of life, *green vegetation,* the carrier of chlorophyll, makes direct use of solar radiation” (ibid., p. 58). He explained subsequently how several studies had shown that these organisms had adapted to this “cosmic function” (ibid., p.58), and explicitly cited among them the work of plant physiologist Julius Wiesner.

In particular, Wiesner’s idea that light “exerted a powerful action on the form of green plants” was emphasised in *The Biosphere* (ibid., p. 58). In order to underline this — that the form of the vegetable is affected by light — Vernadsky next invoked a quote by the Austrian physiologist: "one could say that light moulded their shapes as though they were a plastic material” (ibid., p. 59). He postulated this behaviour as an empirical generalisation, scaling this mechanism up to the planetary: “the green apparatus which traps and transforms radiation is spread over the globe, as continuously as the current of solar light that falls upon it” (ibid., p. 59). As plant physiologists had attested before him, the vegetal form was coupled to light. The photochemical morphogenetic dimension of the interweaving between vegetable matter and the rays coming from the Sun, when up-scaled, provided him with an explanation for the efficient spreading of life all over the terrestrial surface.

In addition, the influence of the work of these plant physiologists in Vernadsky’s model can be witnessed when he next wonders about the cause of plant-light interaction. Is it plants that grow and adapt their shape to a passive background of light, or, conversely, it is light that sculpts them as it had invisible fingers? This was exactly the old and polemical dispute between Darwin and the German physiologists that I addressed in the previous chapter. Following what Wiesner had proposed two decades earlier in his research on phototropism, Vernadsky even suggested a third way: “the solution should probably be sought in a combination of both approaches” (Vernadsky, 1998, p. 59). Wiesner, as I have shown previously, explained how the shape of plants had to be

[112] Vernadsky argued against any theory on abiogenesis — on the origin of life from non-living matter. This is a wrong statement today: since a series of experiments in the 1950s, the abiogenesis hypothesis has been accepted as valid.

understood as an adaptation to their active environment of light. Neither as accumulations of vegetable matter reacting to external forces, nor as free organisms with the ability to experiment with their own form, plants developed leaves where the intensity of light equalled their *Lichtgenuss.* This characteristic of plants was escalated by Vernadsky to the planetary: "The firm connection between solar radiation and the world of verdant creatures is demonstrated by the empirical observation that conditions ensure that this radiation will always encounter a green plant to transform the energy it carries" (ibid., p. 59). Like individual plants, whose leaves are placed where the intensity of light coincides with the value of their *Lichtgenuss*, the living surface is presented in a dynamical equilibrium with light in such a way that every incoming ray ends up meeting the appropriate creature that efficiently metabolises it.

Wiesner considered the plant as a whole and provided a photochemical model for its ability to deploy its surfaces against the varying environment of luminous conditions: the sensitivity of the photographic surface. Likewise, Vernadsky defined living matter as a whole and also proposed a biochemical model to explain its capacity to spread and perform its photosynthetic function everywhere on the Earth. The green apparatus, the latent disposition to transform the rays of light into the chemical energy necessary both to sustain and expand the living, was spread as a biochemical sensitiser over all surfaces of the Earth. That is to say, Vernadsky took the work of a previous generation of plant physiologists on the interaction of plants with light and escalated it to the planetary. He postulated, as an empirical generalisation, that the ensemble of all life forms could be understood as a whole in relation to the metabolism of the energy of light. He named this totality the living matter, and characterised it as a surface in continuous formation, as if it were a vegetable organ adapting its shape in relation to light. The photographic character of the surface of plants that resulted from turn-of-the-century continental plant physiology, then, was brought up to the planetary by Vernadsky. By doing this, implicitly, life on Earth was modelled as a photographic development of the light of the Sun or, in other words, as an image of chemical energy in continuous formation.

Figure 64 *When the Auroras Descended to the Earth*, PhD Viva exhibition, The Winchester Gallery (2019)

Transplant 2. ***When the Auroras Descended to the Earth***

2019. Installation. Dismantled compasses, solar panel, digital projector, electronics. Variable dimensions.

In 1990 a group of geophysicists surveying Hamburg measured big magnetic anomalies by the River Elbe. They discovered a barge loaded with chemical weapons that had been sunk in that location several decades ago. The person responsible for the accident was found to be the German chemist Hugo Stolzenberg (1883-1974), the infamous assistant of Fritz Haber known to have opened the valves of the cylinders of chlorine gas over Ypres (Garrett, 1995, p.11). After the end of the Great War, his life remained devoted to the production of chemical weapons, with several international contracts. In an unknown date between 1920 and 1930, then, when the cargo of his barge started to leak, he decided to sink the boat, leaving its chemical and magnetic leaks to posterity (Garrett, 1995, p.23).

In 1921, Stolzenberg signed a contract with the Spanish government to initiate the works of a factory of chemical warfare (Garrett, 1995, p.11), whose outcomes would decide years later the Rif War in the North of Morocco. That same year, two significant planetary-scaled events had taken place: on the one hand, one of the strongest solar storms of the last century, which gave rise to one of the largest auroras ever recorded (Silverman and Cliver, 2001, p.525); on the other, the by-then biggest factory accident registered, the explosion of the nitrogen industrial complex in Oppau, whose seismographic footprint was recorded more than 300 Km away from the centre of the explosion (Wrinch and Jeffreys, 1923, p.15).

When the Auroras Descended to the Earth addresses these events as an installation where the light of a digital projector is transformed by an array of solar cells into electrical signals that, in turn, are sent to small electromagnets that alter the magnetic fields sensed by a set of compasses placed on the ground. The images projected to the panel are fragments of a series of filmic documents produced by the Spanish government after the end of the Rif War. Despite the document makes no reference to the chemical weapons, my edited montage does, subtly, with the aid of aerial takes, smoke clouds and other visual resources from the original film.

The installation can be seen as a diagram of an aurora: the rays of the projector-Sun are transformed into magnetic fluctuations detected by the compasses on the ground. At the same time, however, the installation recalls also the magnetic footprint of the chemical weapons like those used in the Rif War. *When the Auroras Descended to the Earth* does not pursue to document a single event, therefore, but a characteristic pattern of events linked to the advancement of the chemical industries. And it does it through the crucial mediation of the image, with is links to chemistry, the atmosphere and the aerial.

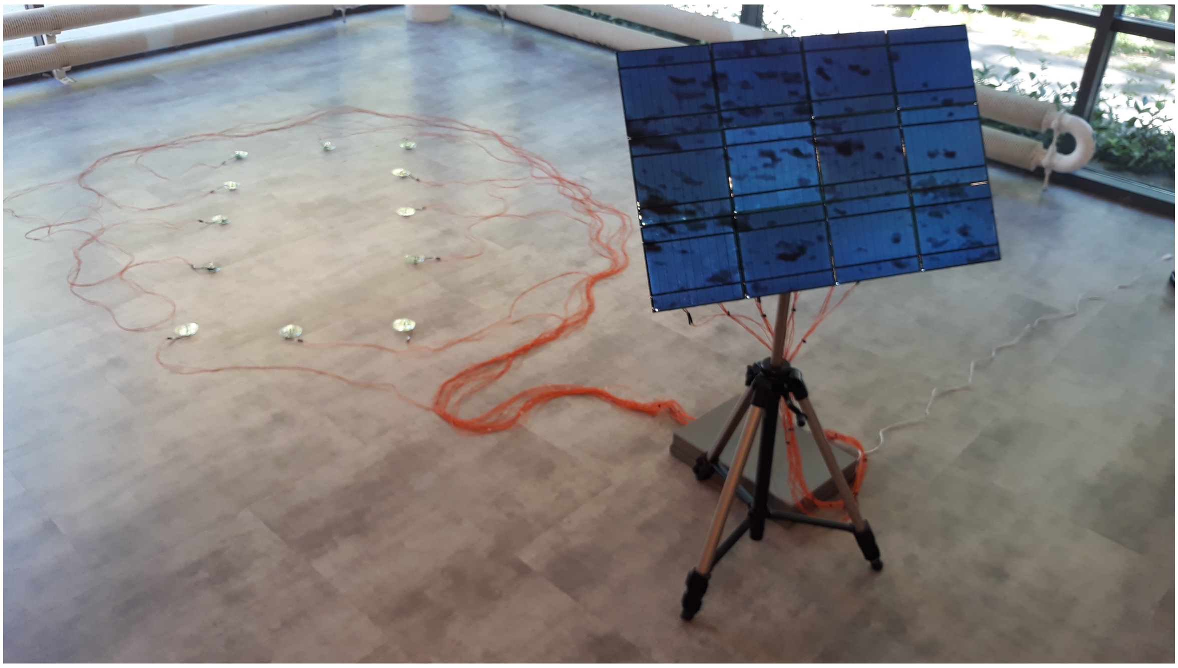

Figure 65 *When the Auroras Descended to the Earth*, PhD Viva exhibition, The Winchester Gallery (2019). View of the solar panel with the projected video and the compasses in the background.

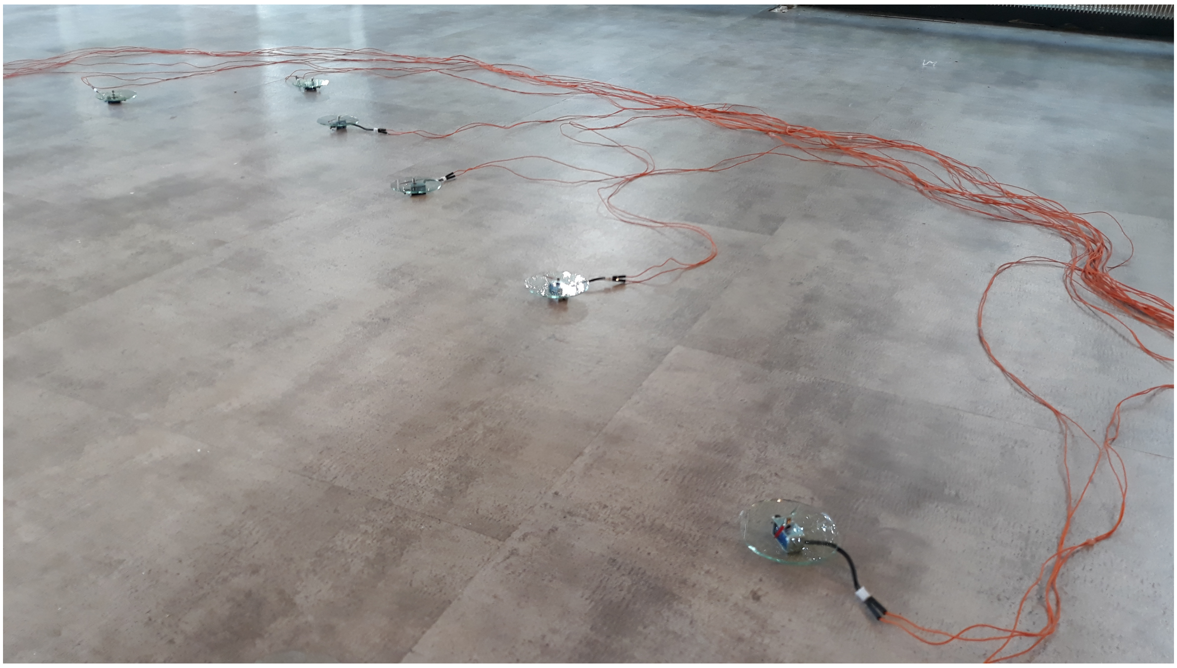

Figure 66 *When the Auroras Descended to the Earth*, PhD Viva exhibition, The Winchester Gallery (2019), detail.

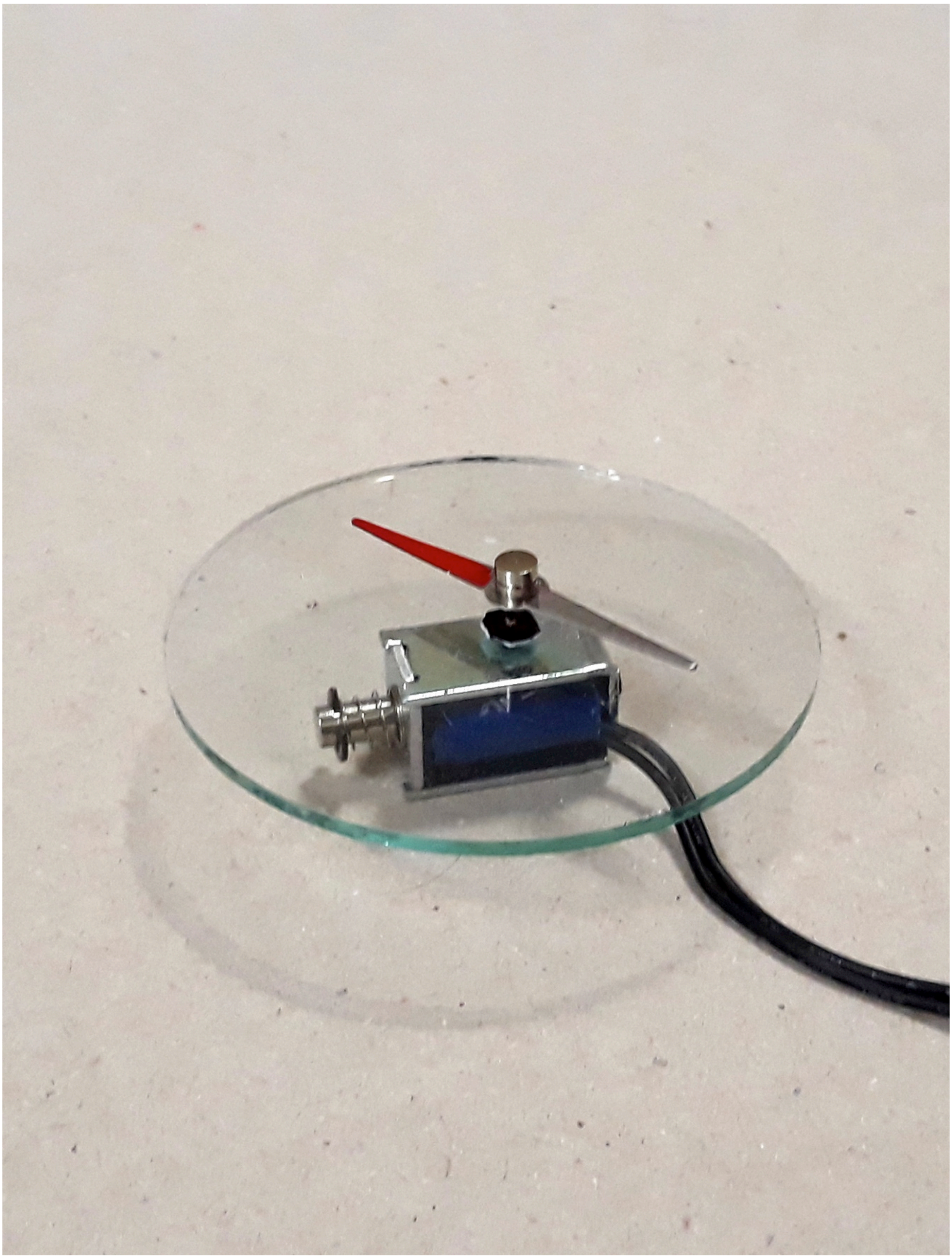

Figure 67 *When the Auroras Descended to the Earth*, studio installation, detail (2019).

3.3 The chemical scaling-up of a cultural technique

3.3.1 The microtemporal architecture of chemistry

With the aid of the empirical generalisations and subsequent escalations, *The Biosphere* was Vernadsky's attempt to arrive at a theory of both the ensemble of living organisms in the planet and its non-organic milieu, such as the totality of landforms, hydric surfaces and gas shells. As a theory, it sought to explain the variability of life in mathematical terms as had been done with the movements of celestial bodies (Vernadsky, 1998, p. 60). This approach to the biosphere thus required a way to deal with the living and the non-living at the same time, without assuming either a mechanistic reduction or a vitalistic position, both of which he disregarded as "alien to science" (ibid., p. 51). As I will show next, this made him place the emphasis instead on the operational dimension of biogeochemistry; that is, on the existence of planetary-spread chains of chemical reactions that involved living and inert matter at the same time.

In order to continue, it is worth recalling now how the above-mentioned ozone cycle demonstrates that a simple photochemical cycle is enough to explain the formation of a planetary shield. In this vein, it is important to remember that the stabilisation of the gaseous layer of ozone is related to the fact that plants continuously emit a net amount of oxygen to the air. When these molecules reach the upper atmosphere, they are hit by ultraviolet light, and broken into free oxygen. The remnants — unstable — recombine immediately to give rise to stable ozone as a result. Reciprocally, ozone is also split when hit by ultraviolet radiation, giving rise again to unstable forms of oxygen. These recombine, in turn, in a new iteration of the loop. As oxygen is fed into the atmosphere by the plants, the stable surface of recombining molecules spreads. The ozone layer grows, on its own, until an equilibrium point is reached; there, the ultraviolet radiation is dynamically cancelled. In that situation, the layer completely envelops the planet, and absorbs the lethal radiation and heats the atmosphere as a result.

Now, it needs to be underlined that, thanks to this model, no empirical generalisation is required to postulate the composition and spreading of the ozone layer. The formation of this gaseous screen can be explained through a photochemical cycle that is able, on the one hand, to escalate up to the planetary and, on the other, to link together the animate and the inanimate. Interestingly, from a media theory perspective these cycles of molecular operations introduce in Vernadsky's model what Wolfgang Ernst has addressed as the microtemporal dimension operative in the materiality of the medium (Ernst, 2016). In order to understand this, it is important to recall that the ozone layer is not produced directly by plants, but by a chain of photochemical reactions where their green surfaces and the cosmic ultraviolet radiation are interweaved. The production of oxygen in the plant and the photochemical assimilation of ultraviolet frequencies are synchronised, as it is the same radiation that fuels the two processes. The ray from the Sun that is filtered by the upper ozone is the one that is assimilated by the photosynthetic organelle in the plant. Oxygen is produced as ozone is split. The mix of molecules in the atmosphere, together with active radiation, gives rise to a temporal texture of connected chemical splits and recombinations. Therefore, the living and the non-living meet in this scaffold of time-critical events that unveil the "chronotechnical condition" (ibid, p. 41) of the atmosphere: its photochemical gaseous composition connected to the radiating background.

Significantly, Vernadsky abstracted this model of gaseous diffusion and turned it into a general archetype of biogeochemical movement, the movement of living matter: "The diffusion of life is a sign of internal energy… and is analogous to the diffusion of a gas" (Vernadsky, 1998, p. 60). In other words, he transformed the biochemical description of the ozone cycle into a model for the biospheric behaviour of life; what Joseph Vogl has addressed as the "becoming media" of scientific instruments (Vogl, 2007).[113] He transferred the microtemporal architecture of the gaseous envelope to living matter. For him, if the ozone layer grew thanks to the production of oxygen due to plants, living matter spread alike thanks to its ability to grow by multiplication.[114] According to the common microtemporal background of biogeochemistry, he described both processes of diffusion in the same terms: living matter was modelled as "analogous to a gas" (Vernadsky, 1998, pp. 59, 61), fluidly overcoming its obstacles and producing pressure in the surrounding environment (ibid., p. 59). He even described a "speed of transmission of vital energy" (65), meant to estimate, numerically, the intensity of the reproduction of the living surface in a specific place. Based on this notion, he defined the time that it would take for a living form to occupy the whole Earth, if it did not have predators or limited resources (ibid., p. 66). He also calculated this time for some species, such as certain bacteria — 36 hours — or termites — "a few years" — (63). In addition, mimicking what physicists had done with the kinetic theory of gases,[115] he even defined the "internal energy" (ibid., p. 61) of this spreading and calculated it as the sum of "the separate energetic movements of its component particles" (ibid., p. 61). The surface of the animate was surrounded by gaseous matter, and it acquired its microtemporal

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[113] In Vogl's case, the instrument considered is Galileo's telescope. Here it is the photochemical cycle of ozone. Further, the above-mentioned work of Alfred Lotka can be analysed in relation to this becoming media of the biogeochemical cycle. Not in vain, Jacques Grinevald has observed how these two scientists can be related to what he calls the Carnotian revolution (Grinevald, 1998, p. 26), inspired in the otherwise crucial conceptualisation of the thermodynamic cycle by French physicist Sadi Carnot in the early 19th century.

[114] Multiplication was precisely the key feature for Vernadsky that distinguished living from inert matter (Vernadsky, 1998, p. 60).

[115] The kinetic theory of gases offered a statistical approach to gases and their thermodynamics.

characteristics. The vital was not reduced to the physical, but was transported by it. Broadcasted as a gaseous signal, it enveloped the globe and exerted pressure on its obstacles. And beyond that, it could be appraised by calculation.

To sum up, so far I have shown how Vernadsky conceived living matter as an empirical escalation of the plant-image that physiology had described before him. Due to its planetary scale, it needed to be understood in a mutually enabling relation with its surrounding non-living milieu. On his model of living matter, this imposed a microtemporal architecture, of its enveloping gaseous shell. The living and the inert were thus deeply interweaved. Aware of the importance of this microtemporal synchronisation, he referred to it accordingly: "this exchange is the *breathing* of organisms" (Vernadsky, 1998, p. 61, italics in the original).

3.3.2 Chemical worlds

Despite the suggestive evocation of the breathing of living matter as it relates to animal respiration, Vernadsky's remediation of the movements of this surface is linked to the re-operationalisation of matter associated to the chemical complex of the industries of his time.[116] Following cultural theorist Esther Leslie's *Synthetic Worlds* (2006), the immense — and literally breathtaking —[117] chemical industry grounded an empire of analogues and replacements. It filled the world with manufactured materials as varied as aniline-based colours, plastics, celluloid, surface coatings and synthetic oils that took the place of organic originals such as natural pigments, ivory or bones. Taking this context into account, I will now show how the microtemporal gaseous skeleton that Vernadsky introduced into the "movement of life" inevitably connects *The Biosphere* to the parallel chemical gasification of agriculture brought about by these corporations.

[116] For the sake of contextualisation, it must be noted that *The Biosphere* was published the year of the foundation of IG Farben, the infamous cartel that gathered together the biggest German chemical corporations of the moment, including BASF, AGFA and Bayer.

[117] As it was involved in the production of explosives as well as chemical warfare. See for instance (Leslie, 2006, pp. 184–188).

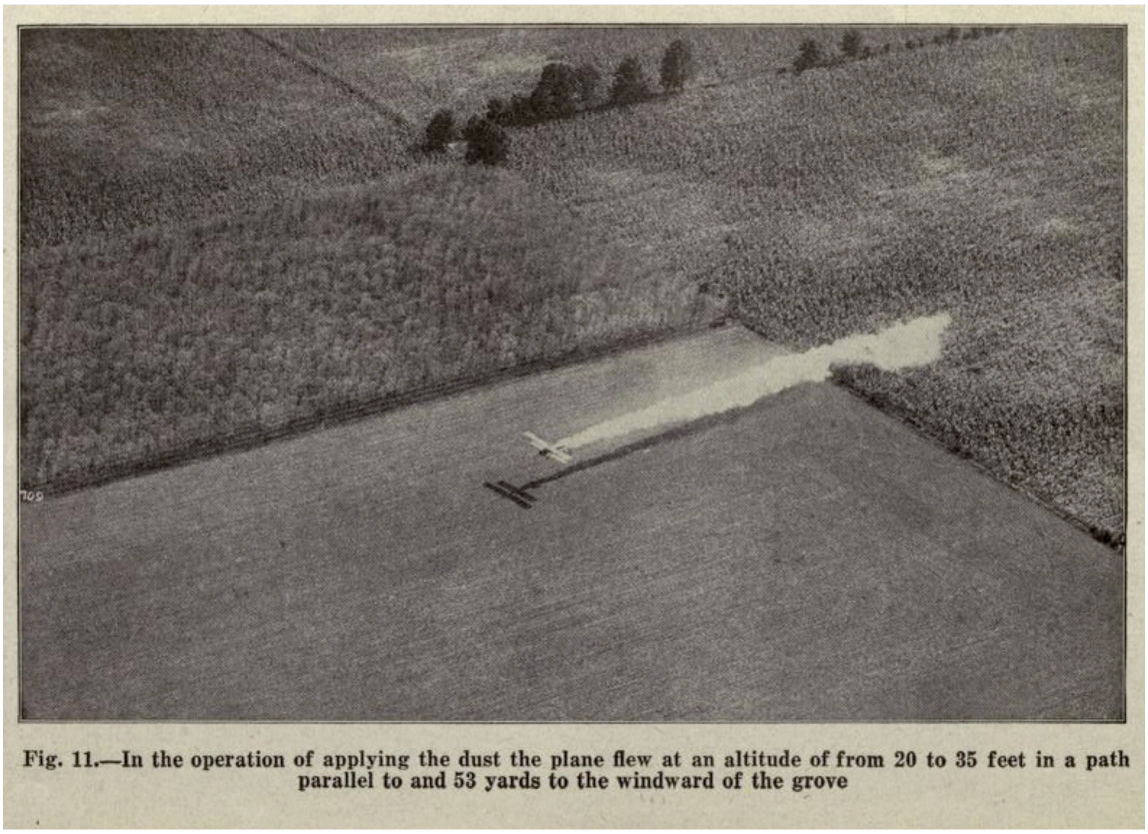

Figure 68 One of the first crop-dusters in operation, testing a pesticide against caterpillars in an agricultural experimental station in Ohio in 1921. Reprinted from (Houser, 1921, p. 134).

Crop-dusters and other fogging techniques were still not present in everyday agriculture in the early 20th century, with the exception of some early experiments during the 1920s in the United States (Figure 68). The Haber-Bosch process that synthesised ammonia as a fertilizer, however, had already been developed and introduced on an industrial scale in 1913. Since the mid-19th century, following an agricultural crisis due to the depletion of soils by intensive practices (Foster, 2000 p. ix), there was knowledge that the fixation of nitrogen was essential for the growth of plants. Nitrogen could be extracted from the vast deposits of guano in South America and added as manure to fields. This improved the yields considerably, and it also fuelled the development of "the new agricultural chemistry" initiated by the German chemist Justus von Liebig (Leslie, 2005, p. 82). As nitrogen is the most abundant gas in the atmosphere, a large number of attempts to extract it directly from the open air followed, but unsuccessfully. All this changed in the first decade of the 20th century with the development of the above-mentioned process by Fritz Haber and Carl Bosch. Nitrogen-based fertilizers could be produced in factories. As a result, the use of synthetically fixed nitrogen spread immediately after its commercialisation (Smil, 1991, p. 569).

Since then, air has been circuited to the soils of the planet in the form of synthetic nitrogen. As I have shown, in the production of ozone Vernadsky found a temporal architecture for the diffusion of living matter in the biosphere. The Haber-Bosch process shows that this same chemical time-criticality had already been exploited to spread agriculture over the surface of the planet based on synthetic nitrogen extracted from the air. As a matter of fact, after the Second World War the growth of the use of these fertilizers was exponential, and they even forced researchers to look for high-yielding varieties of crops, since the standard ones could not absorb the extra nutrients. Bigger consumption of water were involved, and large-scale irrigation infrastructures were needed, therefore, together with different types of pesticides and their related techniques of fogging. Over several decades, this was marketed as the "Green Revolution" (Perkins, 1997), the ensemble of techno-scientific developments, patents, management and communication strategies that led to planetary scaled figures: as chemist Paul J. Crutzen put it in his paper on the Anthropocene, "more nitrogen fertilizer is applied in agriculture than is fixed naturally in all terrestrial ecosystems" (Crutzen, 2002, p. 23).[118]

The spreading of Vernadsky's living matter observed in relation to that of industrial agriculture highlights a material and epistemic context that goes beyond plant physiology and other life sciences. It brings up a chemical background of operations that, interestingly, did not solely exist underneath the agricultural, but permeated the production of images too. Photography in particular, as cultural theorist Michelle Henning has remarked (Henning, 2018, pp. 95–99), experienced its own particular revolution thanks, for instance, to the development of new and faster sensitisers. With their aniline dyes, corporations such as Bayer, AGFA and BASF transferred their industrial mastery of the microtemporal synchronisation of chemical cycles to shortened photographic exposure times, and by doing so expanded, in turn, the operational space of photography itself. Measurements and scientific practices relying on chronophotography, such as the ones linked to the experiments reviewed in the last chapter are an example of this. Another clear case involves aerial photography, linking it directly to the first chapter of this research: during the First World War, these dyes gave rise to specific sensitisers that "reshaped photography in response to the demands of aerial reconnaissance" (Henning, 2018, p. 99). In particular, sensitisers were developed to allow aerial cameras to see through the atmospheric haze. Therefore, chemistry did not only sensitise the exhausted soils of agriculture to produce faster developments of photosynthetic matter; it also increased the rate and range of images produced by photographic surfaces. Recalling again Leslie's work, chemistry refashioned anew all the world's surfaces: photographic plates, soils and, as demonstrated, vegetable surfaces, including the agricultural ones.

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[118] Anthropogenic nitrogenation of soils is currently so excessive that over-fertilization has been considered as one of the main environmental concerns today (Pearce, 2018).

3.3.3 A medianature of zoetic mutualism

In the first two chapters of this research I addressed a set of cultural techniques that transferred vegetable growth — either in the form of crops or as leaves in the plant — to the operational domains of the image. That is, in the experiments and in the administrative and technological practices reviewed there, the formation of plant matter has been understood and managed in terms linked to the photographic image. This links them to that which, since Harun Farocki's work, has been addressed as the realm of operational images. In particular, to the way Hito Steyerl has further elaborated this notion, bringing it to the contemporary regime of the planetary exchange of images. She notes that images are referred and circulated in relation to what they depict as if they were one more "state of matter" (Steyerl, 2013). In the genealogy of the operational image that this research sketches, this particular state of matter is occupied by the movement and growth of the living, and more specifically, living green matter.

Steyerl's invitation to think of a media-state of matter recalls the notion of medianature proposed by Jussi Parikka[119], where the entanglement between media operations and natural resources results in recursive epistemic reconfigurations of elemental distinctions. This is the case, as Parikka has also observed, of the biosphere: "there is a double bind between the relations of media technologies and the earth conceived as a dynamic sphere of life that cuts across the organic and the nonorganic" (Parikka, 2015b, p. 12). In this chapter, these two coupled dimensions of Vernadsky's *Biosphere* have been analysed. On the one hand, its conceptualisations have been observed from the media technologies that led to them; in particular, the emphasis has been placed on the link between living matter and the photographic growth forms of Plant Physiology. On the other hand, the relations between living and inert matter have been scrutinised in Vernadsky's model, to underline the infrastructural mutualism assumed by it.

Regarding this last point, I have shown that *The Biosphere* can be read in terms of a surface tension between the organic and the non-organic that finally is resolved in the gaseous model of living matter. This model, it has been demonstrated, is linked to the parallel spread of the chemical industries, which also proposed a gaseous form of agriculture. In addition, I have related this gaseous model back to the visual technologies that had mediated, in the first place, the observation of plant growth. In particular, I have emphasised the infrastructural role of industrial chemical media in the photographic surfaces that allowed the advancement of the operational and measuring techniques of the camera-less experiments reviewed in chapter two.

[119] On medianatures, see Parikka's article in the Posthuman Glossary (Braidotti and Hlavajova, 2018, pp.251-253).

In Vernadsky's model vital growth is assimilated by the upscaling capabilities of gaseous biogeochemistry. Taking into account the link with the chemical industries, Vernadsky's model can be read as part of a context where vital growth was transferred and re-operationalised as chemical media. From this point of view, Vernadsky's synthesis resonates with an observation made by Rosi Braidotti on the distinction between the notions of *zoe* and *bios* being helpful in order to privilege the former when understanding the medianature double-bind, where both living and non-living display "vital self-organizing powers that were once reserved for organic entities" (Braidotti, 2016, p. 384). The zoetic addresses a dynamic and generative space of mediation, not limited to the living but also observed in the operational character of technological non-living systems. Ultimately, from this point of view, technologically mediated environments such as the biosphere can be analysed as mutually enabling zoetic systems.

Finally, this once again recalls the context of agriculture as the original milieu of elemental *Kulturtechniken*. In his work about the cultural techniques of swarming, Sebastian Vehlken observes how the zoetic entails "a vivacity that lends itself to technological implementation" (Vehlken, 2013, p. 113). This echoes one of Bernhard Siegert's remarks, when he explicates in particular how cultural techniques "may serve to create an awareness of the plenitude of a world of as-yet-undistinguished things that, as an inexhaustible reservoir of possibilities, remains the basic point of reference for every type of culture" (Siegert, 2015, p. 23). Vehlken's phrasing is particularly appropriate as it recalls Serres' notion of the parasite, discussed in the previous chapters. The set of techniques, habitus and infrastructures that constitute agriculture relies ultimately on the vegetal morphogenetic adaptability, its industrious persistence and its preference for cycles. With minimum requirements, plants grow and spread, inevitably. Husbandry, in turn, adds Serres, parasites this. It is not an activity geared towards making the plant grow — as growth comes with the plant itself — but it is geared instead towards removing what is considered as its obstacles — its parasites. And by doing this, it sets up a parasitic mode of relation: growth is enclosed, wrapped, enveloped and measured. It is circuited to new categories and re-operationalised: it is not plants, but crops that grow; it is not crops, but chemical additives that power their growth; it is not chemistry, but a set of refined media techniques that model plant growth. This characterises the different cases of hybridisation between images and plants that I have examined in this research. Images operationalised the growing, spreading and terraforming intensity of plants in their own measuring, partitioning and planetary capabilities, and, in turn, they became operational.

Figure 69 *Mawa*t [installation], installed at the exhibition *Región (Los relatos)*, Museum of Contemporary Art of Castilla and Leon (2018).

Transplant 3. *Mawat*

2017. Installation. Fans, aluminium frame, wood, electronics and digital prints. Variable dimensions.

Mawat takes the name of a law enacted by the Ottoman Empire on the occasion of an agrarian colonisation programme in the last quarter of the 19th century (Weizman, 2015, p.39). It is the name given to those barren lands prone to be expropriated by the government. In order to demarcate them, the rule provided a criterion based on sound: a zone was *mawat* if it was not in production and the sounds and voices of the nearest towns were no more audible. *Mawat* — meaning literally "dead" — became this way the administrative characteristic of the lands without voice.

In the installation, a grid of fans sets in circulation the air in the exhibition space. Periodically, the movement stops and the surface starts to work as a resonant structure[120]. Old songs linked to agricultural practices fill the space during these moments.

As in the Ottoman case, the transformation of the landscape carried out by the National Institute of Colonisation was based too on the identification and renovation of unproductive lands. Significantly, many of the settler towns created during this program were built without graveyard. In *Mawat*, this notable detail is addressed in a sequence of images around the central piece. Absence, movement and reappearance characterise the spectral space of the installation. Instead of the strong visual nature of the colonising programme, the air is brought to the foreground, and with it, the blurred space where wind and voice coincide, undifferentiated, and in continuous flux.

[120] To achieve this effect, the fans are powered with a specifically crafted electric signal, that turns them into devices analogous to speakers.

Figure 70 *Mawat*, Museum of Contemporary Art of Castilla and Leon (2018), detail.

Figure 71 *Mawat*, Museum of Contemporary Art of Castilla and Leon (2018), detail.

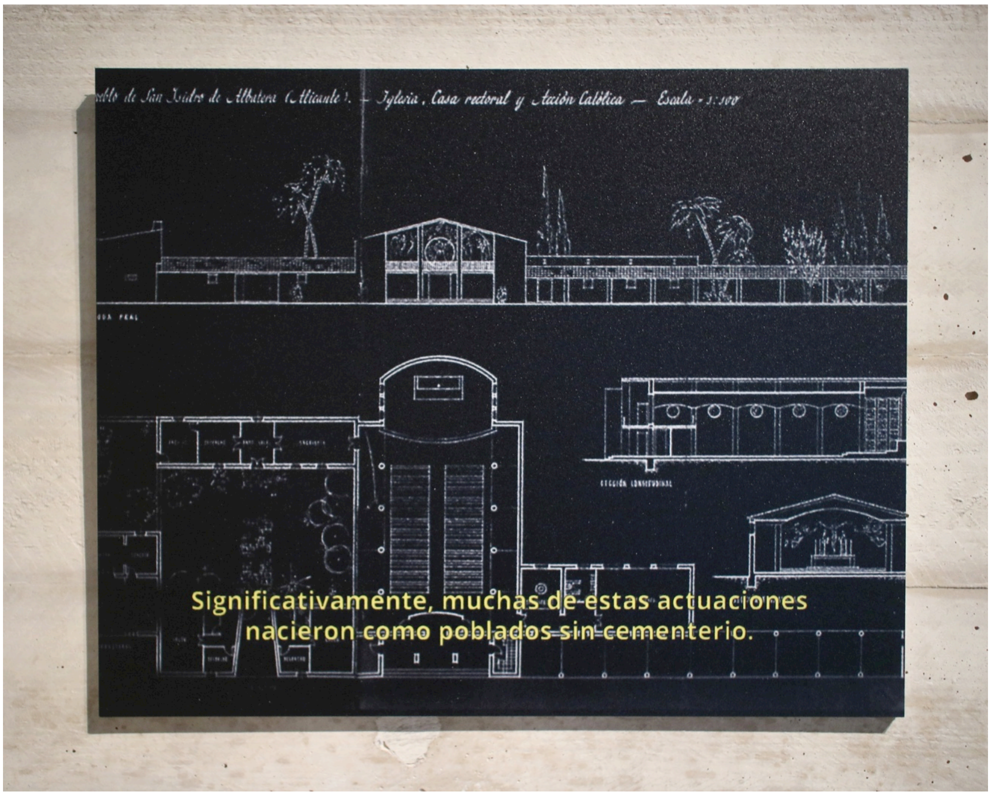

Figure 72 *Mawat*, Museum of Contemporary Art of Castilla and Leon (2018), detail.

Figure 73 *Mawat*, Museum of Contemporary Art of Castilla and Leon (2018), detail.

Figure 74 *Mawat*, Museum of Contemporary Art of Castilla and Leon (2018), detail.

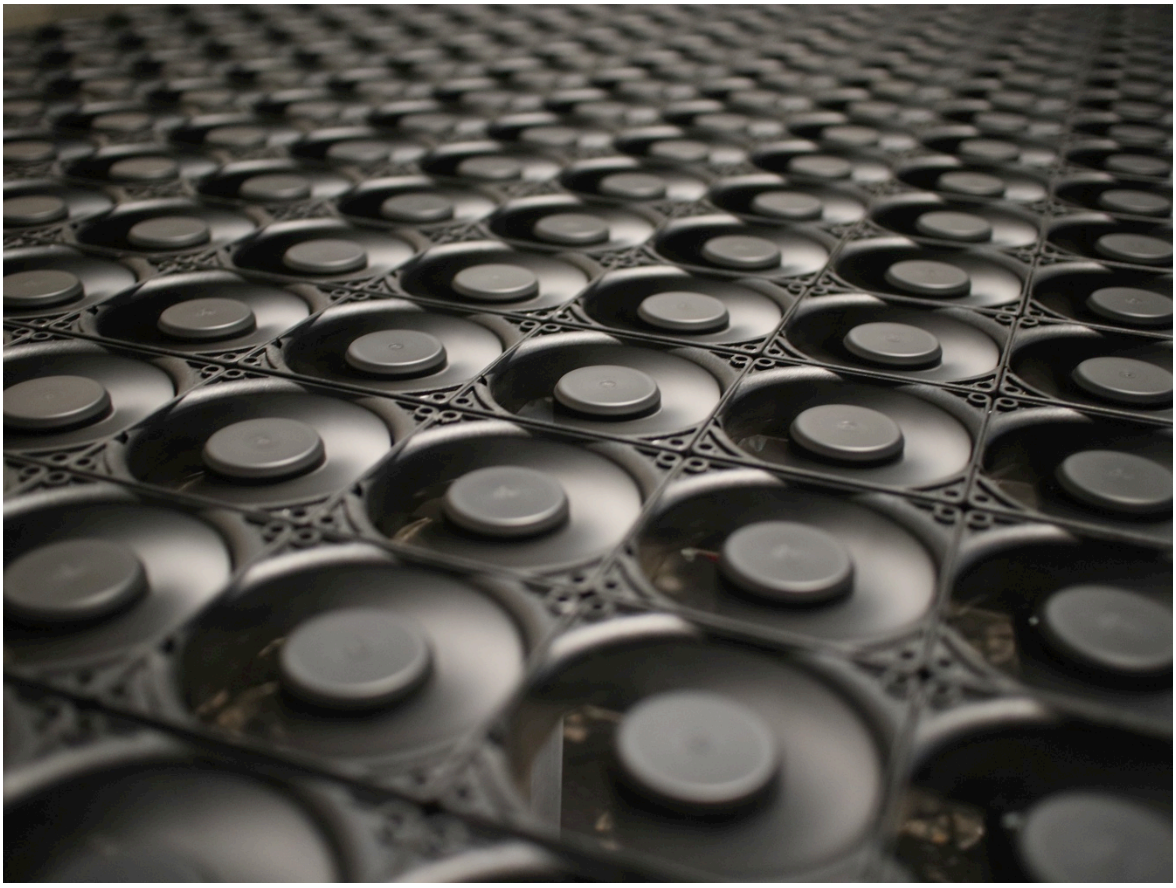

Figure 75 *Mawat*, Museum of Contemporary Art of Castilla and Leon (2018), detail.

Figure 76 *Mawat*, [installation] installed at the exhibition *Región (Los relatos)*, Museum of Contemporary Art of Castilla and Leon (2018).

Conclusions

In 2007, a widely reported incident in a village in South East China, concerned a barren mountainside which was painted green by the local residents[121]. While the reasons behind the action remain obscure, one of the suggested explanations argued that aerial images would recognise the green surface as a forest, resulting in lower taxes for the villagers. The case, as said, is not clear, as it is not clear, neither, if Italian farmers in the 1990s used cardboard sheets with painted olive trees to fool the aerial counting techniques in order to gain a greater share of the European subsidies, as Spanish media broadcasted[122]. The logic at play, in both cases, assumes the existence of a realm of images that regulates the agricultural and forest activities on the surface of lands. This is the domain of operational images that this research has been devoted to analyse: the ambit of imaging practices interweaved with processes of vegetal growth geared to control, measure and regulate its extent and shape.

The first chapter has been dedicated to an agricultural programme that has been shown to be devised from the technical, material and epistemic possibility space of the operational image. The case of the *Inner Colonisation* displays an agriculture broadcasted from a central administrative institution furnished with aerial imagery, ground-level infrastructures as well as the tight control of the settlers. The programme has been related in the chapter to the practices that characterise the current domain of contemporary precision farming, where the circulation of images that measure and prescribe the actions of automated vehicles subsume the production of vegetal growth. The outputs of this visual agriculture are thus connected to imaging technologies in a very particular way: images prescribe how the energy of the sun is transformed into vegetal matter. The growth of crops appears therefore in these cases as if it were a reproduction of these latent images. In other words, vegetal biomass is there produced as a photographic development.

Crops grow like images, being this not only a matter of yield figures but of relations between individual plants also: lettuces of the same field, for instance, are related to each other; they are pixels, so to say, of the same image. In this regard, the notion of operational image that has been presented in this research and its relation to vegetal growth is fundamentally logistical; echoing John D. Peter's words: "The job of logistical media is to organize and orient, to arrange people and property, often into grids" (2015, p.37). This image-like view of crops subsumes also the

[121] See for instance The Guardian's report, 14 February 2007: "China takes DIY approach to mountain greenery", https://www.theguardian.com/world/2007/feb/14/china [Accessed 30 April 2019].
[122] See in this vein "Olivos falsos" [fake olive trees], in El País, 25 November 1997: https://elpais.com/diario/1997/11/25/madrid/880460683_850215.html [Accessed 30 April 2019].

agricultural workers, which become consequently workers of the image. Their labour, following Rossiter's work on logistical media, "underpins the traffic of infrastructure and circuits of capital" (Rossiter, 2016, p.6). From the point of view of the circuits they belong to, they don't farm but operate as a component of a technified environment[123] — while being explicitly represented as such: in the case of the *Inner Colonisation*, as cart-modules. Subsumed within the circuits of the image, however, the characteristic interweaving of soil and agricultural work — which, according to Maria Puig de la Bellacasa's notion of bioinfrastructure, entails also the labour of myriads of nonhuman entities (2014) — remains invisible. There is a tension then between the lands that produce green commodities and the soils and labour of their bioinfrastructure, which is disregarded. This tension characterises the transformation of agriculture into an image-like activity. The practice-based works in this project have worked in this regard as devices that install the process of becoming image in order to materialise this transformation in the exhibition space. Accordingly, the research has been focused on setting up the conditions to display it — and literally assemble it, as installations —. The grid, the digital screen and the systems of machine vision as they relate to landscapes, plantations and surface operations have become the mechanisms for the practice-based works presented in the first chapter to create these conditions.

Figure 77 Image of an advertisement of Toshiba as a hydroponic manufacturer; the farm occupies and old floppy-disk factory. Source: https://www.geek.com/science/toshibas-old-floppy-disk-factory-grows-lettuce-that-doesnt-need-washing-1609617/ [accessed 30-4-2019]

[123] This characterisation of the labour by the settlers in the case of the Inner Colonisation is already present in early critiques to the program, citing Lewis Mumford's megamachine (Gaviria, Naredo y Serna, 1978, p. 18).

Beyond the space between vegetables of the same agricultural field, the scale of the single plant is also affected by contemporary visual agriculture. The case of hydroponics is particularly eloquent in this aspect. While not cited in the dissertation so far, a standard set of images and promotional videos of a hydroponic plant has been particularly inspiring in the research on the topics of the second chapter. The video displays a large agricultural factory, where vegetables are grown in shelves, without soil, inside environments of controlled light and connected to pipes that supply them with their water and mineral needs. When the camera approaches the shelves, a well-known media corporation brand logo emerges to the foreground: Toshiba, with its familiar bold capital letters, is the owner of the farm (Figure 77). While it is no surprise to see a technological corporation involved in hydroponic agriculture, the image of plants being grown in the boxes of calculated artificial light produced by a TV manufacturer crystallises most of the elements that have been addressed in the second chapter.

In that chapter, I have shown how in the context of plant physiology of the last decades of the 19th century, plants were introduced inside experimental set-ups built up with elements linked to visual technologies, photography in particular. Being both photography and vegetal growth practices of light, I have shown how these experiments made camera-less photography coincide with cultural technique. That is, the growth and shape of plants was modelled by these scientists after the photographic formation of images, acknowledging then the ideas sketched in the first chapter. As it has been explicated, also, while contemporary discourses in photography theory have addressed the life-forming character of the photographic cut, I have presented instead the relation between life and photography in the opposite direction: the life-forming mechanisms in plants was modelled after the photosensitive component of photography. In other words, in these experiments, the animated was being transferred from the realm of the plant to the space of possibilities of the photochemical. Moreover, once the growing intensity of the plant was understood as an imaging entity, it immediately started to be measured as such. Accordingly, and announcing the role that visual footprints and indexes would have in the later machine vision monitoring of the vegetal covers of the Earth, several parameters linked to visual media were proposed to characterise plant species: exposure times, the colour of the leaves, the leaf area index and the spectral lines. Therefore, the imaging at play in these experiments was operational: it aimed to prepare the realm of vegetal growth to be measured, classified and arranged in quantitative visual terms.

A double-bind — in Jussi Parikka's sense (2015, p.14) — ties together imaging technologies and vegetal growth: a recursive relation interweaves them, which has been scrutinised in the research by paying attention to the cultural technique of the grid — in the case of the first chapter — as it was present in aerial photogrammetry, irrigation networks and the partitioning of plots, and — in the case of the second chapter — to the cultural technique of camera-less photosensitivity. It is not only that crops and plants are operationalized as images, but the circuits of the image assimilate the singularities and scales of vegetal life too. This has been the object of the practice-based works presented in the second chapter. *The Quivering of the Reed* and *The Growth of the Eye* explore the extractive relation between the movements of plants and early forms of moving images such as the shadow play or the time-lapse, where the animated images rely either on an endless conveyor belt or a defoliation of vegetal forms. Moreover, the upscaling of the extractive greed of the operational image has been further elaborated in the form of a workshop, *An Earthology of Moving Landforms*, where the large scale of the datasets of images needed to fuel machine learning models related to environmental phenomena was brought to the working table, together with the technicalities involved.

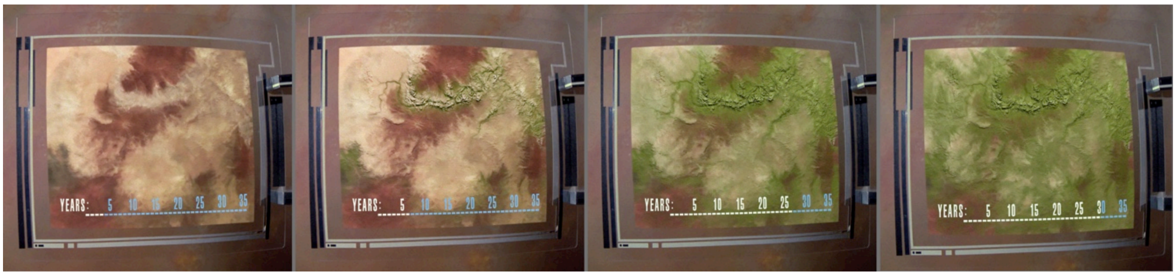

Figure 78 Sequence of images of the animation of the terraforming of a planet in the series Star Trek. Source: https://memory-alpha.fandom.com/wiki/Terraforming [accessed 30-4-2019]

The widening of the domain of operational images to the realm of plants links together the three chapters in the research. The third one, in fact, has dealt with the terraforming ability of plants. The fact that they do not only transform light into chemical energy, but that in the process they liberate oxygen to the atmosphere, regulating its gaseous mix for harmful radiations to be stopped, did not remain unperceived to the plant physiologists of the end of the 19th century, nor to the biochemists of the early 20th. Following this work, in the chapter I have explicated how green became not only the characteristic of the photosynthetic plant, but also the signature of the self-regulated planet. This meaning, as it should be clear so far, that this terraforming trait was being reterritorialised from the surfaces of the plants to a different techno-scientific complex linked to the circuits of the image. Anecdotally, the notion of terraforming popularised by the series Star Trek displays this transfer to the image in literal terms: a 30-year time-lapse depicts it as the spreading of a green layer on top of a static view of the surface of the planet, with the techniques of geo-engineering operating in the background of the colouring process (Figure 78).

Through a critical reading of Vladimir I. Vernadsky's *The Biosphere*, I have demonstrated how in his work the living was considered as a planetary whole in terms very similar to those used by physiologists to address vegetable matter. Despite his careful efforts trying to avoid reductionist approaches when addressing the complexity of life on the planet, the idea of a thermodynamic engine operating through photochemical operations prevails. In the words of one of his contemporaries, this was a World Engine, an empire of biochemical processes linked to the energy of the Sun (Lotka, 1925, p.360). If the plant physiologists of the second chapter had introduced at the core of the animated plant an imaging mechanism able to develop images of vegetable matter, the third chapter has presented its upscaled version, as a thermodynamic engine regulating the homeostatic planet and responsible of the growth and movements of its living matter.

This upscaling has been finally linked in the research to different contexts operating at the same time in the early 20th century. The global circulation of plants between experimental stations and plantations, on the one hand, and the notion of the globe as embedded in the material culture of glass in the life sciences, on the other, have been linked to Vernadsky's work. But on top of these, the vast scale of the transformations due to the chemical industries of the time is presented as the techno-scientific counterpart of the biogeochemists' imaging World Engine. Chemistry, as an empire of replacements and of synthetic colours, in Esther Leslie's words (2006), absorbed at the same time agriculture and the production of the material supports of visual media. In the chemical complex, photosensitive substances were produced next to fertilisers and pesticides. That is, Vernadsky's conceptualisation of the model of the planetary green matter parallels the material spreading of the chemical surfaces all over the planet. The ability to cloth the Earth with new colours and wrap it with endless images coincided with the replacement of its vegetable cover with synthetically nitrogenised agriculture. Imaging and vegetal growth meet again, at the planetary scale, in the chemical alchemy of the synthetic times.

This planetary reterritorialisation is addressed in the installations presented in the third chapter. In the three of them, the phantasmagorical nature of a world made out of images is explored. In a *Still Life with Screensavers and Landscape Fabric* the effect of wrapping monitors with strips of geotextiles used to cover agricultural land makes the orbiting images of plantation fruits appear like spectral presences as their light is filtered through the tiny holes of the plastics. In *When the Auroras Descended to the Earth*, in turn, the magnetic shadow of chemical warfare is presented as a form of ground-level aurora, caused by the light of operational images instead of the rays of the Sun. Its haunted compasses recall also the movements of the fans in the artificial soil in *Mawat*, when they act as speakers able to emit voices. In this last installation, the technical ground of industrial agriculture is presented as a surface of fans that projects likewise currents of wind as well as old agricultural songs. As Donna Haraway put it, "our machines are disturbingly lively and we ourselves frighteningly inert" (1991, p.152). A similar transfer can be observed in a planet were vegetal growth is controlled by images and administered as such. The altered winds, the chemical auroras and the strips of plastic bring to the foreground not only a context of ubiquitous extinction, over-nitrogenation and depletion of soils, but also the role that the growth of visual media has had in this erosion of life in the planet. In the ruins of the image, paraphrasing Anna L. Tsing, different folds of the surface are needed. The simple gestures and elemental operations presented in the research have been an assay of these.

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