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Title:
Un-earthing synthetic biology 'natural' products. A global ethnography of stevia / ka'a he'ê.

Un-earthing synthetic biology 'natural' products.
A global ethnography of stevia / ka'a he'ê.

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A dissertation submitted to the University of Bristol

in accordance with the requirements for award of the degree of

Doctor of Philosophy (PhD) in Global Political Economy

in the Faculty of Social Sciences and Law,

School of Geographical Sciences.

JUNE 2021

(89475 words)

Research Summary.

Over the last decade synthetic biologists have developed novel ways of replicating valuable molecules and compounds naturally found in plants through a technique called biosynthesis. Heralded as a 'disruptive innovation' biosynthesis has become commercially promoted as an alternative to farm-sourced production methods for 'natural' products within framings of efficiency and sustainability. This thesis takes as a lens one of the first synthetic biology 'natural' products to reach the market: a plant known as stevia, or ka'a he'ê, that shot to international fame for its natural ability to rival sugar and artificial sweeteners with zero-calories. Through a multi-sited global ethnography, I follow stevia/ka'a he'ê from its biosynthesis in a corn-fed biorefinery in the USA, to its endemic origins in Paraguay where it is known as a sacred family member, a medicine, as well as a campesino cash crop long promised to bring rural socio-economic development. Once transplanted from Paraguay stevia was increasingly appropriated and (com)modified into a corporate cash molecule, this time shrouded in globalised promises of rural poverty alleviation and farmer empowerment. This research reveals strikingly the breaking of small farmer promises since the 2018 co-emergence of biosynthetic and molecularised versions of stevia hit the market. Following stevia to the original knowers and growers of ka'a he'ê reveals a deep-seated sense of injustice in Paraguay over corporate narratives of sustainability and authenticity of biosynthetic products, gravitating most starkly in the disjunctures over ownership. Ownership and who should benefit from the living world is a key question at the dawn of biosynthetic 'natural' products and is sparking frictious debate in multi-lateral negotiations over the consequences of synthetic biology. In the final part of this multi-sited ethnography, I turn to conferences of the United Nations Convention on Biological Diversity (CBD). There, stevia is mobilised as both an example of a 'genetic resource' requiring a benefit-sharing agreement between corporate users and Indigenous traditional knowledge holders; and simultaneously as an example of a sustainable crop threatened by synthetic biology. Stevia's latest interpretation as 'cash DNA' (a privately held digital genomic sequence) reveals reconfigurations of value and ownership in an emerging trajectory for high-value plants away from small farmers towards the further industrialisation of agriculture. I critique the molecularised logic of governing structures and conclude that four key dis/connects un-earthed by this research, authenticity, sustainability, ownership and (in)justice, expose and entrench processes of expansion and expendability of industrialised food and agriculture. These processes expand corporate consolidation at the expense of complex and diverse socio-agricultural systems, small farms, local knowledge and biocultural diversity. The stories of stevia / Ka'a he'ê hold vital lessons for fair and equitable futures and the stakes riding on (holistic) sustainability assessments guiding uses of the living world.

Author's declaration

I declare that the work in this dissertation was carried out in accordance with the requirements of the University's *Regulations and Code of Practice for Research Degree Programmes* and that it has not been submitted for any other academic award. Except where indicated by specific reference in the text, the work is the candidate's own work. Work done in collaboration with, or with the assistance of, others, is indicated as such. Any views expressed in the dissertation are those of the author.

SIGNED: *M. R. Bond* DATE: 28.6.2021

Acknowledgements.

In September 2014, Will my partner uprooted his life in Cornwall to pursue my academic ambitions in Bristol. His humour, support, and stead-fast positivity have helped me navigate our boat-based family life through countless unchartered water and territory over the past seven years, without whose companionship I couldn't imagine. Thanks to Lowen, our daughter who came along in 2017, to remind me the values of silliness, stories, and play. Thanks to my mum and dad, who have been super grandparents and amazing support and encouragement. And to all my best friends for just being the best.

Were it not for the enthusiasm of my undergraduate dissertation supervisor Dinah Rajak at the University of Sussex I would have never even considered, nor imagined I would be capable of pursuing a PhD. Thanks also to the early support of Andy Stirling, Jeffery Henderson, Gail Davies, Ian Cook, Adrian Flint, Roy Maconachie and Susan Baker who encouraged my application for a '1+3' Economic and Social Research Council (ESRC) award for both Master of Research and PhD.

Very important thanks go to my academic advisors Maria Fannin, Karen Tucker and Clare Saunders who have shared generously their wisdom, time and care. Maria Fannin has been there from the early days of making an application to the University of Bristol, while Karen Tucker and Clare Saunders took me on in early 2016. I so am grateful for all their positivity, enthusiasm and encouragement, as well as of course, their sharp analytical engagement and guidance without which this thesis would not have been possible.

I formed long-lasting friendships and bonds with fellow PhD students and academic colleagues in the Bristol Geography department, the School for Sociology, Politics and International Studies (SPAIS) and especially those of us between departments on 'interdisciplinary PhD pathways'. Very fond are my memories of sunny lunchtimes in the South West Doctoral Training Centre (SWDTC). I later found much warmth and community working on the 'PhD corridor' in the University of Exeter's Environment and Sustainability Institute in Penryn, Cornwall, where I re-located in 2017.

Over the course of my research people came into my life which changed things. One of those pivotal people was Deborah Scott. Debby – a research fellow at the University of Edinburgh's Engineering Life project – joined me in Cancun to attend my first UN Biodiversity 'COP' conference. Having worked at the CBD Secretariat in Canada, Debby's knowledge was invaluable for navigating the politics and processes of UN negotiations. We have since published together and she has become a special friend.

One of the most dedicated campaigners on issues of social and environmental justice regarding new technologies I met during my studies was Jim Thomas of the ETC group. It was Jim who first suggested I register to observe the meetings of the UN CBD to see for myself how the governance of synthetic biology was evolving. I am grateful to Jim for alerting me to the world of multilateral governance, and his kindness and trust, openness and transparency into the operations of civil society organisations and NGO campaigns.

Thanks also to all the delegates during SBSTTA, COP13 and COP14 who agreed to be interviewed, and to the CBD Alliance and all the NGO's and IPLCs for allowing me to sit in on their meetings every morning.

Anthropologist, Marcus Glauser was another pivotal person to my research. Marcus helped bridge worlds between Indigenous, campesino, military, state, rural and urban in Paraguay, his steering through languages and cultures and practical aspects of daily life were invaluable.

Last but certainly not least, I would like to pay great thanks, *muchas gracias* and *aguyje* to all those who agreed to participate in my research, whether it was through interviews, or allowing me to be present as an observer. The kindness and passion of all of those who were willing to teach me about stevia / ka'a he'ê in Paraguay, the bioeconomy in the US, the science of synthetic biology and the knowledge politics of UN negotiations. I hope I have given your knowledge, passion, commitment and hopes the justice they deserve.

This thesis is dedicated to all the children I met on this journey

and to

cultivating a fairer future for all.

(Source: Authors own photo of her daughter Lowen and Pai Tavyterâ boy. A family home, Itaguazú, Paraguay, 2018).

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List of acronyms and abbreviations.

ABS – access and benefit sharing
AHTEG – ad hoc technical expert group
CBD – Convention on Biological Diversity
CEO – Chief Executive Officer
COP – Conference of the Parties
CPB – Cartagena Protocol on Biosafety to the Convention on Biological Diversity
CRISPR – Clustered Regularly Interspaced Short Palindromic Repeat.
CSO – civil society organization
EC – European Commission
EU – European Union
FAO – Food and Agriculture Organization of the United Nations
FDA – Food & Drug Administration (of the U.S. Government)
GMO – genetically modified organism
GRAS – Generally Recognised As Safe
IAASTD – International Assessment of Agricultural Knowledge, Science and Technology for Development
IPLC – Indigenous Peoples and local communities
IPR – intellectual property rights
ITPGRFA - International Treaty on Plant Genetic Resources for Food and Agriculture
LMO – living modified organism
MSE – multi-sited ethnography
NEI – New and Emerging Issues
NGO – non-governmental organization
OECD – Organisation for Economic Co-operation and Development
OCPs – Organisms, Components and Products (of synthetic biology)
PCSBI – US Presidential Commission on the Study of Bioethical Issues
Reb – Rebaudioside
R&D – Research and Development
RRI – Responsible Research and Innovation
SBSTTA – Subsidiary Body on Scientific, Technical and Technological Advice
SCBD – Secretariat of the Convention on Biological Diversity
SDGs – Sustainable Development Goals
SECE – Socio-economic, cultural and ethical
STS – Science and Technology Studies / Science and Technology in Society
SynBio – Synthetic biology
UN – United Nations
UNCTD – United Nations Conference on Trade and Development
UNEP – United Nations Environment Programme
UNFCCC – United Nations Framework Convention on Climate Change
USDA – United States Department of Agriculture
WEF – World Economic Forum
WG – Working Group
WTO – World Trade Organization

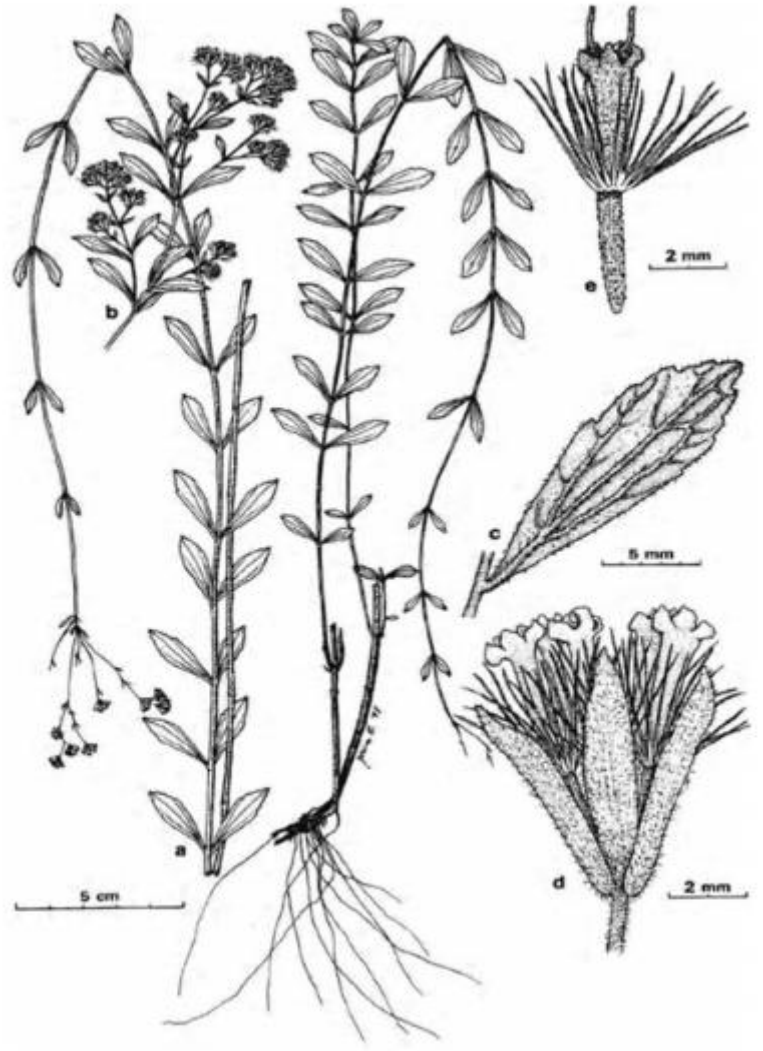


Figure 1. Analytical drawing of Stevia *rebaudiana* Bertoni. (a) A specimen collected from wild population in Paraguay. (b) A cultivated specimen. (c) A leaf, enlarged. (d) A capitulum with open florets. (e) A floret at anthesis. *From collection Soejarto 5174 & 5417* Illustration by Zorica Dabich, Chicago Field Museum.

(Source: Kinghorn 2002: 21)

Introduction.

Plants sustain life. The biological diversity of plants, plant properties and the multi-species ecosystems of which they are part have been intrinsic to human health, culture and socio-economic development and evolution. Beyond basic food stuffs, plant products, compounds, chemicals and processes form the basis of countless modern medicines, oils, papers, waxes, cosmetics, fragrances, detergents, flavours, textures, dyes, and much more. Two hundred thousand natural plant products are known to humanity representing just 15% of approximately 350,000 plant species, and less than 1% are known of an estimated one trillion microorganisms thought to exist (Locey and Lennon 2016; Wurtzel and Kutchen 2016: 1232; Bagley 2017). These estimates suggest humanity has only scratched the surface of a vast number of processes, products and chemicals present in the microbial and plant kingdoms. Scientists working in the interdisciplinary field of synthetic biology assert there are 'a plethora of new chemicals and metabolic pathways' that are 'hidden in plant genomes awaiting discovery' (Wurtzel and Kutchen 2016: 1232).

Synthetic biology is a field defined by its aims 'to facilitate and accelerate the understanding, design, redesign, manufacture and/or modification of genetic materials, living organisms and biological systems' (CBD 2016c). Synthetic biology has been described as the landmark 'step from reading the genetic code, to writing it' (Craig Venter quoted in Pilkington 2007). Synthetic biology (or SynBio as it is commonly referred to) is considered 'a toolbox of techniques' encompassing a number of unprecedented bioengineering and computational advances made over the past 10-20 years, particularly in fast low-cost DNA sequencing and gene synthesis, gene/genome editing (such as CRISPR-Cas9)[1] and synthetic metabolic pathway engineering which combined have grown into a multi-billion-dollar industry (Bueso & Tangney 2017). While the creation of 'synthetic life' may still be in its infancy, 'computational tools for genome assembly' scientists assert 'have revolutionized pathway discovery in plants', and commercial industrial biorefineries have been constructed over the past several years enabling the first biosynthetic 'natural' products to reach the market (Wurtzel and Kutchen 2016: 1232). Natural products are increasingly looked upon as a significant growth area for new products and medicines with forecasts of markets worth trillions of dollars to the global economy (Li and Vederas 2009; Bagley 2017; Wurtzel and Kutchen 2016; Earth Bank of codes 2021).

[1] CRISPR is an acronym for Clustered Regularly Interspaced Short Palindromic Repeat. It is a gene-editing technology discovered in 2012 that is widely labelled as revolutionary for allowing scientists to relatively quickly target specific genes, and 'cut' and 'paste' genes into DNA, its applications are vast and (Harvard 2014)

Chemical synthesis is not new. For over a century, scientists have been trying to replicate the qualities of compounds and properties found in plants. Examples include synthetic rubber, artificial food flavourings, chemical dyes, synthetic drugs, hormones and more. However, advances in synthetic biology have opened up novel ways to *biologically* synthesise natural properties and compounds. 'De Novo Biosynthesis' – as it is referred to – rests on genetically modifying microorganisms (commonly yeast or bacteria) with synthetic genomes using DNA sequences from multiple species, enabling the microorganisms to 'metabolise', 'ferment' or 'convert' sugars (commonly from sugarcane or corn) into compounds that are virtually exact replicas of their biological counterparts (Ni et al. 2015; Bagley 2017). Commercial excitement centres on the ability to market biosynthetic compounds as 'natural' products due to their chemical equivalence to their plant or animal counterpart (despite the vast divergence in the *way* that they were produced). As a prominent synthetic biologist announced the ambition of the new field is 'to make any compound produced by a plant inside a microbe' (Keasling quoted in Spector 2009).

It is this technological shift toward the biosynthesis of 'natural' products, the changing 'nature' of production, and what that implies and reconfigures, that is the fundamental concern and starting point of this thesis.

Having been in the R&D phase over the past 10 years, an increasing number of biosynthetic 'natural' products or 'SynBio products' are entering the market (see table 1 below). Despite the techniques' relative novelty, the biosynthesis of natural products has become a rapidly growing field of scientific and commercial endeavour particularly in Europe and the United States and has attracted substantial public funding and private venture capital and today boasts research centres, specialist journals and global conferences dedicated to the field.

Table 1.0 'Examples of SynBio products that could replace naturally sourced plant- or tree-derived biological resources' (Source: UNCTD 2019: 13)

Compound	Natural source	Status	BioTrade sector
β-ionone	Rose (Rosa damascena, Rosa centifolia)	In development	Flavour/Fragrance
Agarwood aromatic compounds	Agarwood (Aquilaria malaccens)	In development	Personal Care/ Cosmetic
Artemisinic acid	Sweet wormwood (Artemisia annua)	Commercialized	Pharmaceutical
Cinnamaldehyde	Cinnamon tree (Cinnamomum zeylanicum)	In development	Flavour/Fragrance
Cocoa butter	Cocoa tree (Theobroma cacao)	In development	Food
Forskolin	Coleus forskohlii	In development	Pharmaceutical
Geraniol	Madagascar periwinkle (Catharanthus roseus)	In development	Fragrance
Ginsenosides	Ginseng (Panax ginseng, Panax quinquefolius)	In development	Pharmaceutical
Limonene	Citrus	In development	Fragrance
Linalool	Variety of plants	In development	Fragrance
Nerolidol	Variety of plants	In development	Fragrance
Nootkatone	Grapefruit (Citrus paradisi)	Commercialized	Fragrance
Patchoulol	Patchouli (Pogostemon cablin)	Commercialized	Fragrance
Raspberry ketone	Raspberries, cranberries, blackberries	In development	Fragrance
Resveratrol	Red grape (Vitis vinifera)	Commercialized	Pharmaceutical
Sabinene	Comb bushmint (Hyptis pectinata)	In development	Flavour/Fragrance
Saffron	Saffron crocus	In development	Flavour
Santol	Sandalwood (Santalum album)	In development	Fragrance
Shikimic acid	Star anise	Commercialized	Pharmaceutical
Shinorine	Algae (Porphyra umbilicalis)	In development	Cosmetics
Steviol glycosides	Stevia (Stevia rebaudiana)	Commercialized	Food
Squalene	Olive oil, Shark liver	Commercialized	Personal Care/Cosmetic
Valencene	Orange (Citrus sinensis)	Commercialized	Fragrance
Vanillin	Vanilla orchid (Vanilla planifolia, V. tahitensis)	Commercialized	Flavour/Fragrance
Vetivone	Vetivier (Chrysopogon zizanioides)	In development	Fragrance

Announcing the commercialisation of the world's first ever 'fermented' cannabinoid (conventionally sourced from the *Cannabis sativa* plant), the CEO of SynBio company Amyris stated 'we are very excited about the disruptive nature of this molecule' (Amyris 2020). Biosynthesis has been accompanied by celebratory narratives heralding it a 'disruptive innovation' offering economically competitive substitutes to the status quo of unsustainable production methods or unstable trade relations (SynBiobeta 2019; Møller 2014). 'Lab-grown natural products' have been popularised in public discourse as signalling the dawn of 'cellular agriculture' or 'biological cell factories' under banners touting 'agriculture 2.0' framed as a solution to environmental and climate crises in a post-industrial imaginary (Monbiot 2020). Lab-grown meat, honey and human breast-milk have received particular attention, but the biosynthesis of plant products and compounds which represents the majority of current research and development (R&D) has been largely overlooked in mainstream media. This thesis looks at the biosynthesis of plant compounds as they pose a distinct set of questions compared to those raised by the biosynthesis of animal and human compounds and are already entering the market without labelling distinguishing how they were produced. The most notable difference is that companies producing biosynthetic replicas of animal or human compounds have amplified their production as being 'lab-grown' in public discourse, distinguishing the product from its animal or human origin and distancing themselves (to a lesser degree) from ethical dialogues about impacts on the producers, mothers, cattle farmers or beekeepers for example. Whereas companies biosynthesising plant compounds have significantly shied away from the term 'lab-grown' and down-played the word synthetic, instead referring to their products as 'naturally-produced' 'nature-identical' or 'nature-inspired' and touting 'no artificial ingredients' labels, occasionally referring to 'age-old fermentation' as production technique (Cargill 2021b; Amyris 2021). In amplifying equivalence these companies aim to sustain public imaginaries of the product's plant-based counterpart rooted in established socio-ecological and agricultural systems. It is the equivalence to the 'natural' product that is the most lucrative selling point for the commercial developers, who are targeting natural products with which the biosynthetic replica can compete.

The technological and commercial potential of synthetic biology and the envisioned global bioeconomy in which it is positioned to lead, has made the use, ownership and benefits derived from biological and genetic resources increasingly fraught at the international level. Biosynthesis, and the toolbox of synthetic biology techniques underpinning it have been considered a 'new and emerging issue' in governance institutions over the last 10 years (CBD 2012; FAO 2017). As implications of commercialisation begin to unfold they remain understudied and uncertain, a number of UN institutions approach synthetic biology as having both 'potential positive and adverse effects' upon society and the environment, yet the real-world impact of the technologies remain globally contested (CBD 2015 & 2018; FAO 2017; UNCTAD 2018 & 2021). This thesis contributes to the deficit of 'real-world' studies called for by policy-makers and scholars for more 'granular' analyses and nuanced understandings of the 'political economy of synthetic biology' by focusing 'on real-world applications vis-à-vis current modes of production of compounds that synthetic biology seeks to replace' (Ribeiro & Shapira 2019: 318). This thesis focuses and investigates the 'real-world' stories of a plant popularised as the 21st century's answer to sugar and obesity – stevia – and the diverse socio-ecological relations and knowledges that are entangled in the struggle to own and benefit from it.

Un-earthing stevia: research aims and rationale

The tender perennial plant at the centre of this research is known in Paraguay as *ka'a he'ê* (pronounced *car-ar hay-ay*), and elsewhere largely by its Latin classification as *Stevia rebaudiana Bertoni*, a member of the Asteraceae (sunflower) family it is most commonly referred to by its genus 'stevia'.

Stevia is a plant that was little known outside of Paraguay some 30 years ago, but throughout the 2000s and particularly since 2008 stevia has been transformed into a globalised commodity famous for its ability to 'naturally' sweeten foods and drinks 3-400 times more intensely than sugar with zero calories or dental decay. As a less-exploited 'low-volume high-value' crop it has been one of the first targets of biosynthetic commodity substitution by a number of SynBio companies, who promote their products as more 'sustainable' than leaf-derived stevia. However, as this thesis will describe in detail, the potential to substitute not just plant compounds but small farmer livelihoods, knowledges, agro-ecosystems and promises of rural development has made stevia and the sustainability claims around biosynthesis heavily contested and hence why this plant provides a valuable lens to illuminate the diverse stakes, values, subtle shifts and definitional changes, (in)direct impacts and implications of synthetic biology techniques.

To develop a detailed empirically-grounded account, I adopt multi-sited ethnography as a methodological approach to 'follow' synthetic biology through the journey of stevia from its biosynthesis in an industrial corn-fed biorefinery in Nebraska, USA, to its endemic origins in the Indigenous territories on the borderlands of Paraguay and Brazil and across the small farms in Paraguay's stevia growing regions, as well as following the physical, digital and discursive manifestations of the plant internationally, and through the multi-lateral negotiations on synthetic biology ongoing at the UN Convention on Biological Diversity (CBD).

Following stevia ethnographically across the multiple 'worlds' that give the plant meaning provides a way to explore - through real-world encounters - how the shift toward biosynthesis plays out within and between established socio-ecological relations of production, diverse uses and knowledges of plants. In doing so I aim to illuminate what is obscured by chemical molecular equivalence, and the drivers behind biosynthetic obscuration.

Adopting a grounded and ethnographic approach to the field of enquiry my research questions arose through the course of the fieldwork both in response to the concerns raised by the research participants themselves as well as through my own observations of the disjunctures and connections between the (inter)national field sites traversed. I found five distinct ways of knowing and relating to stevia /ka'a he'ê which stood out as transitionary moments marking a change in the way the plant was understood and treated – I characterise these five distinct moments (and the people, places, spaces, concepts and narratives connected to them) as encompassing 'worlds of stevia'.

I ask:

How is 'stevia' understood and given meaning in the social, cultural, ecological, agricultural, political and bioeconomic worlds that have developed around it?

In what ways is synthetic biology implicated across the worlds of stevia?

What does synthetic biology establish or expand? How is the biosynthesis technology being reified, where are the sites and types of expansion happening, who is benefiting and what is being strengthened?

Of equal significance, what is being *expended*, disrupted, or weakened by this expansion. How and where do the reconfigurations of production manifest? How do these expend or reconfigure types of ownership, concepts of naturalness, or ways of life?

What are the stakes riding on the viability of stevia for small farmers?' And what is lost in sustainability comparisons between isolated molecules and complex socio-agro-ecological systems?

It is not simply a question of what and where expansion and expendability are playing out, but *how* they are playing out. Hence this research also unpacks the political drivers, rationales, objectives, values and promissory narratives surrounding both biosynthetic modes of production as well as those ascribed to the diversity of other ways of utilising, reproducing, cultivating and relating to stevia.

Finally, I ask how are such bioeconomic processes, diverse knowledges and contestations I observe 'on the ground' across the worlds of stevia playing out and feeding into global decision-making on synthetic biology at the UN Convention on Biological Diversity?

Answers to such questions were illuminated through thematic data analysis revealing five distinct ways of knowing and relating to stevia /ka'a he'ê and I structure the empirical chapters of the thesis around these distinct interpretations of 'stevia'. I start with the biosynthetic interpretation that understands stevia as a pioneering bioeconomy commodity. Then I return to the original interpretation of stevia as ka'a he'ê as a sacred family member of the Guaraní Peoples. From there the chapters follow on in a chronological order, as stevia was extracted from Guaraní territory and became interpreted as a campesino cash crop for rural development in Paraguay, eventually becoming a globalised commodity and largely interpreted for the sweet molecules found in its leaves which I characterise as stevia's transition into a 'cash molecule'. I interrogate molecularising processes in agriculture being expanded through biosynthesis that are resulting in reductionist understandings, separating culture from 'nature' (the living world) and the social from the ecological, a process I observe reflected in the contestations ongoing at the UN Convention on Biological Diversity (CBD), where stevia is being debated in the context of synthetic biology uncertainties. I characterise the latest interpretation of stevia as 'cash DNA' as the ultimate manifestation of molecularisation, as the plant's entire genome is sequenced and uploaded to a private commercial database.

These five 'worlds of stevia,' although diverse, are inseparable, entangled and most importantly, they are implicated by one another. The interconnectivity between 'worlds of stevia' and the processes and results of expansion and expendability can be most clearly observed through the disjuctures and frictions that connect them. Thematic data analysis found such 'dis/connects' around 4 discursive zones on sustainability, authenticity, ownership and justice, these zones manifested in narratives, practices and experiences between the 'worlds' of stevia, and I consider and contrast their dynamics at the end of each chapter.

It is increasingly recognised that converging nano, bio, digital and artificial intelligence technology within and beyond the field of synthetic biology is outpacing policy-makers ability to comprehend, let alone regulate it (Merchant 2011;

Wynberg & Laird 2017). The challenges are compounded by debates over when is the best time to regulate: implementing rules too soon is seen to stifle innovation, while once technology is established impacts are already playing out and it is seen as too late to regulate (Genus & Stirling 2018). Synthetic biology 'natural' products may enable more benefits to flow to the richer patent-holding countries at the expense of the poorer nations, whose economies rely more heavily upon primary production, and there are mounting concerns over whether this technology will exacerbate the global technological and socio-economic divide (UNCTD 2019 & 2021). Research unpacking the benefits biosynthesis claims to offer has been overlooked, and scholars of 'responsible research and innovation' increasingly recognise that 'without a rich picture that connects synthetic biology to specific places, historical events, expectations, uncertainties and, importantly, the technical and material aspects of transitions, an attempt to draw an agenda for action would be largely speculative' (Ribeiro & Shapira 2019: 312; Schyfter & Calvert 2015). This research contributes to such an 'agenda for action' by providing a 'rich (ethnographic) picture', in the hope that – as one former Paraguayan minister told me – 'stevia should be a learning case for the world'[2].

The research also contributes to a small but growing body of evidence and examples 'from the bottom-up' providing insights for policy-makers, governments, academics, NGO practitioners as well as communities themselves concerned about the dynamics of biosynthesis over other high-value plant compounds which either currently sustain rural livelihoods or are newly- or not (yet) commodified plants, herbal (traditional) medicines, or (socio-ecological) resources, used, cultivated and/or known by Indigenous Peoples or local communities.

Chapter Overview

This thesis is organised into seven chapters.

Chapter One presents an overview of scholarly literature which has informed my approach to the field. I discuss some key conceptual and theoretical work that has developed from a field I characterise as 'biocapitalism studies'. Before I explore the contributions of more recent and empirical body of knowledge at the intersection of synthetic biology, bioeconomy and (fair and equitable) agrarian futures. As a relatively new field of enquiry the social science of synthetic biology involves a multi- and inter-disciplinary set of scholars, who approach the field in differing ways. I focus on the bodies of work which are particularly relevant to the changing 'nature' of production, particularly through the work of political geographers, and agrarian and peasant studies scholars on the global political bioeconomy, and the predominant social science approach to synthetic biology in the UK in the field of 'Responsible research and innovation' studies. I also consider an emergent area of work on disruptive innovation and look at research advocating an application-oriented turn toward real-world cases.

Chapter Two outlines the conceptual and methodological approach of the study. I describe the research method of 'following things' through my adoption of multi-sited ethnography and the central role the method has played not only in defining the object of study as I encountered worlds of synthetic biology, stevia and governance but also how it contributes a more globally connected perspective to previous single-site approaches to the social study of synthetic biology. I describe in more detail my conceptualisation of the 'worlds' of stevia, and the discursive zones of connection,

[2] Personal communication (ref.41). COP13, Cancun, Mexico. 09/12/2016.

friction and disjuncture I identify as 'dis/connects' operating between the 'worlds'. I close by describing my commitment to an 'ethnographic sensibility' as an explicitly ethical approach to fieldwork and research participants whilst also considering and acknowledging its drawbacks and limitations.

Chapter Three is the first of five empirical ethnographic chapters 'following' stevia. Opening with an ethnographic vignette in the Cornhusker state of Nebraska, in the Midwest United States, this chapter follows the cutting edge of stevia production to a vast corn-fed industrial biorefinery. Unpacking the agricultural and historical significance of corn in the United States helps understand the political economic conditions that make the bioeconomy and biosynthesis technology viable and attractive to multinational corporations such as Cargill. I then turn to the promissory narratives and framings of biosynthetic stevia branded 'EverSweet™' by Cargill and their partner SynBio company Evolva as a more sustainable, efficient, and authentic 'natural' product. This chapter builds towards one of my conclusions that the agro-industrial complex from which biosynthetic stevia emerges is conducive to its reproduction. From the United States I follow stevia to its endemic region in Paraguay, a country that knows the plant and product as ka'a he'ê.

Chapter Four is the first of three empirical chapters based in Paraguay. This chapter describes my stay with the Itaguazú Pai Tavyterâ Indigenous community, where I am invited to hear about their historical, cultural, medicinal, ceremonial and spiritual relationship with ka'a he'ê, and other sacred herbs they understand as 'family members'. Participants described living memories of the excavation and appropriation of wild ka'a he'ê by 'outsiders', revealing a familiar story of (neo)colonial accumulation by dispossession of America's Indigenous Peoples and the transfer of a valuable 'genetic resource' from South to North. Inspired by the promise of international access and benefit-sharing (ABS) legislation, the community have joined forces with other Pai Tavyterâ and Kaiowá Guaraní communities to publish a joint Declaration on ka'a he'ê in opposition to past and continuing injustices, and the current uses and ownership regimes over ka'a he'ê. They summon both their cultural identity and legal rights as equally important in their attempt to gain acknowledgement as the true 'owners' of stevia /ka'a he'ê in the hope to receive benefits to maintain their customary way of life and secure territory.

Chapter Five follows stevia/ ka'a he'ê not far from the Indigenous community to the fields and businesses of Paraguayan campesinos (peasant farmers). Told through personal stories of campesinos and small business owners, I examine the promissory narrative that accompanied the domestication of ka'a he'ê in Paraguay as it became a cash crop for campesino families and rural - later *sustainable* - development. Originating in a century-old prophesy of national economic development, stevia performs a distinct role in a Paraguayan agri*cultural* imaginary as a long-awaited promise-in-the-making for subsistence and small farmers amidst significant accusations of corruption and increasing adversity on frontiers of expanding industrial (soybean) agriculture culminating in land concentration, land eviction, debt and agro-chemical contaminated environments. This chapter reveals the dichotomy of two Paraguayan dreams of 'oro verde' (green gold) between the stevia and soybean agricultural models in which diverse interpretations of sustainability, authenticity, ownership and justice demonstrate the entangled nature of biosynthetic stevia within a complex agricultural legacy and an unfolding future. Despite the global shifts and rural struggles in Paraguay, I find stevia/ka'a he'ê continuing to direct individual, collective and national aspirations.

Chapter Six follows stevia as its promissory narrative as a 'powerful leaf' for sustainable development globalised, and the plant underwent increasing (com)modification transforming it into a corporate 'cash molecule'. Told through encounters with the international stevia industry and corporate contract 'third party farmers' in Paraguay, I explore the molecularisation of the plant into a 'gold-standard' sweetener where stevia has come to be interpreted less as a plant and more as a molecule - a steviol glycoside or a rebaudioside – found in the plant's leaves. I follow how subtle shifts in the molecular re-interpretation and re-configured definitions of stevia are obscuring much broader socio-ecological shifts underway in Paraguay. During fieldwork in 2018 I found stevia's promise in turmoil. The commercialisation of biosynthetic EverSweet™ and a new molecularised stevia variety Starleaf™ co-emerged in 2018 as patented commodities and winners in the race to achieve mass-production of the sweetest but rarest stevia molecule – reb M. The change in target molecule marked the breaking of the cash crop promise of stevia for many small farmers in Paraguay (and beyond) and, at the same time the re-making of the 'stevia' promise for new groups of large-scale (former-soybean) farmers and land-owners in Paraguay, as well as corn and former-tobacco farmers in the United States. The effects of these shifts were already starting to ripple out in my encounters with farmers, small businesses and government officials in their confusion and exasperation in Paraguay, and there was a distinct sense of injustice over an 'agricultural legacy' and 'promising industry' 'stolen', 'substituted' and 'expended'. Who should own and benefit from stevia, and whose definition of authenticity, naturalness and sustainability shone out as zones of considerable friction, illuminating the implications of expansion and expendability.

Chapter Seven follows stevia, ka'a he'ê and the frictions surrounding it across the multi-sited meetings and conferences of the United Nations Convention on Biological Diversity (CBD), the highest-level political forum considering global effects of synthetic biology. I observed stevia repeatedly mobilised during these meetings as an example of both a 'genetic resource' requiring a benefit-sharing agreement between corporate users and the Guaraní Indigenous traditional knowledge holders; and simultaneously as an example of a sustainable small farmer cash crop threatened by synthetic biology. This final empirical chapter focuses on the terms, framings and imaginaries through which participants contested synthetic biology R&D at the CBD, and the conflicts and decision-making around two significant sticking points 'Socio-economic, Cultural and Ethical (SECE) considerations', and the so-called '(de)materialisation of genetic resources' through negotiations on Digital Sequence Information (DSI). Stevia mobilised in these contexts reveals reconfigurations of value and ownership around an emerging 'world of stevia' interpreted as 'cash DNA' - a privately held digital genomic sequence. I contrast the terms through which synthetic biology governance plays out with what I observed 'on the ground' to argue that socio-ecological decontextualization and the disaggregation and dematerialisation of the living world both in technological and the policy-making spheres (re)produce a molecularised logic that is ill-equipped to address the joined-up, multi-sited socio-ecological and biocultural issues at stake that stevia has been mobilised to represent.

To conclude, I bring the most important ethnographic insights from each 'world' of stevia / ka'a he'ê together to draw out connection and disjuncture, and to highlight the significance of the transformations unfolding during 2018 and into the present day. I describe and analyse the four key dis/connects of authenticity, sustainability, ownership and justice

which repeatedly arose across and between 'worlds'. These dis/connects, I argue, expose processes of expansion and expendability which I interrogate to draw conclusions and further questions over the trajectory and implications of stevia's biosynthesis. Ultimately, I argue that the stories of stevia demonstrate that synthetic biology 'natural' products are following the grooves set out by industrial food and agriculture, in a trajectory that has expanded corporate consolidation at the expense of complex and diverse socio-agricultural systems, small farms, local knowledge and biocultural diversity. Without strict labelling and regulation on holistic sustainability appraisal to counter the corporate tendency to 'greenwash' and obscure the industrial origins of their products, some of the worst predictions made about the impacts of synthetic biology 'natural' products will repeat the injustices that continue to unfold across the worlds of stevia.

Chapter One.

Emerging technology, responsible research, disruptive innovation. A review of the literature.

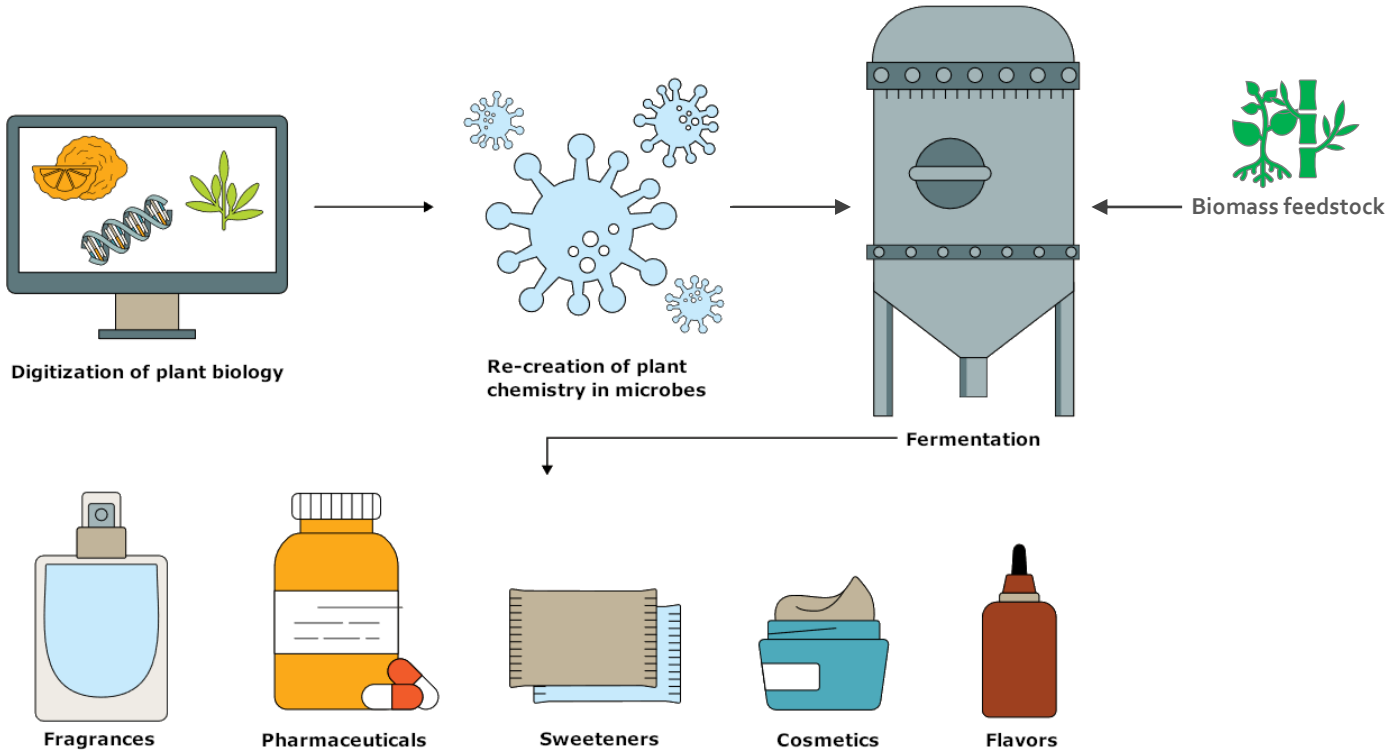
> 'Emerging technologies like synthetic biology will have global impacts. For this reason, every nation has a responsibility to champion fair and just systems to promote wide availability of information and fairly distribute the burdens and benefits of new technologies.'
>
> United States' Presidential Commission for the Study of Bioethical Issues (PCSB, 2010)

From the late 2000's to early 2010's awareness over the profound capacities opened up by emerging and converging digital, nano- and biotechnologies to bring both global benefits and burdens began to be acknowledged, and a long-standing dialogue around ethics and responsibility in innovation was reignited. The US Presidential Commission was one of the first high-level reports to align 'bioethical' issues with global 'responsibility to champion fair and just systems' and to acknowledge the importance of distributive justice over the benefits and burdens of synthetic biology. Another highly influential global platform, The World Economic Forum, underlined synthetic biology and artificial intelligence in their global risks assessment as demonstrating 'the need for governance on a global scale' given 'the many uncertainties in how emerging technologies evolve and their far-reaching societal, economic and environmental implications' (WEF 2015).

Outshining the perceived risks around synthetic biology, however, have been the perceived benefits. Synthetic biology is a technology positioned to lead the globalising bioeconomy 'project' heralded to 'meet the grand challenges of the 21st century' to sustainably 'heat us, feed us and fuel us' (OECD 2009). The basis of a global bioeconomy rests on utilising biotechnology to transform the 'latent' value of biomass, biological and genetic resources into energy, chemical and material commodities (EC 2012; OECD 2009). Promissory narratives, imaginaries and expectations fill hundreds of pages in glossy bioeconomy publications, blueprints, agendas, policy documents and roadmaps of the US (White House 2012), the European Commission (2012), the OECD (2009) and South African government (DST 2013) to name but a few. The promise of a 'bio-industrial revolution' has proven attractive as it responds to the unavoidable need to move away from petrochemical-based production, while opening up entirely new avenues for economic growth. While the bioeconomy project includes a broad range of sectors, techniques and technologies, 'strategic investments in synthetic biology' as asserted in the White House Bioeconomy Blueprint are framed as 'mov(ing) the bioeconomy forward in all sectors' (White House 2012:7). Within the field of synthetic biology 'biosynthetic products

are located in the higher-value end of the bioeconomy spectrum' and are the first products being commercialised (Ribeiro & Shapira 2019:312). Biosynthetic products are framed as being more environmentally sustainable due to reduced land-use and the biorefinery fermentation process fuelled by sugars derived from so-called 'renewable biomass feedstocks' (WEF 2010). The promise of renewable biomass is central to the bioeconomy vision, which one day aspires to re-purpose agricultural wastes and residues, but for the foreseeable future depends upon cheap industrial corn and sugarcane plantations.

Figure 1.1 'SynBio ingredient production with genetically modified yeast'
(Source: adapted from UNCTD 2019: 6, & ManusBio 2018b)



This literature review focuses on the academic research around the three main stages of biosynthesis; the feedstock (industrial agricultural) inputs, the manufacturing of molecules, and the outputs or products. Social scientists have largely engaged with synthetic biology through the 'Responsible Research and Innovation' (RRI) paradigm which has re-oriented the discussion of ethical, political, social impacts in the UK and overseas. Beyond work on the empirics of SynBio innovation, my approach to this field has been greatly informed and inspired by a body of theoretical and conceptual work I call bio-capitalism studies (Bond 2015), an interdisciplinary body that spans science and technology studies (STS), political economy and political ecology. Being a primarily ethnographic contribution, I do not have space to give justice to the full breadth of work on bio-capitalism here, though it is hoped this study will contribute by empirically fleshing out the body of conceptual work to which I first turn.

Bio-capitalism studies

The basic premise of work in bio-capitalism studies is the inseparability of Life Science and capitalist (re)production, particularly in the economic and molecular management of life in the era of neoliberal capitalism. Authors in this field have drawn heavily on the theoretical contributions of Karl Marx (1974 & 1993) and Michel Foucault (1980 & 2003) to illuminate the 'what', 'why' and 'how' in the mechanisms of capitalism and biopolitics (Cooper 2008; Rajan 2006). While differing in their structural approaches Marx and Foucault have been drawn together to make visible the 'operative logic of production relations at work shaping the condition of postmodernity' that remain relevant into the 21st century as life sciences promise infinite growth (Marsden, 1999:I; Nealon, 2008; Bond 2015).

Marx (1974) recognised that the capitalist system of the 19th century must expand without limit in order to exist, as the following quote from *Grundrisse* makes clear, this expansion is reliant upon the '*changing nature of production* through science, innovation and technology' as Marx put it to 'make science a productive force distinct from labour and press it into the service of capital' (Marx 1993:409; Bond 2015:10).

> 'The value of the old industry is preserved by the creation for a new one in which the relation of capital and labour posits in itself in a new form. Hence exploration of all of nature in order to discover new, useful qualities in things; universal exchange of the products of all alien climates and lands; new artificial preparation of natural objects, by which they are given new use values … A new, qualitatively different branch of production must be created, which satisfies and brings forth a new need.' Karl Marx (1993:409)

Industrialists or capitalists, Marx argued, fetishize machinery and are compelled toward technological revolution in the pursuit of surplus value where 'the existing form of a production process [is never seen] as the definitive one' (1974:617). Capitalism, Marx thought 'was largely configured by the material qualities of the 'instruments of production' which determined the 'relations of production, and with them the whole relations of society' (Marx and Engels 1992:4). Technology 'fetishizes' or obscures the metabolism between society and nature. Marx borrowed the concept of metabolism from the discoveries in cellular biology in the 1830s, to describe society's dialectical relation to nature (Bellemy-Foster 2002). Taking technology as a lens or de-fetishising it, Marx elaborates, 'discloses' and thus 'reveals' this metabolism as well as the way in which society understands both itself and the non-human world around it. In Volume III of *Capital* Marx described the rift in the 'universal metabolism of nature' as the living world 'becomes purely an object for humankind, purely a matter of utility; ceases to be recognised as a power for itself,' recognising the faster humans discover the scientific laws of nature, the faster it is subjected to the needs of capital, 'whether as an object of consumption or as a means of production' (Marx, 1974:409; Bond 2015:11).

Foucault's concept of biopolitics or biopower takes Marxist critiques of the utilitarian and objectification of the living world one step further. Biopower refers to the ways in which the 'science of life itself' has enabled its categorisation and division, 'disaggregating the world from the sum of its parts, cells, genes, or even characteristics' has rendered it controllable, easier to manipulate, exploit and ultimately capitalise (Bond 2015:14; Lemke 2011;). Making the 'bio' logical, manageable, calculable and less complex marks an important shift toward what Nikolas Rose identified as the 'molecularisation of society' and exposed a politics of life itself (2007: 13).

> 'This molecularization was not merely a matter of the framing of explanations at the molecular level. Nor was it simply a matter of the use of artifacts fabricated at the molecular level. It was a reorganization of the gaze of the life sciences, their institutions, procedures, instruments, spaces of operation and forms of capitalization....Life was imagined as sub-cellular processes and events, controlled by a genome which is neither diagram nor blueprint but a digital code written on the molecular structure of the chromosome. This is 'the language of life' that contains 'the digital instructions' that make us what we are' (Rose 2007:13).

Biopolitics and the molecularization of life have been influential areas of thought in social sciences for conceptualising the ways in which 'our *ethical* relation to our bodies has changed' as well as our relation to non-human worlds (Braun 2007:10). Rose identified how 'life now appears to be open to shaping and reshaping at the molecular level: by precisely calculated interventions that prevent something happening, alter the way something happens, [or] make something new happen in the cellular processes themselves' (Rose 2007:16). Scholarly attention to the subcellular as a new scale in which ethical and political future-making plays out within and beyond the human body has increased with the proliferation of bioeconomic discourse and the recent discovery of gene editing (Bartkowski et al. 2018). I develop the concept of molecularisation toward the end of this thesis as a way to de-fetishize or illuminate the multi-scalar, multi-species dimensions of biosynthesis. Biosynthesis - where 'digital instructions' from multiple species are engineered into organisms to metabolise carbohydrates into so-called 'natural' molecules they would not *naturally* produce – I argue is the latest stage in a process of molecularisation, exposing what is at stake in the new avenues being opened up between 'biology and capital, as biological matter is translated into mobile and fluid networks of information that can be owned, bought and sold as intellectual property' (Braun 2007: 9), or as I term it, 'cash DNA'.

Although she did not adopt the term 'molecularisation', I find McAfee's (2003) conceptualisation of double reductionism - both genetic and economic - particularly useful for illuminating the effects of molecularisation as an ongoing and mutually supportive process. Economic reductionism, McAfee explains is the theory that all social phenomena have an economic explanation in which the invisible 'self-optimising market' is thought to suspend 'power-relations' and guide self-interested human interaction toward the most efficient and fair allocation of resources, a theory that has permeated bioscience (2003:214). And so 'genetic reductionism' (the notion that 'all complex entities can be completely explained by the properties of their component parts') expands the possibility of the commodification of life (Gilbert and Sarkar 2000:1). Adam Smith first recognised that for something to become a commodity it must be 'disentangled' or 'decontextualized, dissociated and detached' and 'reduced to a format that makes it possible to make an exclusive package or artefact for which an exchange value may be established' (Jacob 2003:127; Callon 1998:19). McAfee (2003) argues that the World Trade Organisation's (WTO 2006) Trade-related aspects of Intellectual Property (TRIPs) epitomise this 'double reductionism', globalising a way of perceiving the living world that is concretised by national legislative requirements governing the patentability of life-forms. I unpack molecularisation, in terms of reductionism in Chapters Six and Seven as a way to glimpse what is reduced, lost or expended as a result of the expansion of molecularised approaches to life, the living world and the economy. I find it is not just the stevia plant and the terms through which stevia is understood being molecularised but the governance framings, regulations and political economic system from which biosynthetic stevia emerges.

The consensus from scholars in this field that 'biopolitics has become inextricably intertwined with bioeconomics' (Rose, 2007: 7), and that the marriage of life-science and market forces 'represents a new face, and a new phase of capitalism and, consequently, that biotechnology is a form of enterprise inextricable from contemporary capitalism' has informed my analytical approach (Sunder-Rajan 2006:14). The adoption of multi-sited or single-sited ethnographic methods have been particularly insightful for grasping the complexities and granularity of technoscientific practices and their implications for daily life and lives (Marcus 1995; Haraway 1997; Ong & Collier 2004; Brooks 2005; Scott 2015). In *Biocapital* (2006:3) Kaushik Sunder-Rajan applies a multi-sited ethnography of post-genomic life across India and the US, observing how 'new biological technologies and techniques emerge within a constrained set of mutual investments, the investments of the market in the life sciences, and the investments of the life sciences in the market' (Rajan (2012:34). Equally inspiring has been Melinda Cooper's (2008) work on the 'transformation of biological life into surplus value', unpacking biotechnology policy, history and militarised experiments in the US, she observes: 'In the age of postmechanical reproduction the point is to generate and capture production itself, in all its emergent possibilities' (2008, 24). Cooper exposes the ambition of neoliberal life science 'to overcome the ecological and economic limits to growth through a speculative reinvention of the future' (2008:19). These works have shone light on the politics of knowledge, illuminating as Jasonoff aptly described in the idiom of 'co-production' of science and social order that 'the ways in which we know and represent the world are inseparable from the ways in which we choose to live in it' (Jasonoff, 2004:6).

Scholars of bio-capitalism assert that no longer can the scientific production of knowledge be separated from the capitalist production of value, indeed power through the production of tangible commodities has been replaced by the 'production of knowledge, information and biological futures' (Kutting and Lipshutz, 2009:97; Lemke 2011; Bond 2015). Foucault influentially described power/knowledge as inextricable and capillary, 'far from preventing knowledge, power produces it' (Foucault 1980:59). Foucault illuminated how a 'politics of truth' operates, creating particular 'discourses' as 'systems of meaning' that – as Wendy Larner put it - 'constitutes institutions, practices and identities in contradictory and disjunctive ways' (2000:12; Bond 2015). Discourses 'govern existing groups of statements and regulate the generation and distribution of new statements' (Larner 2000:12; Marsden 1999). As new biosynthetic techniques and molecules have emerged, companies have begun promoting and disseminating their products with strategic discourses, for example the packaging on the most recent version of biosynthetic stevia obscurely tells consumers their purchase 'respects mother nature' and is 'keeping nature natural' (NutraSweetNatural 2021). In this thesis I pay attention to new forms of knowledge and changing discursive zones around concepts including 'efficiency', 'naturalness', 'authenticity' and 'sustainability' and how friction and disjuncture within discursive zones contributes to the governance and intervention of new and emerging domains.

Through the chapters of this thesis diverse knowledges and worldviews emerge about stevia, highlighting the centrality of the literature recognising the struggle towards epistemic and ontological plurality and justice in science (Stirling 2009). Arun Agrawal (1995:433) highlights how 'multiple domains and types of knowledges, with differing logics and epistemologies' demonstrate the need for a decolonial dismantling of the divide between western 'scientific' and 'indigenous knowledges' in recognition that capital S Science is but 'just one knowledge system among many' (Nakishima and de Guchteneire, 1999:57; Harding 2008). As part of a growing body of decolonial and feminist critique

on the objectivity of scientific knowledge, patriarchy, and Eurocentricity, Sousa-Santos has been particularly influential for thinking though the ways in which dominant euro-centric epistemologies - through cause and consequence – can erode epistemic and biocultural diversity (Sousa-Santos 2008 & 2014; Hanspach et al. 2020). The work of decolonial and feminist scholars on 'multiple modernities' and mulitple knowledges and particularly how 'gender and colonialism frame the conventional contrast between modernity and tradition' have informed my approach to researching synthetic biology, its governance and its practice (Harding 2008; Escobar 1998; Shiva, 2000; Harding 2008; Sousa-santos 2014; Tucker 2020).

Much work in biocapitalism studies has taken the biomedical gaze upon the human body as an empirical site for exploration (Fannin 2016 & 2020, Mitchell & Waldby 2006; Rajan 2012). While there are numerous theoretical crossovers, biopolitical analyses of plants, agriculture and food production systems have received less attention, though they are subject to far weaker regulation than biomedical interventions, consequentially it is often corporate entities determining the terms of regulation and self-regulating (Hetherington 2020). Nally (2010) describes the 'new moment in the commercialisation of food systems [as] accumulation by molecularisation', in which he combines Foucault's biopolitics with Harvey's (2003) work on 'accumulation by dispossession' of marginalised populations to argue that 'corporate agribusiness – in partnership with the life sciences – is attempting to recondition human, animal and bacterial life in order to quicken the reproduction of capital' (p.37). Hetherington (2020) an anthropologist of soybeans, takes Paraguay as a genealogical site to describe 'agribiopolitics' as 'a political technique that made certain populations of humans thrive alongside [certain] companion crops'. As a central site in my research, Paraguay's agricultural history – fraught with multiple cases of rural dispossession of Indigenous Peoples and campesino communities, and now facing 'accumulation by molecularisation', or 'dispossession by biosynthesis' – connects biocapitalism literature on surplus life (and surplus corn) in the US (Cooper 2008) with insights from scholars such as Tanya Murray Li (2010) on surplus populations to expose the realities of molecular expansion (making live) or expendability (letting die), particularly affecting rural communities.

This rich and broad body of work has informed my approach and understanding of the emerging field of synthetic biology's natural products and instilled in me a decolonial feminist awareness and commitment to gather as diverse and inclusive a picture about what is happening across the multiple worlds of stevia as possible. I now turn to a summary of the literature considering the three stages of biorefinery: the feedstock inputs, the manufacturing of molecules, and the outputs of 'disruptive' or 'responsible' innovation.

Fuelling the Bioeconomy (inputs).

Social scientists working on synthetic biology have largely overlooked the input end of biosynthetic value chains (also acknowledged by Ribeiro and Shapira 2019). However, scholars in the fields of agrarian political economy, political ecology and peasant studies offer insights into the global workings of agrarian capitalist relations in industrial food systems in the context of new biosynthetic commodities. Borras et al. (2015) posit that biorefinery processes generate increased demand for biomass and contribute to the dramatic rise of 'flex crops' or monoculture crops (namely soya; oil palm; sugarcane and corn) grown for multiple and flexible industrial purposes, whether animal feed, human food,

biodiesel, ethanol and increasingly feedstock for biosynthesis operations. US corn and Brazilian sugarcane are already used as feedstock to fuel fermentation of biosynthetic stevia among other lab-grown 'natural' products. Borras et al. highlight that the economic viability of industrial biorefinery processes 'depends on low-cost feedstock, which can be cheapened by several means, e.g. mining nature, super-exploitative labour, more intense market competition and land grabs' (2015:94). While biological resources are framed as renewable, scholars question their sustainability, reporting detrimental effects of widespread monoculture including high use of pesticides and herbicides on biomass plantations polluting aquifers and affecting the health of local communities and ecosystems (Dauvergne and Neville, 2010, Neville 2015). While some note the increasing 'monopolistic internationalisation of the sector', with corporate consolidation over inputs, facilities, trade and distribution methods becoming ever-more entrenched (Dauvergne and Neville, 2010; Birch et al. 2010; Mendonça et al. 2013:3). Others cite reinforced historical inequalities and patterns of enclosure linked to the mass production of biomass crops in processes resulting in forced land acquisition characterised as 'land grabs' and 'green grabs' in the literature (Scoones et al. 2012). Low-income rural communities are disproportionately affected and displaced from their land, resources and livelihoods (Li 2009; Bringezu et al. 2012). In Brazil, a country where industrial biorefineries have started biosynthesising natural compounds alongside ethanol biofuel, scholars have reported a rising incidence of 'forced labour', the 'expropriation of small producers and indigenous peoples' land' as well as the 'substitution of food crops' amid mass land-conversion to sugarcane and soya plantations in recent years (Mendonça et al. 2013:3; Hetherington 2020)

Though work on the bioeconomy addressing the global and molecular politics of synthetic biology and biosynthesis (and the degree to which it entrenches monopolistic tendencies of industrial food systems) has been limited (Rossi 2013), it nevertheless offers insights as a field dedicated to unpacking power-laden ecological relations and the 'winners' and 'losers' of rural transformations (Brooks 2005; Smolker 2008; Stirling 2012). Such considerations have become particularly imperative in areas where the bioeconomy has become a guiding narrative justifying or promoting such transformations.

Manufacturing 'natural' molecules.

Aside from the physical infrastructure required to build a biorefinery and the 'urgent need for prospective studies to investigate the potential environmental benefits and risks of biosynthetic value chains and compare them to incumbent natural and synthetic methods of production' (Ribeiro & Shapira, 2019), a global focus on the molecular politics of microbial cell factories underpinning the biosynthesis of plant compounds has predominantly been addressed by socio-legal scholars, particularly those writing on access and benefit-sharing over genetic resources. Legislation on access and benefit sharing, commonly referred to as ABS, was established within the United Nations' Convention on Biological Diversity (CBD) which entered into force in 1993. Ever since, ABS has guided global policy on how scientists or 'bioprospectors' *should* access and utilise the sovereign genetic resources of states, Indigenous Peoples or Local Communities in a fair and equitable manner, in order to ensure that all those who contribute to an innovation (whether in knowledge, cultivation or conservation) share in its benefits. ABS was thought of as a 'grand bargain' – not only would it incentivise the halt of biodiversity-loss by re-valuing nature as an untapped genetic treasure trove worth billions of potential dollars – but it would heal a history of unequal exchange of natural resources between the 'users'

of the Colonial North and 'providers' of the Global South (Wynberg & Laird 2009; Bond & Scott 2020). As a global attempt to govern ethical exchange over genetic resources, ABS has repeatedly collided and exposed contradictions between the CBD's approaches and that of the World Trade Organization's 1995 agreement on Trade-related Aspects of Intellectual Property Rights (TRIPS) (WTO 2006). The legal dominance of the TRIPS agreement set a 'precedent for treating genetic materials as standard commodities to be patented and traded, without any reference to ABS', and has solidified 'trends towards the reclassification of nature as a form of industrial property on the international level' (Oldham, 2006: 126; Bond & Scott 2020:26)

Recent work on the interface of ABS, the bioeconomy and emerging technologies highlight that so-called 'strategic ambiguities' in the CBD's legal text on ABS left open questions of geographic and temporal scope and most significantly whether genetic resources are defined solely by their physical materiality or by the information encoded in their genetic sequences (Bavikatte & Robinson 2011; Laird & Wynberg 2016; Bagley 2018; Laird et al.; 2020; Bond & Scott 2020). The latter question is of particular concern to this research, as scientific leaps in digital genetic sequencing and synthesis (i.e. the reading and writing of DNA) are increasingly at the centre of efforts to engineer molecules as 'microbial cell factories' in biosynthesis operations. The issue of digital sequence information (DSI) remains highly controversial internationally amid concerns that scientists (un)intentionally are bypassing ABS rules and committing so-called 'digital biopiracy' (the (mis)appropriation of genetic resources) (TWN 2016; Bagley 2018). In chapter seven I return to this unfolding global controversy. For now, suffice to say that the issue of DSI is demonstrative of the significant challenges posed by the digitisation of plant biology and synthetic biology 'natural' product innovation to global (environmental) justice, and of the 'herculean task' facing policy-makers outpaced by the speed of biotechnology R&D (Wynberg & Laird 2017; Laird et al. 2020).

From the biomass fuelling the bioeconomy, to the manufacturing of molecules, to the implications of the outputs of innovation, this research is one of the first contributions considering all three stages of biosynthetic 'value(s)' chain together. Social science engagement with SynBio research and development (R&D) has burgeoned over the past decade, it has largely done so through the empirical and conceptual prism of responsibility (Calvart & Martin 2009).

Responsible innovation (outputs).

Since the early 2010's post-industrial countries particularly the US, UK and in Europe have seen a shift in the onus of governmental responsibility over innovation, to the responsibility of the neoliberal self-regulating scientist. As a consequence, social scientists working on ethical or social aspects of synthetic biology have focused increasingly on evaluating or facilitating 'responsible research and innovation' with groups of scientists and/or in collaboration with synthetic biology research projects. 'Responsible Research and Innovation' (more often referred to as 'RRI') has been predominantly promoted by engineering and biology research councils and innovation-focused public finance strategies as a means to better align scientific and innovation 'processes and outcomes with the values, needs and expectations of society' (European Commision 2020; BBSRC 2019). RRI can be thought of simultaneously as a concept, a project, a practice (EC 2020), a package (EC 2020), a marketing strategy (Evolva 2017), an agenda (BBSRC 2019), and a framework

(Stigloe et al. 2013). RRI has captured the attention of synthetic biology promotors and road-mappers (SBLC 2012; PCSBI 2010), ethicists (Nuffield 2017), research centres (BrisSynBio 2016, SynBioChem 2021) SynBio companies (Evolva 2017) and engulfed the majority of social science and humanities engagement with synthetic biology through the publication of a plethora of books, reports, guidance documents, artworks, performances and countless academic articles since *The Journal of Responsible Innovation* was created in 2014 (Owen et al. 2012; Von Schomberg 2019; Macnaghten 2020)

The 'RRI turn' has redirected the focus on risks, risk governance and the so-called 'ELSI' (Economic, Social and Legal Impacts) agenda developed during the 1990s' internationally collaborative Human Genome Project, to a focus on innovation, innovation governance and individual responsibilities (Zwart et al. 2014, Balmer et al. 2015). Many social scientists refer to RRI as the 'new governance of science' (Irwin 2006; DeSaile 2020; Balmer et al. 2015; Macnaghten 2020). This new form of governance reflects the shift starting in the West towards a knowledge-based economy where 'sound science' could no longer be seen to apply the 'deficit model' in the response to public resistance and controversy (Wynne 2005, Balmer et al. 2015). 'Sound science' became seen to require (at least some) ethical and social analysis, as well as 'informed' public deliberation and public engagement in order to legitimate research agendas. Much RRI social science research has been structured around societal expectations and responses and public engagement to new SynBio techniques (Meckin & Balmer 2017); conceptual work on the 'societal alignment' of innovation (Burget et al. 2017); public values and perceptions (Engineering Life Project 2020); synthetic biologist collaborations with the arts (BrisSynBio 2018; Fannin et al. 2020); as well as international RRI projects such as SYNENERGENE funded by the European Union as a 'four-year mobilisation and mutual learning action plan on RRI in Synthetic Biology' in order to 'establish an open dialogue between stakeholders concerning SynBio's potential benefits and risks' based on collaboration and public participation' (Synenergene 2017). Many have welcomed RRI as a re-alignment of innovation with societal values calling it a 'paradigm shift' to steer science and technology with the 'right impacts' (Von Schomburg 2013).

The year I began my PhD research, six new synthetic biology research centres and two SynBio doctoral training centres had been established in the UK. From the outset RRI has been framed as an important part of synthetic biology research, and the BrisSynBio research centre at the University of Bristol has its own director of RRI. As an ethnographer following the worlds of synthetic biology during the development of these research centres, I found myself at multiple times attending RRI 'dialogues', science cafes, SynBio-art exhibitions, role-plays, and performances involving synthetic biologists, publics and school children all deliberating how responsibility should be understood, assessed, encouraged and ensured. My experiences were characterised by various degrees of 'stakeholder' engagement (and at times awkward encounter between scientists striving to repair public opinion of genetic engineering and those who remained rather sceptical that the underlying issues hadn't been resolved). Yet in virtually all cases, aside from raising awareness of the potential of synthetic biology, the ultimate outcome of such RRI experiments was the scientist returning to the lab with perhaps a greater sense of their responsibility as moral decision-maker**.** Rather than focusing solely on the outputs of innovation, advocates of RRI purport that establishing notions of responsibility at the start of the innovation process, with the scientists themselves, will align the outputs of SynBio with the desires of society (Owen et al. 2012).

While I could see the value of RRI in shifting attention towards the process of innovation itself, in practice I frequently observed it play out as a public relations exercise (run by University PR team) seemingly focused on making genetic engineering more socially acceptable .

I am not alone in my observations, many working in the centre of the field have become increasingly critical of the RRI turn as an attempt to 'reframe' or 'refocus' the Human Genome Project's ELSA programmes – in order to give the 'economic valorisation' of technology more prominence (Block & Lemmens 2015: 21). Zwart et al. (2014) argued that the metonymy, or the change in rhetoric from impacts to 'innovation' can be seen as censorship strategies reducing the space for a critique of technology. Similarly Van Oudheusden (2014) makes explicit the lack of politics across RRI. A number of social scientists working on responsible synthetic biology in the UK and EU have expressed discontent with the funding landscape chaining social science 'scholars engaging in sociotechnical fields' to RRI agendas, they write;

> 'There are worries that we have become unable to say 'no' to technoscience or to be critical when working with natural scientists and engineers. Invitations to engage in discussions of the future of technosciences presuppose that the technology will emerge and will necessarily have positive outcomes. At the same time, there are concerns that if we emphasise an 'ethics of suspicion', distrust and antagonism, we are left unable to engage with the often effervescent hubris of promises about future technologies except through the prism of resentment and criticism' (Balmer et al. 2015:3).

Balmer et al. (2015: 20) highlight the need to open up 'discussions of unshared goals' and for social scientists not reliant upon SynBio funding streams to play a more critical and provocative role in the trajectory of synthetic biology. Their statement also makes clear from a UK perspective the presupposition and inevitability of technology emergence. Despite synthetic biology remaining globally contested between countries, synthetic biology is a central part of the UK Conservative government's vision for economic growth (Synthetic Biology Leadership Council 2016; Bond & Scott 2020; BBSRC 2021). In the private biotech sector – where a large proportion of SynBio R&D is occurring – Rosemann and Molyneux-Hodgson (2020) question how seriously RRI is on the agenda highlighting how too frequently it is interpreted as Public Communication. I argue RRI shares crossovers with how 'corporate social responsibility' (CSR) has been captured by corporations as PR strategy rather than leading to any fundamental change in the socio-ecological practices upon which they depend (Rajak & Dolan, 2016; Bendell 2000). While what responsibility might mean in a global context is only beginning to be addressed; barely any work engages with those who stand to be affected by a synthetic biology innovation, or considers dynamics of global stakeholders or diverse worldviews relating to the living world (Campos et al. 2017). In general, RRI lacks global engagement on issues of global justice, distributive justice, socio-ecological resilience, or technology ownership especially within places, spaces and peoples of the global south (Zhang et al. 2011; Marris 2013; Ribeiro & Shapira 2019; De Saile 2020).

In one piece addressing this gap in the literature on the tensions and paradoxes of 'Responsible innovation across borders' 22 Brazilian, US and European academics describe RRI as a 'Northern political artefact', developed as a specific policy response to controversial and potentially disruptive hi-tech innovations (Mcnaughten et al. 2014). They critique RRI as being 'interpretively flexible, culturally framed and politically entangled' and that it could 'unwittingly reproduce

or reinforce relations of dependence that are far from emancipatory for the global South' when deployed as an instrument of 'intellectual neo-colonialization' or of 'science-diplomacy' (ibid:193; Koch 2020). They recognise the diversity in culturally-specific interpretations of responsibility, concluding that RRI should locate and engage with 'local contexts, cultures and practices', and highlight the need for scholars to pay attention to 'local and traditional, non-Western forms of knowledge, social and religious contexts (including gender-related issues such as patrilineal systems of behaviour and power), property rights and patterns of ownership more generally' (Mcnaughten et al. 2014: 194). More recently responding to instances where the 'burdens' of an innovation on the majority outweigh the 'benefits' to a minority, some have started asking: would the most responsible option be not to innovate? This has led to the counter-concept of 'Responsible Stagnation' to advocate a slowing down of the economic growth imperative of fast-paced R&D to ensure time to assess and understand benefits and risks before proceeding (DeSaille et al. 2020). And an increasing awareness over 'inequity in science' and 'epistemic justice' is starting to be considered in RRI circles (Koch 2020; De Saille et al. 2020)

Another area overlooked in social and ethical studies of synthetic biology is the long-standing and ongoing global debates during the UN meetings of the CBD which provide what Laird et al. (2020) describe as a platform 'for important and otherwise orphaned dialogues on ethics and equity in research, ownership, and control of genetic resources and traditional knowledge, capacity building, technology transfer, and other issues' including socio-economic considerations (Laird et al. 2020). Laird and Wynberg (2016) attempt to highlight how a more 'holistically engaged' concept of RRI might be inserted 'into the full range of policy processes of the CBD', advocating for a broader interpretation of responsibility which could institutionalise 'approaches of anticipation, reflection, and deliberation; framing responsibility in the context of uncertainty and on-going change; ensuring transparency; and moulding governance and policy to prevent harmful or unethical practices in research and innovation' (Laird & Wynberg 2016:198). These authors seem to subvert RRI from its initial purpose in crafting publicly-engaged self-regulating innovators back full circle back to the moral responsibility of governments again.

Indeed, recent work under the RRI umbrella emphasises the centrality of anticipatory governance and the 'calls for an application-oriented turn in the social studies of SynBio and a focus on its real-world dimension' (Ribeiro & Shapiro 2019; Marris & Rose, 2012; Schyfter & Calvert 2015; Campas et al. 2017). Very few 'real-world' studies have been carried out, and even less have taken place outside Europe or North America. This is perhaps partly due to the novelty of SynBio practices that only moved from proof-of-concept to the 'real-world' over the last 5 -7 years, while many innovations remain in multi-year processes of R&D. Biosynthetic replicas of natural products are among the first applications of synthetic biology, today becoming commercially circulated and creating 'real-world' transformations. Very few studies have attempted to grasp what biosynthetic replicas of commonplace or ubiquitous natural products imply to the changing 'nature' of production and the places, spaces and communities that are implicated, disrupted or displaced.

Disruptive Innovation (or 'radical displacement'?)

> The invention of cheap, synthetic alternatives to high-value agricultural exports such as vetiver could suddenly destabilize vulnerable economies by removing a source of income on which farmers rely
>
> World Economic Forum (2015:40)

Vetiver, an aromatic grass, is the key ingredient in some of the world's most expensive perfumes. Haiti, the poorest country in the Western hemisphere, is the world's leading producer. Grown on 10,000 hectares, vetiver cultivation supports an estimated 60,000 Haitians who 'depend on vetiver as their primary income source' (Brown 2014). The World Economic Forum spotlighted vetiver production as one of the potential risks of synthetic biology for severe socio-economic impacts in the face of market destabilisation to low-income communities dependent upon such natural resources (WEF 2015). This risk is underlined by the financial attraction and benefits of biosynthesis to multinationals seeking lower-costs and reliability by consolidating commodity chains away from logistically complex, diverse and multiple small suppliers, as well as for corporate long-term risk mitigation strategies to secure production networks in the face of social, political or climate change instability and their effects upon agriculture.

Compounds sourced from plants such as vetiver, vanilla, saffron or stevia have a higher financial value because they are rare, difficult to obtain or require particular ecosystems, careful cultivation and manual labour. With income opportunities in rural areas significantly lower, the importance of high-value crops as the primary income source for subsistence and smallholder farming communities globally has been recognised for their contributions to socio-economic development and environmental sustainability under UN development projects on biotrade. Biotrade is defined as 'the collection, production, transformation and commercialization of goods and services derived from native biodiversity (species and ecosystems) under environmental, social and economic sustainability criteria' (UNCTD 2019). The United Nations Conference for Trade and Development (UNCTD) that supports biotrade 'value chains' programmes has recently considered the most foreseeable consequences of synthetic biology as 'the displacement of naturally sourced ingredients with ingredients produced through the use of synthetic biology' with consequences upon 'the livelihoods of those who rely on growing and harvesting natural products', namely due to farmers and others dependence upon 'robust markets for natural products for their economic survival' (UNCTD 2019: 18).

Patterns suggest that the targets of biosynthesis are often globally traded 'high value' commodities, which are generally 'low-volume' and not required in huge bulk quantity. Saffron, for example is more expensive per weight than gold. Like vanilla, it requires specific ecological knowledge, careful cultivation and labour-intensive harvesting. Natural products with perceived barriers to trade such as conflict or illegality, such as opioids or cannabinoids, are targets for biosynthesis companies supplying - what they term - 'clean' ingredients to the pharmaceutical industry, despite these crops providing vital albeit often illicit livelihoods for thousands (TNI, 2016; Amyris 2020). Other plants targeted for biosynthesis are those for which global demand is high or anticipated to grow, such as palm kernel oil or stevia (Sun et al. 2021).

It was over a decade ago that the first academic article considering the *political economy of development and synthetic biology* was published (Wellhausen and Mukunda 2009). The authors forecast as inevitable the widespread 'technological displacement' brought about by synthetic biology - framing it as a 'disruptive innovation' (Wellhausen and Mukunda 2009). The 'cheap mass production of naturally occurring molecules', the authors predicted, would have differentiated impact 'on trade and investment' and 'traditional producers in developing countries' depending on the product synthesised and the state's ability to 'cushion the pain' and 'facilitate industrial restructuring' (2009:119). The authors based their assumptions on the historical analysis of the impacts of the 19th and 20th century chemical substitutes of Indian indigo and Malaysian rubber as demonstrating worse and better outcomes of disruptive innovation.

While these cases highlight differences in the Indian or Malaysian states' ability to 'redistribut(e) resources to cushion these newly impoverished labourers despite the decrease in their tax base' (ibid:120), the current round of synthesis differs significantly from the displacement caused by synthetic chemical substitutes. Today, the substitutes can be sold as 'natural' or biologically 'equivalent' to the agriculturally-derived or plant-based product. Often chemical replicas could not quite imitate the specific qualities of the naturally produced commodity, so in many markets the plant-derived product retained a share of the market. Chemical synthesis nevertheless had a dramatic impact on the cultivation of many natural products. Vanillin for example lost over 90% of its market to chemical synthesis, the remaining 10% is today grown by smallholders who sustain the delicate balance of rainforest ecosystems that are required to harvest vanilla pods (Braw 2014). The interrelationships between socio-ecological resilience and sustainable livelihoods are increasingly recognised as inextricable (Smith & Stirling 2010; Bond 2016b). While comparisons with the historical rounds of technological displacement offer insights, they cannot be used to neatly explain, let alone normalise, the present round of biosynthesis.

Wellhausen and Mukunda's technologically determinist and fatalist account of the winners and losers of SynBio's *unavoidable* 'technological displacement' (2009:116) posit the 'role of chance' and 'market forces' as central factors. They base their assumptions on the economic concept of 'disruptive innovation' (Christianson, 2003), developed from the Schumpeterian theory of 'creative destruction', a political economic characteristic Harvey equates to neoliberal capitalism (Schumpeter 2006; Harvey 2007). Disruptive innovations succeed – according to Wellhausen and Makunda – 'because established actors are almost universally unaware of their potential impact; these same actors are unlikely to be motivated to use their political influence to block the innovations until it is too late', hence providing 'substantial protection against regulatory and political strategies meant to limit their use' (2009:121). The shortcomings in Wellhausen and Makunda's account centre on a lack of empirical analysis and broad assumptions about 'established actors' who are not necessarily small farmers ignorant of the technological shift happening around them. As my research shows, 'established actors' can be small or medium-size producers who may alter their practice or production style to compete, as well as incumbent multinationals quickly able to co-opt new techniques. These multiple shifts imply a range of disruptions, indirect consequences and complex interactions and implications within plant specific cultures and social-ecological relations, that cannot be easily generalised without empirical analysis (Stirling 2010).

Disruptive innovation as a form of creative destruction has become framed in popular discourse as being a positive marker of technological progress (Chaddha 2019; Amyris 2019a). Synthetic biology innovations have emerged over the last decade shrouded by promissory narratives and technoscientific imaginaries over a disruptive potential to the unsustainable 'status quo', promising new 'green' production techniques or addressing deficits in public health (Manyika et al. 2013; Berry et al. 2016; Monbiot 2020). The interplay between promissory disruptive and responsible innovation narratives has not been interrogated in the academic literature, but civil society groups have produced analyses to show that the majority of synthetic biology research into biosynthesis is funded and owned by the status quo of 'big pharma' and industrial agri-business (ETC group 2012). They argue that the farmers, growers, pickers and harvesters will be at 'the sharpest end of this disruption' (ETC group 2016). Aside from limited reports by civil society groups and environmental NGOs, there is very little academic analyses of 'real-world applications' of synthetic biology and the socio-ecological entanglements from which they emerge, as Scott (2015) recognises 'no-one is tracking potential impacts [of synthetic biology], so they remain unstudied and the source of vigorous speculation' (p.167). There are increasing calls for 'end-to-end assessments' and 'case-by-case' approaches (Ribeiro & Shapira 2019). I now turn to two cases that have received a degree of scholarly attention – the biosynthesis of artemisinin and of menthol – to assess what insights they offer to my focus on stevia.

Case-by-case:

(Biosynthetic) Artemisinin.

The key anti-malarial plant compound artemisinin has been the most publicised and celebrated example of the biosynthesis of natural products (Keasling, 2005; Joyce, et al. 2013). Until recently, the sweet wormwood plant, *Artemisia annua*, had been the only source of artemisinin over a 2,000 year history of the plant's medicinal use. Drug-makers source the plant – cultivated by thousands of small farmers mainly in China and Vietnam as well as Madagascar, Kenya, Tanzania, and Uganda – then refine its derivatives, combining it with other drugs to prevent resistance developing in the malaria parasite (Peplow 2016; Heemskerk, 2006; Dalrymple, 2010).

Commercialised in 2013, biosynthetic artemisinin was the product of the early scientific research on synthetic metabolic pathway engineering of the Isoprenoid pathway, which in the plant kingdom is responsible for producing around 80,000 natural compounds (including vanillin, menthol and steviol glycosides). With US$53.3 million of support from the Bill and Melinda Gates Foundation, the team comprising a University of California spin-out synthetic biology company Amyris and pharmaceutical company Sanofi announced their genetically engineered yeast 'cell factory' fermenting the precursor artemisinin compound as a 'triumph for synthetic biology' that marked a 'pivotal milestone in the fight against Malaria' (Path 2013; Sanders 2013).

In the years proceeding biosynthetic artemisinin commercialisation, the Royal Tropical Institute of the Netherlands produced a report stating that it was 'possible to cultivate sufficient artemisinin to cure all the malaria patients in the world' and 'that increasing cultivation would boost local economies to meet increasing demand' (Heemskerk et al. 2006; Bond 2015: 26). The Dutch Institute cautioned that flooding the market with 'artificially subsidised synthetic

artemisinin' could destabilise prices dissuading farmers from planting and losing their source of income, while the shift of 'production sites to Western pharmaceutical companies' would move the 'production, extraction and manufacturing [of artemisinin]' further away from 'regions where malaria is prevalent' (Heemskerk et al. 2006; Bond 2015). In 2009 the 'Assured Artemisinin Supply System' (A2S2) was established as a supply-chain funding and monitoring program to support the cultivation of artemisinin and ensure adequate botanical supplies for antimalarial drugs, demonstrating that agricultural cultivation was sufficient to meet demand. However, one year after biosynthetic artemisinin was commercialised, prices of botanical artemisinin dropped to a decade low, and plantings were down by two-thirds (A2S2, 2014). The prediction by Heemskerk et al. (2006) that 'pharmaceutical companies will accumulate control and power over the production process' by replacing a diverse set of small suppliers was described as inevitable when the lead scientist of the biosynthetic Artemisinin project publicly stated 'early on, it was not about replacing the agricultural form […] and now I think it's nearly inevitable that it will shift over' (Keasling quoted in Thomas, 2013). The same scientist was quoted in the journal *Nature*, recognising the necessity of 'gradual introduction to avoid driving conventional producers out of business', until 'we have enough installed capacity to take over the entire world supply' (Keasling quoted in Peplow 2016).

As of 2020 the take-over of the 'entire world supply' has not happened (yet) and the pharmaceutical company struggled to compete with lower costs resulting from a glut of farmer cultivated artemisinin. In 2016 the Gates Foundation stepped in again to offer a further US$5 million to help lower production costs in-line with agricultural prices (Peplow, 2016). In 2019, a UNCTD reported that 'Amyris continues to work on improving its process for artemisinin' and that 'several other biotechnology companies have won grants from the Gates Foundation to develop low-cost supply of SSA' (UNCTD 2019). Notably, one of those other companies funded by the Gates Foundation is ManusBio, which as of April 2021 became the third company to commercialise biosynthetic stevia (ManusBio 2018 & 2021). The UNCTD report warned that 'the long-term implication of SynBio artemisinin for farmers of sweet wormwood could be profound, as it could eventually eliminate, or significantly reduce, the market for the natural product (UNCTD 2019: 13).

The case of artemisinin has been invoked to imagine the moral benefits of the biosynthesis in conversations I have had with synthetic biologists and during SynBio conferences I have attended. However, Marris argues the 'grand claims of saving thousands from malaria' alongside portrayals of 'African children, menacing-looking mosquitoes and stark numbers for malaria cases and deaths', are 'simplistic and exaggerated', as they overlook real-world complexities and the 'role of interlinked technological, economic, social and political factors' (Marris, 2013). Biosynthetic artemisinin has been described by Oxfam practitioners as a 'dangerous distraction' from fundamental investments required in community health (Dransfield, 2012). Yet little sustained or rich empirical research with artemisinin farmers in Malaria prone countries exists to offer a picture of the multiple and evolving impacts and implications of this highly-charged moral, political and socio-ecological field.

Scholars of Science and Technology Studies and those predominantly involved with RRI projects, have referred to synthetic biology's tendency toward techno-solutionism as part of a long history of science (often inadvertently) misdiagnosing socio-economic or political problems by prescribing technology as the solution (Borup et al. 2006; Stirling

2012; Marris, 2013). Amplifying or inflating promises are key to emerging technosciences, such as synthetic biology, who need to attract funding. The strategic use of metaphors, technoscientific imaginaries and promissory narratives to reframe and shape expectations or re-assure sceptical publics that SynBio innovations will address global problems has been well studied (Molyneux-Hodgson et al. 2016; Joly 2010; Marris 2015; Boldt 2016). Yet very little work has empirically addressed how such metaphors, imaginaries, expectations and promissory narratives play out on the ground through connection and disjuncture in the complexity of 'real-world' entanglements. In this thesis, I pay attention to these dynamics and particularly the deployment of promissory narratives about (biosynthetic) stevia, and their diverse interpretation. Next, I turn to the most recent body of work taking an anticipatory approach to the 'real-world' implications of biosynthetic menthol. I then conclude this literature review by outlining why stevia offers a powerful lens in illuminating the significance of the stakes and challenges confronting the future of natural products.

(Biosynthetic) Menthol.

At the University of Manchester Research Centre for Synthetic Biology of Fine and Speciality Chemicals in the UK, research and development (R&D) on biosynthetic menthol is underway. Proof-of-concept has been demonstrated for the production of menthol via a 'microbial cell factory' whereby *E.coli* bacteria genetically engineered with genes from *N. tobacum* (tobacco plant) and *M. piperita* (peppermint) replicate the metabolic pathway existent in peppermint (Toogood, 2015). Unlike artemisinin and steviol glycosides, R&D in biosynthetic menthol is still in its infancy and technical and economic feasibility of scaling-up production has not been evaluated. Nevertheless, a group of RRI researchers working to 'anticipate the benefits and risks of SynBio early on in the scientific and innovation journey and feed this into decision-making' have produced a body of work on 'menthol in everyday life' (SynBioChem 2020; Ribeiro & Shapira 2019; Meckin and Balmer 2017).

An important aspect of this work has been focused on assessing 'real-world' implications of what they refer to as the 'bio-turn', or the 'anticipated socio-technical transition' from conventional to synthetic biology production of menthol. This work has included mapping the 'rationale, objectives, promises and expectations' behind the agricultural, chemical and biosynthetic production processes, and unpacking the goals, values and 'fundamental drivers of transition' (Ribeiro & Shapira 2019: 312). The authors recognise that despite the promise and expectation, research unpacking the benefits biosynthesis claims to offer has been overlooked. They argue for a more 'granular' and nuanced understanding of the 'political economy of synthetic biology and a focus on real-world applications vis-à-vis current modes of production of compounds that synthetic biology seeks to replace' (Ribeiro & Shapira 2019: 318).

Through the lens of mint production in India - where the livelihoods of an estimated 15 million people depend on growing mint supplying 80% of global demand - the authors anticipate the direct and indirect implications that biosynthetic menthol might have were it commercialised (IFEAT 2014). Their analysis concludes by highlighting 'five areas' for those directing the 'responsible development of synthetic biology'; including social and distributive justice; geographical particularities of sociotechnical arrangements; assumptions of environmental sustainability; the implications of changing modes of production; and the dynamism of public uncertainty around new technologies (Ribeiro & Shapira 2019:318). These five areas of concern played out across my own encounters following the

interlinkages of stevia. Stevia farming in Paraguay shares characteristics with mint farming in India where farmers are often impoverished small-scale or subsistence producers, 'already struggl(ing) with a lack of basic infrastructure and difficulties associated with regulated marketing and support price systems' (Ribeiro & Shapira 2019:316; Kumar et al. 2011). The 'burden of changing markets on societal groups who are already vulnerable' the authors argue, raise a significant social justice challenge (Ribeiro & Shapira 2019:316). Pertinent questions remain unanswered over how to appraise the potential indirect impacts, and attribute and allocate responsibility of a 'radical displacement of the supply chain if biosynthetic menthol were to be produced by companies in Western, higher income countries?' (*ibid*:316). It is a sign of the progression in thinking through responsibility that these questions are coming to the fore at the R&D phase of biosynthetic menthol in 2019, however in the context of stevia such social justice challenges have been unfolding largely unaddressed for the last five years. I hope that this research will contribute insights to the call for more granular and nuanced understandings of this new 'nature' of production.

Like the lead scientist of the artemisinin project who naively suggested that displaced farmers of sweet wormwood could grow potatoes, the synthetic biology scientists in Ribeiro and Shapira's study share 'misleading' expectations that current producers '(i.e. impoverished farmers) could find alternative uses for land or alternative markets for their products in the event that they lose their export markets' (2019:316; Thomas 2013). In asking 'what mechanisms are available to ameliorate, if not avoid, displacement?' Ribeiro and Shapira also highlight the challenge of social resilience as a relevant yet overlooked aspect of research on synthetic biology. Resilience and adaptation, they assert, 'depends on several factors that are at the same time technical, socio-economic, cultural and political-institutional' (2019: 316). The authors do not elaborate the ecological entanglements of resilience and adaptation, I found were central to rural communities and 'natural product' dynamics in understanding how effects play out on the ground (Smith and Stirling 2008).

This highlights one of the gaps in Ribeiro and Shapira's analysis as well as analyses of artemisinin and other biosynthetic vis-à-vis natural (botanical) examples more broadly: the persistent lack of empirical accounts from those groups, spaces and places who stand to be affected, 'radically displaced', disrupted, and destabilised – and thus the important contribution of this research. On the other end of the scale or 'value chain', the lack of empirical accounts of the groups, spaces and places that stand to benefit, that are expanded, strengthened or secured. For example, how does such technology solidify the power of incumbent industrial food and agriculture? It is critical to comprehend both processes of expansion and reduction as two sides of the same coin to assess the kind of development pathways such technologies open up, what is lost, what is gained, and for whom. In taking this approach I advocate a distinctly political-ecological perspective, explicitly questioning the societal desirability of the technology, rather than framing it as an inevitable 'bio-turn' or transition. While Ribeiro and Shapira nod to the fact that situated 'end to end assessments' of synthetic biology should include the 'perspectives of vulnerable groups who are typically excluded from expert-driven assessment processes' the authors' starting point is the perspectives of the SynBio scientists themselves, and is demonstrative of the lack of studies grounded and carried out in the places and with the people implicated in the 'innovation'. Like Wellhausen and Makunda (2009) and many social scientists striving for 'technology justice' (Trace 2016), Ribeiro and Shapira fail to acknowledge those being disrupted as actors other than the 'vulnerable farmers'. I

argue that an equally important opposite side of the same coin is the resilience and ability of multinationals to adapt, strengthen and consolidate their dominance over sectors. Rather than solely looking 'up' to the economic systems, or 'down' to the vulnerable on the ground, it seems imperative to look *through,* and to follow how processes weaken as well as strengthen certain trajectories in the context of contingency and transformation (Shore & Wright 2003).

Why stevia?

> Will sugar always be more advantageous than Ka'a-he'ê? We cannot suppose this. The superiority of sugar as an energetic food will not be contested, but this does not stop our plant from being stronger as a sweetener.
>
> Ka'a he'ê, Its Nature and Its Properties, Paraguayan Scientific Analysis. Bertoni 1905

This statement about ka'a he'ê in 1905 by Paraguayan ethnobotanist Moises Bertoni – a man historically attributed as having 'discovered' stevia, after centuries of use by the Indigenous Guaraní Peoples – was one of the first to prophesise about the plant's riches and the socio-economic development it would bring to Paraguay.

Since then, repeated prophesies and promises have spread and globalised around the potential of this small but miraculously sweet-tasting plant. Most recently and particularly in the Global North stevia has come to symbolise a 'green' solution to the global obesity crisis for its ability to 'naturally' sweeten foods and drinks with 200-300 times more intensity than sugar, and significantly - with zero calories and zero dental decay. Isolating the sweet molecules found in the leaves has become big business, incentivised by the introduction of national sugar taxes in many countries since 2018. Stevia's popularity increased 400% between 2008 – 2012; its global market value was estimated at US$1.4Billion in 2019 and continues to grow (Amyris 2019; Estenssoro 2019). It has become a sought after 'green' 'healthy' sugar replacement among the world's largest food and drinks multinationals including Coca-Cola, Nestle, PepsiCo, Cargill, Unilever and Kraft, and can now be found in supermarket aisles globally in products as diverse as toothpaste to baked beans to soft drinks. The World Health Organization estimated in 2015 that stevia was poised to replace 20% of the 160 million ton worldwide sugar market, valued at over $50 Billion annually (ICC 2015). Alongside its 'naturalness' credentials (compared with artificial sweeteners), the emergence of global commodity stevia has also been accompanied by marketing narratives framing it as contributing to solving the global 'obesity pandemic', and that (biosynthetically) increasing supply would contribute to the UN Sustainable Development Goal (SDG) on improving global health (Avansya 2021).

Until 2018 stevia's high-intensity sweetness has meant that – unlike sugarcane plantations – it didn't need to be produced in vast quantities to produce profit. Stevia cultivation has been suited to non-mechanised small-scale agricultural systems farmed by smallholder and peasant farmers due to its high-labour and care requirements. However, like artemisinin, mint, vanilla and vetiver, it is these very socio-ecological and agricultural characteristics of stevia as a 'high-value low-volume' product that have made it a target for synthetic biology as a not-yet-industrialised agricultural commodity that can be scaled up at industrialised volumes. Since around 2015, NGOs and civil society groups have mounted campaigns raising the alarm over the potential negative consequences of synthetic biology for peasant farmers relying on stevia (and other natural products) for their livelihoods (ETC group 2015; Friends of the

Earth (FOE) 2016; SynBiowatch 2016; TECLA 2018). In a separate campaign also starting around 2015 the Indigenous Pai Tavyterâ and Kaiowá Peoples of Paraguay-Brazil publicly accused multinational food companies of biopiracy for their appropriation of 'traditional knowledge' without prior and informed consent or mutually agreed terms for access to stevia or sharing of benefits derived from it (Meienberg et al. 2015). With synthetic biology utilising stevia DNA (encoding the plant's metabolic instructions to produce stevia's sweet molecules) the plant has simultaneously been amplified to debate the new techniques in digital gene sequencing and synthesis and the potential to commit 'digital biopiracy'. This trio of dynamics make stevia an important lens to observe and unpack the ways in which recent technological abilities to utilise, digitise, sequence and synthesise the 'natural' world are playing out in multi-sited locales.

This chapter has considered how scholars have approached various issues surrounding and connected to synthetic biology 'natural' products and the inputs and processes of biosynthesis. I started by outlining some of the key theoretical and conceptual work on biocapitalism that has influenced my approach to the field, particularly the critical potential of how genetic and economic reductionism in processes of molecularisation are increasingly influencing the way the world is known and governed, and how this expert-driven agenda privileges specific types of knowledge and decision-making. Attuned to a decolonial, class and feminist struggle, I outlined my commitment to a political ecology approach paying attention to power-relations and historical imbalances and injustices. I discussed the separate bodies of work relevant to the three separate stages of biorefinery: the inputs of monocrop biomass feedstock that fuel the bioeconomy; the science and politics of sequencing, synthesising, editing and engineering genes, organisms and DNA; and the outputs of biosynthetic 'natural' products which have emerged alongside contrasting framings, narratives and critiques of 'disruptive' innovation and 'responsible' innovation.

This thesis unites these bodies of work by being one of the first projects to consider all three stages of biorefinery together, and to go directly to the places, spaces and communities who stand to be most affected. The next chapter explains the methods and concepts I develop in which to do this.

Chapter Two.

Following synthetic biology *through* stevia: concepts and methodology.

It is increasingly recognised that 'ethnography needs to work differently if it is to understand a networked or fluid world' (Law 2004:3). This chapter develops the conceptual and methodological approach supporting the research questions and themes laid out in the introduction. As natural products become substitutable on the molecular level, the starting point of this research sets out to explore what the shift from land-grown natural products to lab-grown implies in those places, spaces and peoples connected to a 'natural product', such as stevia.

In this chapter I outline why multi-sited ethnography overcomes some of the gaps and limitations of previous work on synthetic biology's 'real-world applications' (Ribeiro and Shapira 2019) and how 'objects of study' emerge as design and product of the methodology of 'following'. Tracing connections and disjunctures between situated knowledges illuminates significant relationships within and across the complex worlds that synthetic biology touches directly and indirectly. Following stevia from industrial synthetic biology production, to the growers, knowers and traders of the plant reveals a diversity of stakes rooted in multiple orientations to the living world. This diversity is illuminated and unpacked through what I term 'dis/connects' or four key zones of encounter, connection and disjuncture that have emerged from the methodology of following. Through a work of ethnographic juxtaposition I aim to broaden understandings over what is at stake with biosynthesis in the diverse worlds of stevia. This methodology may not produce standardised numeric or 'measurable' implications, rather it offers a richer, deeper picture of what is happening 'on the ground' with those adjusting to, contesting, or rejecting the emergence of synthetic biology 'natural' products. Multi-sited ethnography offers a lens capable of capturing the significance of what is being obscured by seemingly subtle definitional shifts taking place in and between the worlds of stevia.

Following things.

At the conceptual level this research explores the dynamic of emergence, how novel 'things' enter socio-ecological socio-technical worlds as both productive forces and products of (historical) connections, junctures, (in)equities and frictions *(be they epistemic, ontological, promissory or related to power).* Emerging technology produces connections between fields where new and old technologies, local realities, promises, political agendas and global policy processes intersect, form relations, or assemblages through which meanings and knowledges affect and are affected by diverse actors and narratives across scales and sites. The notion of 'the field' then as a dynamic and multi-scalar research site

lies at both the conceptual and methodological heart of this study, rooted in practices of multi-sited ethnography (MSE).

Marcus and Fischer (1986: 91) first put forward an agenda to broaden ethnographic attention from a 'concentrated group of people in a community, affected in one way or another by political-economic forces, [to] 'the system' itself - the political and economic processes spanning different locales, or even different continents. Ethnographically, these processes are registered in the activities of dispersed groups or individuals whose actions have mutual, often unintended, consequences for each other, as they are connected by markets and other major institutions'. Later Marcus published a manifesto towards multi-sited ethnography which has become a guiding methodology for a large body of research across social science (Coleman & Von Hellerman 2011; Falzon 2012) 'designed around chains, paths, threads, conjunctures or juxtapositions of locations in which the ethnographer establishes some form of literal, physical presence, with an explicit, posited logic of association or connection among sites that in fact defines the arguments of the ethnography' (Marcus, 1995:105). It is exploring the connections between sites, just as much as the sites themselves that are central to this approach. The practice of MSE moves beyond the traditional ethnographic 'object of study' centring on the fixed study of people(s) and culture, to *following* things, metaphors, plots, stories, allegories, lives, or conflicts (ibid, 1995). Anthropologist Arjun Appadurai (1986) first recognised that 'things' are more than objects for exchange, they have politics that is to say, they have 'social lives'. From this perspective, following synthetic biology as a 'thing' means understanding it not solely as a new technoscientific field or innovation, but simultaneously as a practice, metaphor, economic strategy, and world view. Appadurai argued 'we have to follow the things themselves, for their meanings are inscribed in their forms, their uses, their trajectories. It is only through the analysis of these trajectories that we can interpret the human transactions and calculations that enliven things' (1986: 5). Following the forms, use and trajectory of synthetic biology 'social life' into stevia 'social lives', uncovered multiple and diverse meanings of stevia both in relation to and far beyond the biosynthetic paradigm. 'Following things' has broken loose from the confines of academia and has become a popular and critical tool for public awareness, activism and ultimately change. Ian Cook et al*'s* spoof 'Amazon' website 'followthethings.com' has been at the forefront of connecting and juxtoposing the worlds along and beyond 'commodity chains', 'production networks' and assemblages. The website features a broad collection of works exposing the social life of objects, artifacts, plants, money and more, bringing to the fore the entangled political nature of not just production and consumption, but colonialism, policy, aesthetics, disease, transport, ecologies, chemicals, labour control and surveillance (Followthethings 2021; Barnes et al. 2007)

I was particularly inspired by Anna Tsing's take on MSE as 'an ethnography of global connection' following an Indonesian rainforest 'not confined to a village, a province or a nation' but as a story she writes encompassing the worlds of North American investment practices, stock markets, Brazilian rubber-tappers advocacy, United Nations Environmental Funding, international mountaineering and 'the overthrow of the Suharto regime, among other things' (Tsing 2005:i). Tsing's most recent book follows a mushroom to postulate 'on the possibility of life in Capitalist ruins' (2015). Unearthing and illuminating the social, ecological, political assemblages (through spaces, places and people, material and semiotic elements) that coalesce around the Matsutake species of fungi she argues offer 'sites for watching how political economy works' elaborating 'if capitalism has no teleology, we need to see what comes together – not just by prefabrication, but also by juxtaposition' (Tsing, 2015:23).

Following synthetic biology through stevia allows exploration of what synthetic biology implies by examining what changes and remains the same or what is expanded or reified, or diminished and expended, between the established and emerging worlds of stevia. Stevia as a lens illuminates multiple worlds drawn into synthetic biology, where practices play out, where things have effects, and trajectories or narratives are affected in response. Following stevia I found it interpreted simultaneously as 'more-than' plant, compound, religious deity, livelihood strategy, genetic resource, DNA information. Synthetic biology and stevia as emergent 'things' produced an enquiry where the 'contours, sites and relationships are not known beforehand, but are themselves a contribution of making an account that has different, complexly connected real-world sites of investigation' (Marcus, 1995). Adopting this methodology, I approached 'the field' with purposely loosely defined and flexible set of questions, tracing lines of inquiry until they either reached saturation, or required further unearthing.

Sowing seeds.

I started following synthetic biology from day one of constructing my doctoral research proposal. At the outset 'following' was online via email threads, stock market notifications, and civil society campaigns. But as the University of Bristol welcomed its first ever cohort of synthetic biology PhD students at the same time as I was enrolled on one of the first 'interdisciplinary social science' pathways on Global Political Economy, I began interacting with this first generation of SynBio scientists about how our 'interdisciplines' intersected. As one of the few researchers following and engaging in the worlds of 'SynBio' in 2014-15 I was invited to and participated in a number of 'dialogues' and 'deliberations' over 'Responsible Research and Innovation' (RRI) such as the Forum for the Future 'opening up the conversation on Synthetic Biology' in London where a 'deliberation aid' was created to help the public decide whether it would be ethical to consume biosynthetic vanilla (FFF 2015; BrisSynBio 2016). Other events I attended were funded by the European Synenergene project hosted in various countries including one at the UN International Labour Organisation in Geneva co-organised by the International Union of Foodworkers and ETC group exploring *'How Synthetic Biology will Impact Rights, Livelihoods and Life?'.* At this later event the Swiss NGO 'Public Eye' presented their preliminary report on biopracy of stevia (Meienburg et al. 2015). Questions over stevia were just one of many looming questions being thrown about over implications of synthetic biology and I began physically mapping out uncertainties, frictions, contestations and connections on large pieces of paper on the office floor of the doctoral training centre. In April 2016 I attended the week long 'SBSTTA 20' - the twentieth meeting of the Subsidiary Body for Scientific, Technical and Technological Advise to the UN Convention on Biological Diversity - where, as a permitted 'observer' I encountered for the first time the global divisiveness, and visceral emotion and friction sparked by synthetic biology between countries, companies, Indigenous Peoples' representatives, and civil society groups (Bond 2016).

Upon return I decided upon stevia as a lens through which I could follow this frictious space. Stevia brought together many of the issues and unfolding dilemmas faced by international governance, and the uncertainties and concerns I had encountered in the UK 'SynBio scene'. From that point onward, I plunged into the worlds of stevia. Until then I had not noticed, let alone tasted stevia. I set out reading everything I could find on stevia, I wanted to know its origins, its history, what it was, who grew it, how it grew, and how it was bred, patented, sold, marketed, and governed. It wasn't straightforward finding information on stevia. Compared to other natural products, stevia's 'discovery' beyond its

endemism is relatively recent. Aside from a few plant science books at the British Library, some with limited ethnobotanical records related to the role of 'Guaraní Indians', there was barely any literature on domestication or farming of stevia. Most accounts of stevia were found online. I became increasingly attuned to stevia. This coincided with a stevia boom across Europe and I started to notice stevia springing up everywhere. I noticed brands in my local supermarket and wholefood store swapping sugar for stevia in beans, ketchup and chocolate; cafés offering stevia sachets alongside conventional sweeteners, and a roadside billboard advertising green Coca-Cola Life 'with stevia plant extract' as a rebellious alternative on 'Turbo Island,' a notorious 'hangout' in Stokes Croft, Bristol. Due to the Zika virus outbreak and becoming pregnant I could not visit Paraguay until 2018. Serendipitously however the time in which it had taken me to adjust to motherhood equalled the delay in the commercial launch of biosynthetic stevia due to industrial problems and costs of scaling-up at the Cargill biorefinery where it was to be manufactured. And so, by the time I left the UK on the trail of stevia, some big changes were starting to take shape across the little plant's many worlds.

Figure 2.1 Coca-Cola Life billboard in Stokes Croft, Bristol, June 2015. (Source: authors own photo).

Juxtaposing 'worlds'.

Only in *following* synthetic biology *through* stevia have I found the 'objects of study' diversely defined by mobile and multiply-situated understandings and orientations to the living world. Multi-sited ethnography brings 'together in one frame of study', both the social and political economic grounds towards 'idealised' innovation and the situated communities concerned, moving beyond the traditional 'studying down' of the effects upon local communities (Marcus, 1995:100), or indeed the 'studying up' solely upon those who make decisions or innovate. As Shore and Wright describe, MSE allows the 'studying through': bringing phenomena that conventionally have been kept 'worlds apart' in academia towards tracing the 'ways in which power creates webs and relations between actors, institutions and discourses across time and space' (2003: 14). MSE conceptualises the global as an 'integral part of parallel and related local situations' rather than something external, or as a socio-political space rather than a strictly geographical scale

(Shore and Wright 2003; Gupta and Ferguson 1997), where 'the local' entails illuminating process trajectories as 'relatively coherent bundles of ideas and practices realised in particular times and places' (Tsing, 2002: 472-6).

Marcus describes the act of 'following' *as* the object of study through the 'practices of construction through (planned or opportunistic) movement' which are inevitably characterised by a comparative dimension, in the form of juxtapositions of phenomena (Marcus 1995). From the outset my encounters of synthetic biology were characterized by a juxtaposition of views and values between corporate representatives, public relations facilitators, GMO critics, and young synthetic biology scientists deliberating questions around ethics, responsibility and public acceptance of biotechnological innovation. Despite these at times awkward encounters happening over funded dinners at nice restaurants, or buffet tables at conference venues, rather than in farmers' fields, Indigenous enclaves, or deforested lands, the value of these interactions inscribed into me a commitment to follow and represent the diversity in views and values around the innovation to biosynthesise 'natural' products. What I had observed resonated with Cook and Crang's (1996) assertion that the way in which 'commodity systems' (or in my case, biotechnology commodity-innovation systems) are known, imagined and acted upon 'from within are fragmentary, multiple, contradictory, inconsistent and, often, downright hypocritical,' and where understanding and learning 'comes not from smoothing them out, but through juxtaposing and montaging them … I found was equally true for my own instinct to dissect the rhizomatic dis/connects, as it was for allowing audiences to 'work their ways through them and, along the way, inject and make their own critical knowledges out of them,' (Cook & Crang 1996: 41). In this thesis I do not conceptualise a 'commodity system' as such, but my findings certainly examine processes of commodification *in action* as the chapters chronicle stories of stevia increasingly drawn into circuits of capital through intellectual property mechanisms and molecularisation. Rather I conceptualise 'worlds of stevia' each characterised and interconnected through interpretations, mobilisations and socio-ecological plant-related practice. Each world of stevia I followed on this ethnographic journey was characterised by a community of people, and their socio-economic, technical, (agri)cultural or ecological relations with the plant, its diverse uses, and ultimately diverse ontological and epistemological values ascribed to 'what stevia actually is'. Hence each empirical chapter represents a 'world' in which stevia plays a particular role and describes the way stevia is known within a particular set of understandings.

The 'worlds of stevia' form the structure of the thesis through five empirical chapters of following, encountering, unearthing and analysis. I start with the latest incarnation of (biosynthetic) stevia that is re-making stevia into a promissory bioeconomy commodity among US corn producers and (global) industrial biotechnology businesses. Next, I trace stevia to its endemic origins alongside the Pai Tavyterâ Peoples in North-East Paraguay who understand stevia (or ka'a he'ê) as a sacred herb and spiritual family member. Staying in Paraguay, the third world of stevia is structured around its domestication into a promissory campesino cash crop offering sustainable livelihoods for low-income families. Following stevia into a fourth world where it becomes globalised, molecularised, modified, optimised and refined into a corporate cash molecule, here stevia's story takes multiple geographic directions including China, Malaysia, Kenya and back to Paraguay, all the while remaining rooted in imaginaries of endemic authenticity. Fifth and finally I follow stevia back to the world of global decision-making on synthetic biology at the UN Convention on Biological Diversity (CBD), where 'worlds collide over 'what stevia is', and different characteristics of diverse

interpretations are mobilised to contest emerging decontextualised, digital and dematerialised interpretations of stevia as 'cash DNA'.

Following stevia unearthed five juxtaposed 'worlds' demarcated by distinct interpretations of stevia, where it was predominantly understood as a *bioeconomy commodity*, a *sacred herb*, a *cash crop,* a *cash molecule* and ultimately *cash DNA*. The chapters incorporate empirical data collected and generated in Nebraska, USA, and across multiple sites in Paraguay, as well as in the meetings of the United Nations Convention on Biological Diversity (CBD) which took place in Canada, Mexico and Egypt.

The starting and end point of the fieldwork has been the Convention on Biological Diversity (CBD). I attended SBSTTA 20 followed by COP13 in 2016, travelled to the US and Paraguay in 2018, and returned to COP14 in November 2018. This global governance arena – geographically mobile yet with permanent spatial and physical presence within the UN institutionalized system of multilateral conferences of the parties (COPs), scientific advisory meetings (known as SBSTTAs), and ongoing online information-gathering processes – has undeniably influenced the way in which I followed stevia. In total I have observed over five years of CBD deliberation, debate and decision-making on the topic of synthetic biology, with a particular interest in how decisions and knowledge about synthetic biology are performed and produced and the composition of human and nonhuman actors that coalesce around the topic. I have been present as an 'academic observer' during SBSTTA20 (2016), COP13 (2016) and COP14 (2018) for a total of 6 weeks, on top of being 'present' through ongoing online CBD governance processes, as well as working as a research assistant on a study commissioned by the CBD (Para. 9 (e) of decision CBD/COP/DEC/14/20), and participating in other related policy events around SynBio and the CBD (Scott & Berry 2017). As part of this ethnographic research on the governance of synthetic biology I conducted 14 formal interviews and had countless informal exchanges with delegates and participants during the conferences, preparatory meetings and side-events, on top of physically observing at least 50 hours of multilateral governmental negotiations on synthetic biology often late into the night (two nights of negotiations went on until past 3am).

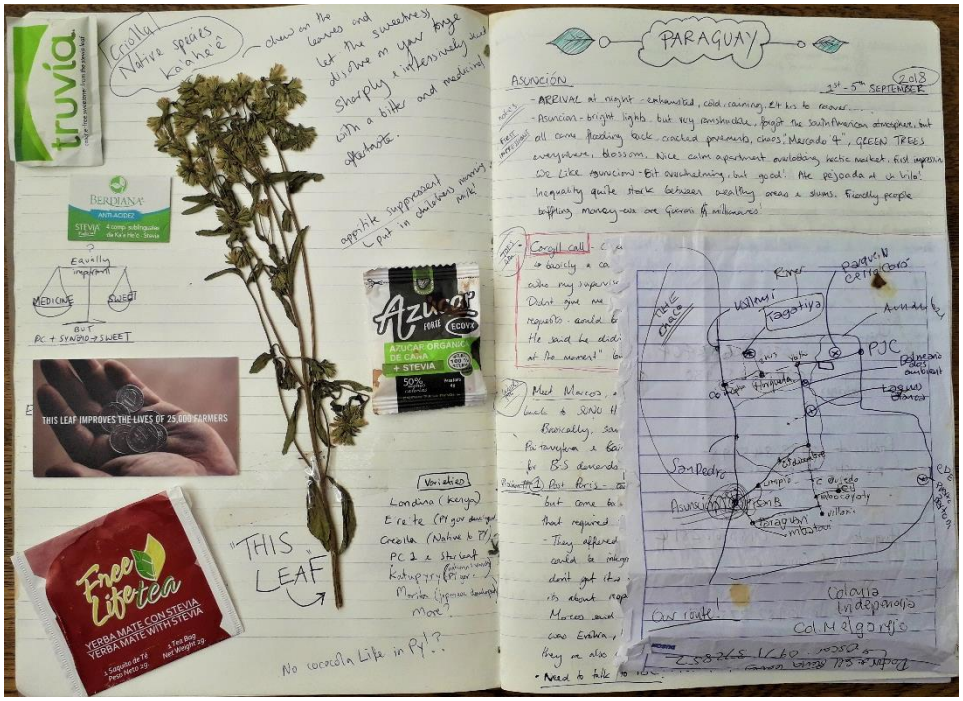
Desk-based research trying to unearth the basis for the industrial fermentation and biosynthesis of steviol glycosides at the industrial biorefinery owned by Cargill proved very limited. I secured funding to travel to the industrial site itself situated in the heart of the corn communities of Nebraska USA, in the hope that 'being there' would open new opportunities. In Nebraska I carried out 7 interviews and gained a guided tour of the industrial facility alongside numerous informal exchanges in and around the corn and synthetic biology community connected to the biorefinery, speaking to bio-industrial scientists, corporate spokespeople, corn farmers, the local chamber of commerce and officials working at the Nebraska state Corn Board. As I explain in chapter three accessing specific sites of interest or key spokespeople for biosynthetic stevia was not straightforward, and I was repeatedly referred to online webpages. As a result, such web 'sites' became a location of the multi-sitedness itself.

In Paraguay I dedicated almost 3 months to following stevia/ka'a he'ê on top of my desk-based research in the UK. In Paraguay I conducted 31 interviews with small, medium and large stevia businesses, community and spiritual leaders in the Pai Tavyterâ community, stevia farmers and farming families, NGOs, civil society groups, academics, scientists, agronomists, and local and national government officials. I also attended talks and rallies, toured test plots, small farms,

production facilities, and warehouses, and on occasions stayed in the homes of participants. Interviews and interactions took place in English, Spanish and Guaraní. I was assisted by a translator for conversations in Guaraní, and in rural Paraguay where campesinos often speak a combination of Spanish and Guaraní.

Across all the areas I 'followed' from the UK, to the CBD, to the US and to Paraguay, I kept a written ethnographic diary and 'scrapbook' containing remnants of stevia packaging and labels, photographs, small samples and gifts given to me including pressings of stevia leaves, and flowers, sweetener sachets, stevia medicinal supplements, dark green powdered stevia leaf, and brown bottles of stevia extract, as well as flyers and pamphlets I picked up in company or government waiting rooms, business cards, maps and contacts. My diaries are testament to the joys and messiness of unravelling and following.

Figure 2.2 Extract from one of my ethnographic diaries 2018.



Dis/connects.

Conceptualising 'worlds of stevia' emerged as a product of the methodology, following spaces where juxtaposed meanings of stevia surface, and where deeper and more nuanced disjuncture and connection 'jump out'. Beneath the surface of the more obvious connections of space, place, flows and people, and what constitutes a 'thing' e.g. the endemic origins, the history of a thing, the established cultivation or incumbent production systems, industrial inputs, processes and outputs, marketing and advertising narratives, all of which can be researched with relative ease, there also lie other, less explicit connections between these worlds which cannot easily be drawn from cursory analysis. They are a product of physically encountering these spaces, the key strength of this methodology. 'Ethnographies of global connection' become visible, asserts Tsing (2005), through:

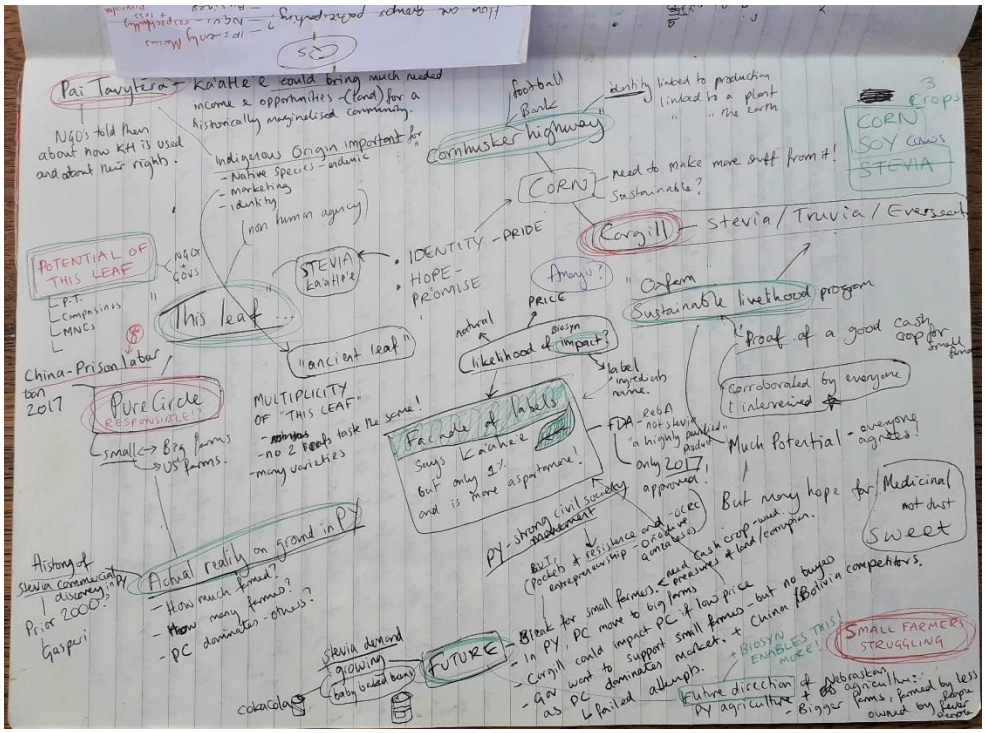
> [F]ocus[ing] on zones of awkward engagement, where words mean something different across a divide even as people agree to speak. These zones of cultural friction are transient, they arise out of encounters and interactions. They reappear in places with changing events' (2005:xi).

Tsing's approach illuminating the dynamics of zones of friction is central to my own approach and findings in this thesis. Marcos (2010) similarly conceptualises ethnographic following of connections as 'zones of discourses' operating across 'ecologies of knowledge'. The disjunctures and connections within 'discursive zones' or, as I will term them 'dis/connects,' may be observed through the verbal testimonies, interpretations, daily realities, practices and material, ecological environments of spaces, places and people as their 'worlds' are connected through particular words, but are divided by their reification, meaning, understanding or practice.

Four frictious zones or dis/connects that jumped out bridging and permeating my multiple encounters around stevia, were **authenticity, ownership, sustainability and justice**. I unpack these throughout the thesis as I encounter different ways in which they are being mobilised. The four discursive zones bridge the worlds of stevia but are not necessarily coherent or imply the same, which is why I emphasise their disjuncture or *dis*-connectivity. Within each discursive zone dis/connects play out through (promissory) narratives, imaginaries, contestations, and approaches and orientations to the living world. As an example, notions of authenticity were mobilised connecting all the sites traversed following stevia, but various actors and narratives manifested 'authenticity' uniquely through diverse understandings of naturalness, imaginaries of digital-material-molecular equivalence, or amplification of historical entanglement. Likewise, diverse conceptualisations and contestations over 'sustainability' played out across sites, playing either explicit or implicit roles in the dis/connection of worlds. While notions of justice were mobilized and amplified in some worlds more strongly than in others, justice pervaded as a concept connecting all worlds of stevia, whether stevia was interpreted as bioeconomy commodity, a sacred herb, a cash crop, a cash molecule or cash DNA.

The dis/connects in the discursive zones of **authenticity, ownership, sustainability and justice** emerged through fieldwork and analysis as research findings, but they have led to further findings illuminating underlying and indirect stakes, nuances and subtleties, expansion and expendability. They can only be fully understood within the context of the ethnographic journey where they are described and discussed at specific junctures, which is why I only summarise them here. Suffice to say that unearthing these discursive zones of dis/connect demonstrate that stevia represents a diverse ecology of knowledge and practice.

Figure 2.3 Mapping dis/connects. Extract from my one of my ethnographic diaries 2018.



Ethnographic sensibilities of a circumstantial activist.

The researcher's literal movements and conceptual, discursive and physical linking of spaces and sites, Marcus (1995) asserts, makes the multi-sited ethnographer a 'circumstantial activist', not in the political or scholarly sense of the word, but in the playing out of the feminist sense that the 'personal is political' or indeed that the 'personal is methodological.' This undoubtedly raises ethical challenges (Marcus, 1995; 1998). As Sally Brookes (2005:71) describes in her ethnography following crop biofortification:

> 'It is not a straightforward matter of declaring a position at the start: multi-sited research requires constant reflexive attention to processes of positioning and repositioning during the course of the study. Decisions as to the selection and ordering of sites, the framing of the research on arrival at each site and the selection of information and insights from one site shared at the next were all part of an ongoing process of 'mobile positioning'.

Processes of mobile positioning meant that for me, plans unfolded equally through serendipitous encounter as through pre-identified sites or actors of importance. One poignant example is the bird that dropped from the sky in a farmer's stevia field in Paraguay due to recent pesticide spraying on neighbouring soy fields, a moment that changed not just the tone of the encounter, but led to new sets of questions over viable crops and dependence on stevia's success for campesinos in areas of soy expansion. Another example was a rural social forum in Northern Paraguay which unexpectedly took place during the week I was meeting members of a campesino co-operative. This event opened multiple new insights into campesino vis-à-vis industrial agricultural politics, including an unannounced talk from the former president of Paraguay, Fernando Lugo. Other opportunities arose sporadically on social media, including a meeting with a farmer in Nebraska who had posted publicly on the Facebook page of the Cargill biorefinery describing

his experience unloading corn at the site. Every farming family I met offered contacts to others with shared or differing experiences. I proceeded on this basis, keeping track of my movements as I travelled between sites, meeting people and their families, their environments, following up on what I encountered, travelling to new sites, listening for corroborations or contradictions between narratives, historical records, perspectives, understandings across these worlds, until similar accounts reached a point of 'theoretical saturation' (Crang & Cook 1995:12). In order to be transparent and reflective as to the framing, selection and ordering of sites, I open each chapter or encounter with 'ethnographic snippets' - a section of descriptive writing from my diary of what led me to the site or community, why I was there, what I sought to understand, or my sense of 'how it felt'.

Although I have organized my findings into chapters characterized by 'worlds of stevia' in terms how stevia is being predominantly interpreted as a bioeconomy commodity, a sacred herb, a cash crop, cash molecule, or cash DNA, it is important to acknowledge that a distinctive boundary where one 'world' ends and another begins is far from concrete. My findings emphasize that there are multiple worlds of stevia and unpack the processes and mechanisms by which one world (characterized by actors, plant uses, epistemologies, and ontologies) of stevia has the potential to erode, transform or enhance other worlds around stevia.

Similarly, it is important to acknowledge these 'worlds' are not distinct, uniform or universal. Each world is messy, complex and entangled in and between much more than stevia, reflecting the complexities of social and ecological worlds more broadly. I use stevia as a way to tease out these contradictions, tensions, patterns and indirect factors to offer a richer picture of the conditions through which biosynthetic stevia emerges (and the worlds it supports). Despite pursuing this non-linear research methodology, I was nevertheless able to draw conclusions, contradictions and patterns connecting synthetic biology steviol glycoside reproduction playing an influential role in the making, breaking and remaking of the worlds I encountered. I situate synthetic biology stevia reproduction as a part of broader trends toward molecularisation and agricultural industrialization through moments which can be identified in stevia's evolving story. While I cannot claim to have a definitive answer to some of the looming questions and concerns surrounding biosynthesis as a production method (as each natural product brings with it a distinct set of socio-ecological and politico-economic considerations), the methodology enabled the development of specific critiques, further questions, and concerns over policy responses. It brought attention to the experiences, responses and insights from actors and environments often overlooked in previous research on implications of emerging technologies. As Geertz affirmed, an overarching aim of ethnographic research is to 'draw large conclusions from small, but very densely textured facts; to support broad assertions about the role of culture in the construction of collective life by engaging exactly with complex specifics' (Geertz 1993: 28). While I focus less on 'culture' per se, and more on process trajectories, ethnographic engagement with 'complex specifics' will contribute to calls for granularity (Ribeiro & Shapira 2019).

This project set out to follow stevia to all the places and peoples connected to it, there were of course many I could not reach, most notably China, which overtook Paraguay in the 1990s as the world's top producer of stevia. While I could not physically visit Chinese stevia plantations or businesses for practical, financial, and timescale reasons, stevia stories from China at many points enter this research through the relationships and imaginaries of research participants, as well as through my own unearthing following-up encounters with the world's biggest stevia company operating in both

China and Paraguay. I would have equally liked to have visited Kenya, where the same company promoted stevia to small farmers as a poverty alleviation crop, but similar constraints meant that Kenya came into my research through corporate narratives of farmer testimonies alone. I chose to include such secondary accounts rather than first person, as they demonstrate how the stevia promise has globalised, been commodified and transformed, and although I could not reach every site where stevia plays an important role, acknowledging them demonstrates that the diversity of stevia 'worlds' presented in this thesis alone is likely to be increased by further studies.

Multi-sited ethnographers through choices and processes of tracing, mapping or following, Marcus warns, find themselves with 'all sorts of cross-cutting and contradictory personal commitments. These conflicts are resolved perhaps ambivalently, not by refuge in being a detached anthropological scholar, but in being a sort of ethnographer-activist, renegotiating identities in different sites as one learns more about a slice of the world system' (1995:113). The ethical implications of this mean that in some sites, 'one seems to be working with, and in others one seems to be working against' various groups and research participants (Marcus 2012). This causes personal frictions as different spaces are negotiated. Scholars drawing upon the idea of 'emergent design' in ethnographic practice when working on or engaging 'multiplicity, indefiniteness, and flux' across spaces and scales, argue that ethnography should be a politically situated practice which reflexively critiques the notion of academic 'value-neutrality', where the issue is not whether we should take sides, but rather as Becker (1967) famously asked 'whose side are we on?' (Law 2004:117; Lewis & Russell 2011; Coleman & Hellerman 2011).

Such a question was asked directly by an employee of Cargill on a call interviewing me to decide whether or not I would be granted access to interview them: after questions about my research and my university supervisors, the Cargill employee concluded 'so what's your hypothesis, biosynthesis is good or biosynthesis is bad?' and I replied, 'I do not have a hypothesis, I'm looking to understand what biosynthesis is, explore the actors involved, and the promise surrounding the technology…' Needless to say, it was not easy to gain access to Cargill, the company shrugged me off to read websites I had already seen, or watch pre-recorded PowerPoint presentations on YouTube scripted for corporate investors, clients and consumers, none of which addressed the questions I had, nor aspects I wanted to understand. Through a process of following though, the wariness of one the world's biggest privately-owned corporations became in itself a finding of the research.

Due to the polarisation around SynBio as the latest field stemming from a divisive history over GMOs and biotechnology, there continues to be great suspicion on both sides of the debate, so-much-so that forms of 'SynBio-phobia-phobia' have been identified as a form of fear *of* public fear resulting from the first wave of consumer backlash against GM crops (Marris 2015). Many events I observed on synthetic biology took place under Chatham House rules, to enable participants to talk as freely and openly without their identity being disclosed or connected to their positions. Similarly, some interviews with government lawyers and scientists took place on the condition I did not record or quote, raising challenges in reflecting the reality of the field. Another challenge I encountered was asking difficult questions to scientists or businesspeople about negative possible future scenarios of work about which they were passionate, without being dismissed or perceived as an anti-GM critic, provocateur or opponent. This challenge is an issue also recognised by Law (2004:14): 'social science investigations interfere with the world […] things change as a

result. The issue, then, is not to seek disengagement but rather with *how to engage'*. Aware of the passion and divisive history surrounding agricultural biotechnology, I tried to operate in an as neutral-as-possible status, often taking a quieter observer role in polarised debates. My moral judgements were largely guided in terms of who, what and where is winning or losing as a result of what is happening, and what do such juxtapositions reveal about what biosynthesis implies. I was equally motivated to explore understandings and perspectives from those most excluded from processes as much as those driving the processes. My own moral directions, values and motivations were guided through a commitment to what scholars refer to as an 'ethnographic sensibility'. Which implies that the very choice of ethnography as a research methodology is imbued with a particular logic and ethical sensibility performed through adhering to fundamental principles of practice.

Edward Schatz described ethnography as 'a sensibility that goes beyond face-to-face contact. It is an approach that cares – with the possible emotional engagement that implies - to glean the meanings that the people under study attribute to their social and political reality' (2009: 5). In her multi-sited research Karen Tucker (2011) describes three ethical and methodological orientations in approaching 'fields' with an ethnographic sensibility. Firstly is a focus on being attuned to the ways in which 'meanings are transmitted, operationalised and negotiated in concrete social practice' rather than taking meanings as fixed or pre-ordained (2011:63). This was particularly important considering meanings attributed to participants' social, ecological and political realities surrounding stevia in a state of flux, as well as how individual and 'local historical trajectories flow into complicated transnational structures' (Appadurai 1991: 209). Secondly, an ethnographic sensibility implies 'approaching the field of enquiry with a flexible set of research questions, and an openness to refining them based on understanding gained through interacting with research participants' (Tucker 2011:63). This reflects the underlying ethos of a 'following' methodology, underscored by the importance of 'remaining as open as possible to the unpredictable and the informal in social life' (Coleman and Collins 2006:12). At multiple times my research questions and directions changed as new avenues emerged and previously obscured issues came to light. Thirdly, tracing 'global' processes with an ethnographic sensibility entails a sensitivity to complexity and diversity in the 'ecologies and politics of knowledge' that play out within and between different 'worlds' (Marcus 2010: 72). Operating with a 'sensitivity to complexity, diversity and the politics of knowledge', Tucker asserts, enables ethnographic researchers 'to develop theories and understanding which are attentive to the complex interplay between differently situated knowledges, rationalities and processes, and which thus avoids reproducing the generalising models and narratives produced by other approaches' (64). This approach offers a rich picture 'connect[ing] synthetic biology to specific places, historical events, expectations, uncertainties and, importantly, the technical and material aspects of transitions' beyond the lab (Ribeiro & Shapira 2019:312)

Ethical considerations.

A researcher's overarching ethical responsibility is first and foremost to the individuals and communities who participate in the research (American Anthropological Association, 1998). All fieldwork undertaken was reviewed and approved by the University of Bristol Faculty of Social Science and Law Ethics Committee. At each stage of making contacts, carrying out interviews and observations I was open and transparent about the purpose of and plans for my

study, my source of funding (ESRC), and I always ensured there were opportunities to discuss the nature of my research or to ask further questions. I automatically anonymised participants, unless they explicitly informed me that they would like to be acknowledged. I carried around printed information sheets about myself and my research in the languages required, and asked participants to read consent forms if deemed appropriate. At times it was necessary to gain verbal consent due to either the cultural norms of the participant, or in situations of unexpected encounters.

Adhering to an ethnographic sensibility meant my movements required constant ethical reflexivity, which in my case took the form of an ethnographic diary, which offered an opportunity to continually re-visit and refine emerging themes, where I had been and where I was going, and consider and broaden the range of positions, in what Marcos referred to as a 'constantly mobile recalibrating practice of positioning' (1995:113). Each location and community encountered presented different ethical considerations as different groups raised different sets of questions, according to roles and relationships around the plant, product or 'thing'. For example, the indigenous community, with a history of oppression and genocide by outsiders, required a different kind of sensitivity and care in learning about their relations to stevia as a sacred and spiritual family member than, for example, Cargill, for whom stevia is one of thousands of global commodities traded daily.

Before arriving in Paraguay I was very much prepared for the playing out of the 'personal as political' from previous experiences in Latin American countries negotiating my positionality as single, white, 'western', female (albeit from a working-class Cornish family). This time however I was travelling as a family in Paraguay, with a male partner acting as full-time carer to our 9-month-old, which on the one hand worked to soften our immediate appearance as outsiders. Allowing research participants to hold my baby inadvertently built trust, and informal exchanges over parenthood created bridges across socio-economic, cultural and geographic divides. Yet on the other hand, my partner's and my non-conformist gender roles also worked to confront and confuse patriarchal and religious traditions particularly in rural areas, although this led to more amusement and bemusement rather than negative reaction.

Some valuable connections I made in Paraguay were thanks to the help of a Paraguayan anthropologist, Marcos Glauser, who had recently completed his PhD and had serendipitously return to his motherland. Having time between jobs he helped make contacts and arrangements to travel and stay with the Pai Tavyterâ Itá Guazú community. His shared fascination with the history of stevia in his country, experience studying for a PhD in Europe, alongside the years he had spent as a single-sited ethnographer living with Indigenous communities in Paraguay including with Itaguazú families, as well as his fluency in Pai Guaraní, Spanish and English proved invaluable in bridging the linguistic and cultural divides. He helped me understand customary behaviour to ensure I showed respect for those who agreed to participate in the research. Any use of a linguistic or cultural interpreter or translator of course brings with it ethical risks in terms of representation over what does or does not get translated or emphasised (Borchgrevink 2003). The anthropologist had a record of academic publishing on issues facing Indigenous communities in Paraguay (Glauser 2011; Glauser & Rodríguez 2018). The trust and respect bestowed upon Marcos by the indigenous community themselves was clear in the actions of the leader, inviting us to stay in his home, share food and open interactions with other community members, signalling to me that the anthropologist was 'on their side' and unlikely to intentionally

misinterpret what they said. Nevertheless, both Marcos and I were mindful that all conversations and interviews with Pai Tavyterâ took place with free, prior and informed consent. While this cannot neutralise power imbalances imbued in all research encounters, it at least offers space and information for participants to question the researcher and make informed decisions whether to participate or not.

Many of my solo initiatives tracing stevia in Paraguay took place through interviews and encounters in Spanish, a language in which I am proficient but not fluent. I was lucky that every research participant in Paraguay consented to be audio-recorded which assisted more robust translation and transcription upon return to the UK. I ensured that I offered a printed information sheet and consent form in Spanish for all those I visited. I also employed a Paraguayan midwifery student to ensure my interpretation of the Spanish and Guaraní interviews were correct.

Coming back to the political and polarised terrain of studying what the emergence of biosynthesis implies, it is worth noting that in Paraguay, I was particularly careful not to frame my encounters with communities specifically under the lens of 'change' or of synthetic biology. My goal was to take a snapshot of what was happening with stevia in Paraguay at that very moment in time. I did not want the threat of or possibility of disruption or change, to tint or alter responses given to me. Because of this I approached all my interactions with participants in Paraguay from an exploratory position, asking questions like, what does stevia mean to you, how have things been, what are things like now, and what are your plans, hopes, thoughts for the future? Only before the very end of my conversations or interviews with participants, if they had not mentioned it beforehand, did I ask their thoughts on biosynthesis. I purposely left time to discuss questions and perspectives on synthetic biology and the ability to replicate stevia and other natural compounds.

My research at the CBD was aided in large part by the openness and transparency of CBD Alliance[3], and in particular through members of the International Civil Society Working Group on Synthetic Biology (ICSWGSB), many of whom have worked for years at the interface of international governance of techno-sciences, environmental policy, the rights of marginalised communities and experiences of those affected 'on the ground'. The ICSWGSB are a group with a well-known critical stance on the promises and politics of synthetic biology, the motives of biotechnology industry and consequences of GM crops (ICSWGSB 2012). However, as both research subjects and gate keepers they were invaluable as the only group working between 'worlds' and connecting people, places, and spaces surrounding stevia and beyond. On a personal level, I also found them to be particularly transparent in their actions, lobbying techniques and motives, characteristics none of the other groups operating at the CBD could offer or were willing to share. But as Tsing (2005:xii) acknowledges in her ethnographic involvement with activists fundamental to her studies of rainforest destruction, 'habits of restraint and care are demanded'. While I was welcomed into civil society organisations' conversations, strategy meetings and targeted policy workshops, there were times where my status as a neutral-as-possible 'outsider' observer was not welcomed, where I unexpectedly became the target of great suspicion, told to stop making notes or informed strictly that I can 'participate' on the condition I do not 'observe' – although impossible in its

[3] The CBD Alliance call themselves 'a network of civil society organizations who have a common interest in the Convention on Biological Diversity' (CBD Alliance 2020).

entirety, as all experiences contribute to forming an overall understanding – I have no recorded observations from many unique and insightful opportunities.

The anxieties of participants and my own apprehensions of engaging in a field characterised by controversy and secrecy could be only overcome by uniting the diverse spaces and the different roles I chose to play, both 'performing neutrality' as well as 'taking sides', and by being both participant and observer, with an ongoing reflexive approach to ethical deliberation throughout the research process, and by paying attention to, as Tsing (2005:x) puts it 'the researcher's surprises and learning experiences', as well as personal frictions and feelings of encountering new terrains. All the while I grappled with acknowledging what is being included and what is being omitted and why, in the process of building my own ethnographic narrative and account of the field, through taking decisions and my own interpretations of events and encounters.

A 'real world' approach to researching synthetic biology.

In this chapter I described a methodological and conceptual approach to comprehending the transformations between synthetic biology and established socio-ecological assemblages of knowers, growers, spaces, places, and orientations to the living world. Adopting a multi-sited ethnographic approach 'following' synthetic biology *through* stevia's connections within and between the worlds that give it meaning, I seek to address some of the gaps and limitations of previous work on synthetic biology's 'real-world applications' (Ribeiro and Shapira 2019). These 'worlds' form the structure of the thesis chapters as I encounter stevia diversely interpreted as a bioeconomy commodity, a sacred family member, a campesino cash crop, a corporate cash molecule, and ultimately contested cash DNA. The juxtaposition of these worlds helps to tease out the contradictions, tensions, patterns and often overlooked 'indirect' factors to better comprehend the political economic conditions through which synthetic biology stevia reproduction emerges, situating biosynthetic 'natural' products as a part of broader trends toward molecularisation and agricultural industrialization.

I describe how following and unearthing stevia's changing socio-ecological story expose what I term zones of discursive disjuncture and connection or 'dis/connect' bridging the chapters of the thesis. Dis/connects arose as a product of this methodology, and were particularly pronounced around concepts of authenticity; ownership, efficiency, sustainability. These frictious zones emerged at specific junctures within the stevia and synthetic biology story, and form threads weaving between the worlds recounted in the thesis.

Finally I argue in favour of an ethnographic sensibility that is sensitive to the politics and ecologies of situated knowledges and the local differences, rationalities and processes that manifest and play out across and between sites. While also paying attention to the ethnographer's own surprises and learning experiences, this methodology offers an approach which commits to research flexibility and ethical reflexivity in the face of changing circumstances as part and parcel of the process of 'following', and particularly important in the study of an emerging and unfolding topic.

This methodology may not produce standardised numeric or 'measurable' implications, rather it offers a richer, deeper picture of what is happening 'on the ground' with the commercialisation of a synthetic biology 'natural' product and

with those adjusting to, contesting, or rejecting the new trajectory. Most significantly multi-sited ethnography offers a lens capable of capturing what is being obscured by seemingly subtle definitional shifts taking place within and reverberating across the worlds of stevia.

Chapter Three.

Turning corn into stevia, turning corn into everything! The promise of a bioeconomy commodity.

Figure 3.0 Cargill's Blair Biorefinery. Source: Natureworks 2021

It all starts with corn.

Driving east on Highway 80 towards Lincoln the capital of Nebraska, it is clear why this mid-west area of the United states of America (USA) is known as the Cornhusker State. Mile upon mile of a golden-crowned green desert interspersed by occasional cattle ranches, burger joints and motels swooshes past our hire car window. I have travelled all this way to see how corn is being transformed into stevia in one of the world's largest biorefineries, owned and operated by a company called Cargill. Cargill - the largest privately held corporation in the United States - is the very epitome of a multinational corporation (MNC) operating across a bewildering array of global production networks and commodity chains. For Cargill, corn is the fundamental feedstock required to biosynthesise stevia. Amid surplus corn at historically low prices Cargill's new technology inspires hope among the corn communities in Nebraska and beyond.

This chapter is divided into 3 parts interspersed with ethnographic "snippets''. In the first part I dig into the historical, political economy and ecology of corn in Nebraska and the US, and the conditions that make biosynthesising stevia both viable and desirable. Unearthing the role corn has played historically and strategically as food, feed and fuel for

colonialism and capitalism, I situate stevia within a history of commodification and industrialisation of agriculture. In the second part of the chapter, I follow stevia to the Cargill biorefinery where corn is processed into multiple commodities. Here I find stevia simultaneously 'present' in multiple physical, material, digital, and imaginary forms. I explain the synthetic biology technology and techniques, the process of research and development (R&D) and the broader significance of this burgeoning industry based on concepts such as biological 'cell factories', 'specially crafted baker's yeast' and 'age-old fermentation with a modern twist'. Finally, I interrogate the promissory narratives behind such obscure concepts employed in the promotion of Cargill's 'next-generation stevia sweetener' and identify two key discursive zones (on sustainability and authenticity) that start to form a thread of connection and disjuncture throughout the thesis.

The Cornhusker state(s).

During my first few days in Nebraska it was impossible to miss the importance of corn not only to the state's economy, but to Nebraskan culture, identity and diet. From Cornhusker Highway to the Cornhusker Bank to people on street corners clad in 'Huskers' football shirts supporting the state team, to souvenir shops selling everything corn from keyrings to kid's toys. Before visiting the biorefinery, I had set up two formal interviews: one with a professor of biosystems engineering tasked with expanding the uses of corn at the University of Nebraska's Centre for Industrial Agricultural Products and another with the state director of the Nebraska Corn Board, a government agency located in the state municipal building in Omaha.

I asked my interviewees to describe the importance of corn to the region. 'The foundation of the state is wrapped around this golden triangle' declared the state director of the Corn Board, 'a golden triangle of opportunity, is what we call it, we've got the corn, we've got the livestock, and we've got the biofuels […] but it starts with corn', he went on, 'to me, corn being that feedstock is really the critical foundation that we begin with in regards to building economics and vitality for rural Nebraska but also rural America'[4]. The biosystems professor explained that in Nebraska it's known as the 'corn-beef-ethanol system' - most corn doesn't go directly into food he explained - '40% of the corn grown in the state goes into ethanol production'' for biofuels, and the by-product of this process - 'wet distillers grain' - is then fed to the cattle[5]. Only when the cattle are 'gaining their last weight before being processed', are they fed whole corn kernels[6]. In the lobby of the Nebraska Corn Board a glass cabinet displayed multiple objects made from corn, including carpet, plastic cups and crayons. Beside it stood a rack of glossy literature including backdated 'World of Corn' reports of the National Corn Growers Association, and issues of 'CornsTalk' a quarterly publication by the Nebraska Corn Board. Among these publications, the message is clear, corn is foundational to the economic security of Nebraska, and the economic power of the United States.

The United States has long been the world's largest producer and exporter of corn. Today corn is planted on over 90 million acres of land and is one of the most important commodities for the nation's economy (USDA 2019). Cultivation dates back over 3000 years in the US as the dietary mainstay of the Native Americans who developed over 200 varieties

[4] Personal communication (ref. 22). Omaha State municipal building. 27/08/2018
[5] Personal communication (ref. 20). University of Nebraska. 20/08/2018
[6] *Ibid.*

long before European settlers arrived on the continent (Smith et al. 2004; Clampitt 2015). Indeed without corn, and gleaning botanical knowledge from the Native Americans[7], the European conquest of the Americas would have been impossible (Warman 2003; Smith et al. 2004). Corn 'became the organizing axis of pioneer agriculture and pioneer subsistence', allowing these early settlers to push into the 'frontier' in successive concentric circles to settle new territories (Warman 2003). Corn quite literally fed the transition to capitalism in the American colonies as essential subsistence for both slaves on the cotton and tobacco plantations, and for workers and animals on pioneer farms, freeing up agricultural and livestock surpluses as commodities to create markets (Warman 2003:169).

It wasn't until the abolition of slavery that corn, which had never directly been a commodity of colonial trade, began to gain its status as the important export crop it is today. Without slave labour the tobacco and cotton plantations became increasingly unprofitable. The scarcity of labour and abundance of land, alongside ideal ecological conditions, allowed corn cultivation to flourish particularly in the Midwest where developments in transport and machinery were opening up further frontiers across the once impenetrable prairie grass lands and forging connections to markets within America's fast-growing cities. Corn cultivation took well to the uniformity and mechanization of agriculture (Warman 2003). By the end of the 19th century it was calculated that the combined value of corn and corn-fed livestock in the US was greater than all agricultural production combined (Brooks 1916: 216). Diverse small farms and sharecroppers on former plantations were increasingly replaced by specialised commercial farms. The Midwest became referred to as the 'Corn Belt', a region stretching between what are now the states of Illinois, Iowa, Missouri, eastern Nebraska, Kansas and western Indiana. Until the 1920s US farmers had largely been their own seed providers, farming families often shared or swapped seeds they had selected for the best characteristics from each harvest to replant the following season (Clampitt 2015). Yields increased only incrementally.

Over the 20th century the political ecology of corn in the US underwent dramatic transformation. Yields rocketed from 20.5 bushels per acre in 1930 to 174.6 bushels in 2016, from virtually the same cultivated area of land (USDA 2019). This spike in productivity was accompanied by the steady reduction in labour hours required to harvest the crop. Behind these transformations lay a succession of intertwined technological advances, political changes and the expansion of the private sector into smallholder and sharecropper agriculture. The US Department of Agriculture became what Warman (2003) describes as 'a powerful scientific organization that generated knowledge and technologies, compiled information, and promoted legislation in order to regulate any manifest problems' (p.10). Roosevelt's New Deal era included policies such as the Agricultural Adjustment Act designed to reduce surpluses and stabilise agricultural prices by giving farmers subsidies to decrease production (Hurt, 2002). The government effectively paid farmers to produce less, and bought and stored surpluses of grains. Subsidies have become an important part of farmers' incomes ever since. After the Second World War, over three-quarters of seed sown in the US was hybrid corn, and an ever more 'complex and intricate network of direct government subsidies or indirect subsidies in the form of price supports' spurred 'rapid agricultural growth' into the second half of the 20th century (Warman, 2003:27;

[7] Despite historical records framing Native Americans as Noble savages willingly sharing their botanical knowledge of maize, other accounts report enslavement, force and coercion, as well as theft of plants (see Warman 2003 and Carrier 1923 in Warman)

Genoways 2015; Nickel 2017). The interplay between subsidies and surplus have remained one of the fundamental dynamics in US agricultural political economy to the present day.

Surplus Corn, strategic corn.

Back in the lobby of the Nebraska Corn Board I picked up a leaflet titled 'A growing opportunity: finding new uses for Nebraskan Corn'. The leaflet explains how the corn-refining industry has long produced numerous products and by-products including pastes, oils, gums, waxes and multiple types of sugars and starches. Despite this the overarching goal of the agency is to 'expand the demand and value of Nebraska corn' (Nebraska Corn board, 2019). The goal is funded by the 'corn check-off', a 1/2-cent-per-bushel 'investment' by farmers required by law on all corn marketed in the state. I ask my interviewees, if Nebraska does so well out of this 'golden triangle', why the need to expand demand and find new uses for corn? They respond similarly:

> **State director[8]:** We're producing more, but we're also doing it on about the same amount of acres, our yields are increasing, our supply continues to increase, we've got to find more demand.
>
> **Molly:** Because the value is going down?
>
> **State director:** Yes.
>
> **Molly:** So there's over-production?
>
> **State director:** You could say in years where we have fantastic yields, above average, significantly above average, we're probably overproducing. This year with the world supply and demand of corn, we'll probably be stable, but thought process is if this continues.. (pauses) livestock across the US is mainly flat. Biofuels is mainly flat. We've got to look around the world right now for increase uses, or we need to find that next part of the triangle here in regards to new uses.

The biosystems Professor[9] answers the same question:

> **Biosystems Professor:** What a lot of people don't realise is in the United States we're sitting on about 2 billion bushels of corn that's just sitting and that's because, well we can't export it, we can't use it, so it's sitting, but people keep growing, so I would argue why are we growing so much?
>
> **Molly:** Well, why are you growing so much?
>
> **Biosystems Professor:** well part of that is, a lot of it is based on policy...
>
> **Molly:** is it subsidised? (I interrupt)
>
> **Biosystems Professor**: absolutely it's subsidised!…

[8] Personal communication (ref. 22). Omaha State municipal building. 27/08/2018
[9] Personal communication (ref. 20). University of Nebraska. 20/08/2018

The biosystems Professor elaborates the complexities of the current US farm subsidy system. Alongside federal crop insurance, there are a complex array of financial supports (including various direct payments, loans and assurances) available to farmers (EWG 2019). These subsidies are supposed to mitigate fluctuation in market prices and extreme weather to maintain profitability and stabilise the food supply. However these subsidies have become increasing controversial across the US political spectrum. Recent reports have found that the largest 15 percent of farm businesses which produce the 'five major program commodities of corn, soybeans, wheat, cotton, and rice' receive 85 percent of the subsidies, while the majority of farmers do not benefit from subsidy programs (EWG 2019, Cato Institute 2017, Andrzejewski 2018).

Whether it is down to the support of subsidies or the combination of advances in technology and relatively stable recent climatic conditions, both of my interviewees cautiously admitted overproduction across the Corn Belt, the production of surplus, and the problem this causes for low value of corn. Overproduction is not new, a Reuters report recently questioned whether - with the global grain glut now in its fourth year and historically high supplies and low grain prices - 'the world really needs more corn'? (Nickel 2017)

Grain gluts don't happen by accident, there are multiple factors and forces that regulate the supply and price of a global commodity such as corn aside from climatic variability, including the expansion of corn cultivation across the world, and stockpiling and export capacities increasing across China, Brazil and the Black Sea regions of Russia, Ukraine and Kazakhstan (Nickel 2017). Much of this is of course connected to the price and politics of oil, with industrial corn cultivation heavily dependent on oil in the form of fertilizer, processing, transport and more (Smith et al. 2004). This combination of factors and forces, makes global agriculture in general, but corn especially in the United States, inherently political.

With its roots in the 1954 US Agricultural Trade Development and Assistance Act (Public Law 480) surplus corn became a 'tool of diplomatic leverage in the form of foreign aid' and at the same time a 'weapon' with which to 'defeat the communists' (Genoways 2015; Warman 2003: 180). Dismissing rising concerns about the effects of agro-chemicals on the environment, the Secretary of Agriculture under President Eisenhower promoted the production of surplus corn to slowly nurture the dependency of both ally and enemy countries upon US corn, increasing the states' power over global supply and price (Carsen 1962). Over the years these policies to export US agricultural surplus abroad became re-framed as Food for Peace programmes and the flooding of foreign markets with cheap grains became more altruistically re-framed with the goal of eradicating world hunger. Dependency theorists have critiqued these policies demonstrating that US strategic political, economic and military interests were the principal beneficiaries of these programmes, not the populations of the target countries, where 'dumping' practices disrupted developing economies (McMichael 1998; Murphy & Hansen-Kuhn 2019).

Indeed the geopolitics of corn especially in the US-Chinese 'trade war' (ongoing at time of writing) was one of the main topics of concern that came up in all of my interviews and conversations with people in Nebraska from farmers to government. Starting in early 2018, billions of dollars of tariffs have been imposed on one another's goods over a dispute on unfair trade and intellectual property initiated by then-President Trump, resulting in rock-bottom prices for

corn and soybeans. This trade war however highlights the counterpoint of US strategy based on exports of surplus corn when the US economy and agriculture is heavily dependent on the international market (Murphy & Hansen-Kuhn 2019) With no quick solution on the horizon for the trade dispute I ask my interviewees; 'So it's quite tough for farmers at the moment?'. They both agree. The biosystems Professor replies;

> That's right, and so that's also very tough on the Nebraskan economy because agriculture is still a huge part of our economy as you can probably tell just by being around driving. So yes anything that can increase demand for corn is going to be welcomed including things like what Cargill's doing. [10]

Cargill's Corn, Cargill's stevia.

I ask 'how important is Cargill's Biorefinery for the region?' and interviewees talked of the hope that is pinned on the Cargill Biorefinery to expand demand, reiterating the need to secure the *next* part of Nebraska's 'golden triangle' because future demand from livestock and biofuels is not likely to increase. The biosystems professor replied;

> It's really significant to us. When that plant was being discussed about being located in Nebraska, this Checkoff board made some investment in regards to the early research of bioplastics […] We felt that it was a huge way to diversify our demand portfolio, so to speak, so as that facility was built, you've seen that huge diversity expand.
>
> And;
>
> We believe the best way that we can add value back to producers is to find the new opportunities for use and diversifying this whole portfolio beyond just livestock and biofuels.[11]

The Cargill Biorefinery which began operations in 2001 was the first of its kind, built at the height of excitement and subsidies for biofuels. It has been the single largest private investment in the state of Nebraska -approximately USD $2 billion.[12] With falling fossil fuel prices, the rise of shale gas in the US and discovery of new oil reserves globally, biofuel ethanol has not proved to be the valuable commodity it was promised to become in the early 2000s. The need to diversify is driving the re-structuring and retro-fitting of these biofuel plants toward commodities with higher value returns from surplus corn. As the state director informed:

> Again, instead of mainly it being focused on biofuels at the plant, now we're starting to think of them as biorefineries. The number of products has grown which diversifies their portfolio, so we're not so constrained to the supply and demand of just one product dictating that market.[13]

Indeed the Cargill biorefinery I have come to see, referred to locally as the 'Cargill campus', is now home to numerous other operations, some of which are Cargill subsidiaries and some are partner companies leasing land from Cargill, tapping into their raw material and refining capacity.[14] The latest company to lease land on the site is synthetic biology

[10] Personal communication (ref. 20). University of Nebraska. 20/08/2018
[11] *Ibid.*
[12] Personal communication (ref. 19). Novozymes Blair Biorefinery. 28/08/2018
[13] Personal communication (ref. 22). Omaha State municipal building. 27/08/2018
[14] Cargill originally located a corn milling operation on the campus in 1995 to produce high fructose corn syrup, regular corn syrups, citric acid, industrial and food grade starches, corn oil, and corn-based feed ingredients. The campus has steadily expanded with other companies including NatureWorks owned by Cargill itself making bioplastics, Evonik making feed-grade lysine and Corbion-lactic acid and Novozymes producing industrial enzymes among others.

company Evolva (Nebraska Government 2017). Although I have come here to learn about how natural products such as stevia are going to be synthesised from corn using synthetic biology, this biorefinery produces multiple objects, ingredients and chemicals using corn. As the state director explains:

> That campus alone has a number of different companies that are using various components of the kernel in their operations, and that's still not the finished product. The way we look at it is if we can add value to the kernel of corn in some way, that just continues to multiply until it finally gets to a retail product. Looking at the various components of that kernel and the number of businesses that are on that campus… it's amazing how that has built up. From an economic standpoint, from a demand standpoint, it's huge for us![15]

My enthusiasm to visit the biorefinery to learn how corn is being transformed into stevia compounds, however, is met with scepticism. The professor smiles,

> Cargill is a privately held company as you know and so it's very tightly... (he locks his fingers together, pulls tough expression and laughs) ….yeah so when you asked about if there's going to be people to talk to, I don't know… ummm it's going to be dependent on the kind of things that you're talking about.[16]

After our interview, he reassures that *now* he knows the kind of questions I'm asking he would try to 'help get a door opened'. My respondent's pessimism reflected what many others had told me. My multiple attempts at trying to speak to a Cargill representative, let alone a Cargill scientist involved in the production process of biosynthetic stevia, were ultimately unsuccessful[17]. Without shareholders, privately-held companies are under less obligation and have fewer legal requirements to disclose information, and notoriously avoid critical or political questions (Whittel 2014). As noted by the Library of Congress, 'researching private companies often requires considerable creativity and patience' (LOC 2019). I was careful not to ask too many probing questions, but deciding what to talk about and what to strategically leave unmentioned was a constant tussle. Cargill has reason to be suspicious of researchers; a recent 50-page report titled 'Cargill: The worst company in the world' by Mighty Earth (2019) received global media attention, and is certainly not the first to be written accusing the company of deforestation, environmental degradation, human rights abuses, child labour and pollution (Greenpeace 2020; Bloomberg 2020).

As a dominant actor across my research sites from the US to Paraguay, it's necessary to explain more about this pervasive but notoriously secret company, described as 'one of the most powerful in the world' (Jorden et al. 2020). Cargill's website home page depicts how the company prefers to be perceived as being 'committed to helping the world to thrive'. Behind this slogan is a slick montage of moving images: a giant industrial facility surrounded by a grey-brown landscape of harvested fields; a family walking through a field of soy; a huge tanker ship being loaded with corn; (what appear to be) Indonesian women in a cacao nursery; a giant barge taking soy down a South American river (a scene I witnessed in Paraguay); feeding school children; and a scientist in lab coat analysing a Petri dish under a blue light. These images represent just a fraction of Cargill's global operations.

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[15] Personal communication (ref. 22). Omaha State municipal building. 27/08/2018

[16] Personal communication (ref. 20). University of Nebraska, United States. 20/08/2018

[17] Over four months prior to my visit to Nebraska I sent emails to Cargill employees, and other companies connected with the Cargill production of stevia as well as US-based journalists, academics and local government officials in attempt to request interviews and access to learn about the operations.

Founded in 1865 as a company that stored and transported corn, Cargill is commonly described as a 'grain trader' and is referred to as the biggest amongst the 'ABCD' of companies (**A**rcher Daniels Midland (ADM), **B**unge, **C**argill, and Louis **D**reyfus) that dominate global trade in agricultural commodities (Oxfam 2012). While grains and oilseeds are a central part of the company's operations in the 'origination, shipping and processing' of - to name a few - wheat, corn, soy, and vegetable oils, such as palm oil and rapeseed, Cargill is also a producer of other lucrative commodities including cacao, tobacco and cotton. It is also a global supplier of meat, poultry and eggs; as well as of aquaculture and livestock feed. It is a leading supplier of sugar and sweeteners for food and beverage manufacturers as well as other products, ingredients and services for food and pharmaceutical companies (Cargill 2021). During the 2000s Cargill developed global biorefining capacity to produce biofuels and expand a range of bioindustrial applications. Cargill owns the world's largest fleet of ships allowing the corporation to dominate commodities transportation and trade (Alexander, 2014). Outside of agribusiness it also deals in salt and mining operations of iron ore and steel. The final arm of Cargill's pervasive reach is across finance; since the 1990s it has offered a range of risk management and commodity trading services entwinning 'a select group of the world's largest and most respected institutional investors including pension plans, endowments, foundations, family offices and asset managers' (Cargill 2019).

Despite operating in 70 countries, and employing 160,000 people, Cargill is often referred to as the 'silent giant' because comparatively few consumers are aware of its dominance in many aspects of daily consumption (Sorvino, 2018). Up until recently it has focused on supplying ingredients, industrial inputs, transport and processing for consumer facing brands such as McDonalds and Tesco rather than placing its own branded products on shop counters. However, in 2008 Cargill commercialised a product that moved its brand into the kitchens of homes globally, under the name Truvia, described as 'a calorie-free sweetener from the Stevia Leaf'. Cargill supplied 'Truvia' to Coca-Cola in 2013 to produce a new stevia-sweetened 'Coca-Cola Life' that was sold around the world. By 2017 it had become 'America's #1 natural, zero-calorie sugar alternative' (Truvia website 2019). Cargill is so proud of 'Truvia', that it is marked as one of only 20 major historical milestones on the company timeline since 1865 (Cargill website 2021). In an interview with *Forbes* magazine, Cargill's CEO predicted 'stevia sales will eventually reach $500 million', adding 'a full 5% to its bottom line' (Alexander, 2014).

With Cargill's total global revenue (in 2018) of USD $114.7 billion, 5% demonstrates that the hopes pinned on this small South American plant are significant. The expectations placed on stevia derived from both land *and* lab, the promise of profit, the protection over its patents, and anxieties over consumer acceptance, may point to some of the reasons why a Cargill representative reasoned with me on the phone 'ya know Molly, there's a lot going on here with stevia right now' eventually avoiding my repeated requests for an interview[18]. Despite the scepticism many in Nebraska had on my chances of entering the Cargill plant, I decided to press on, in the hope that *actually being there* could achieve something.

[18] Personal communication (ref. 18). Cargill employee speaking on a Skype call on behalf of the research request committee. 4/09/2018

Turning corn into stevia.

We drive north from Omaha into rural Nebraska to the small town of Blair nestled on the bank of the Missouri River bordering Iowa. Blair is home to Cargill's biorefinery. As we come over the crest of a hill, the enormity of the industrial facility comes into sight. It resembles an oil refinery in both scale and infrastructure, metal pipes criss-cross between large industrial units and up and down cylindrical vats, steam billows out of tall silver chimneys, and people and vehicles look like ants. Instead of petroleum being pumped in, it is truck load after truck load of corn.

We rent a white picket family home in Blair for 10 days to allow time to negotiate a visit to the biorefinery, time during which I also learn some of what the biorefinery and corn production mean to the local people. In the centre of the town's main street stands the Blair Area Chamber of Commerce office, and inside another glass cabinet proudly displays things produced in Blair at the Cargill plant. Front and centre are the green and white packets of Cargill's 'Truvia'. The reception desk has a little pot of free Truvia samples. 'It's not just corn getting trucked into the town' I exclaim to the receptionist, 'stevia leaves get processed here too!' She nods, slightly baffled over my excitement. The next day I schedule an interview with the director of the Chamber of Commerce, she shares my curiosity over stevia leaves getting shipped into town, explaining 'Truvia is very popular right now', and is probably the most iconic thing being 'made right here in Blair'.[19]

Unlike the new biosynthetic stevia that does not require the stevia plant to be grown, leaves that eventually end up in Truvia – albeit after a highly refined process – are transported from Argentina where according to the brand's website they are grown by farmer co-operatives (Truvia 2019a). Certainly, the imagery of stevia's iconic green leaves on the range of Truvia products in the display cabinet underpin the product's selling point, as its strapline goes: 'The best sweetness comes from nature. Truvía® sweetener is natural, great tasting sweetness born from the leaves of the stevia plant' (Truvia 2019b). It seems ironic that both stevia derived from the leaf and biosynthetic stevia are being produced in the same factory.

The Chamber of Commerce director tells me how 'extremely important' the Cargill plant is to the area, supplying 'hundreds of jobs' and that 'more people continue to move to the area' leading to 'new housing developments' and 'new businesses'. The director beams with pride 'within the last couple of years, there's been several hundred million dollars' worth of expansion', and 'I can't imagine where Blair would be if that wasn't here'[20]. I ask whether there is enough corn to keep expanding the refinery capacity and the director replies, 'yes, absolutely. They're in the perfect spot. They get plenty of corn from Iowa. It's like a whole belt. You've got Iowa, Missouri and, obviously, Nebraska, but they can get it from really anywhere within hundreds of miles and they all can bring it in'.[21] With around 300 trucks unloading approximately 300,000 bushels of corn at the biorefinery daily - the Blair director goes on - those that can't

[19] Personal communication (ref. 21). Blair Chamber of Commerce. Nebraska, USA. 24/08/2018

[20] In line with their professional role to promote the economic development in the area, my respondent painted a rosy picture of Cargill's industrial operations at the site and its impact on the people and environment. This perspective however, was not shared by all of Blair's residents. In informal chats in local playgrounds my husband and I met disgruntled parents struggling to make ends meet, talking of insecure work, layoffs at the plant and complaints about the odour of the refinery.

[21] Personal communication (ref. 21). Blair Chamber of Commerce. Nebraska, USA. 24/08/2018

deliver due to overcapacity at peak harvest times unload into ‘grain bins’. The ‘grain bins’ large silver grain storage cylinders stand out as prominent landmarks throughout the town and surrounding countryside.

Two days later I find myself standing inside one of these vast ‘grain bins’ talking to two farmers supplying the Cargill plant with corn. The farmer explains that this ‘bin’ alone (branded in Cargills’ logo) can store 4.4million pounds of corn equivalent to 80,000 bushels. His voice reverberates as though we are inside the belly of a rocket. I look up to the tiny hole of daylight where the corn gets poured in, below us, he explains, is a ‘30 horsepower fan that blows air through this perforated floor, that helps keep the corn dry’.[22] The two farmers’ stories very closely reflect what my first two respondents from the university and the government agency told me. That with record yields that they only foresee increasing, the price for corn is far too low, and that the ‘trade war’ with China is amplifying their problems. ‘It's dropped our prices 25% and before that we were just at a profitable level and now we are below our cost of production’ the younger farmer said. The older farmer recalls ‘the big companies told us we need to grow all these bushels for a growing population, the world population, but we don't have people buying it.’ I asked whether other farmers are being affected, ‘everyone’s in the same situation’, they agreed[23]. Eager for me to learn about the life of a ‘Midwest farmer’, both proudly show me around their farms and their gleaming combines and tractors, machinery much grander than I had ever seen in the smaller farms of the UK’s south-west.

It just so works out that on the same day I go from farm to factory, following the corn feedstock to the biorefinery. At last I have been offered a tour of the Cargill biorefinery. My persistence has paid off. I am not, however, being invited by Cargill themselves, despite receiving an email that my ‘request to research Cargill’ has now progressed to the ‘next stage’ of consideration by the vetting authorities inside the multinational (and a Skype call scheduled for Cargill to interrogate my interest in the company). Neither am I going to be able to see the entire plant, nor unfortunately, observe how exactly biosynthetic stevia compounds are being manufactured. The company who invited me are called Novozymes and they are one of the companies that like the synthetic biology company Evolva, leases land, infrastructure and supplies from Cargill. Although from the outside it appears as one enormous industrial unit, the Cargill plant entwines several operations. Novozymes are connected to the Cargill refinery through pipelines of water, waste, steam and the glucose syrup feedstock Cargill calls the ‘dextrose stream’. It is this glucose syrup that feeds Novozymes’ tanks of micro-organisms which ferment a range of enzymes used in agriculture, animal feed, and biofuels industries. While they do not produce biosynthetic stevia, Novozymes use a production process very similar to it known as industrial fermentation (See a simplified diagram in Figure 2.). The Blair complex was described in a Reuters article as ‘a giant computerized grid of chemical compounds being refined, remixed, refashioned’ (Stebbins 2010).

[22] Personal communications (ref. 23). Corn farm. Nebraska, USA. 28/08/2018
[23] Citations throughout paragraph from: Personal communications (ref. 23). Corn farm. Nebraska, USA. 28/08/2018

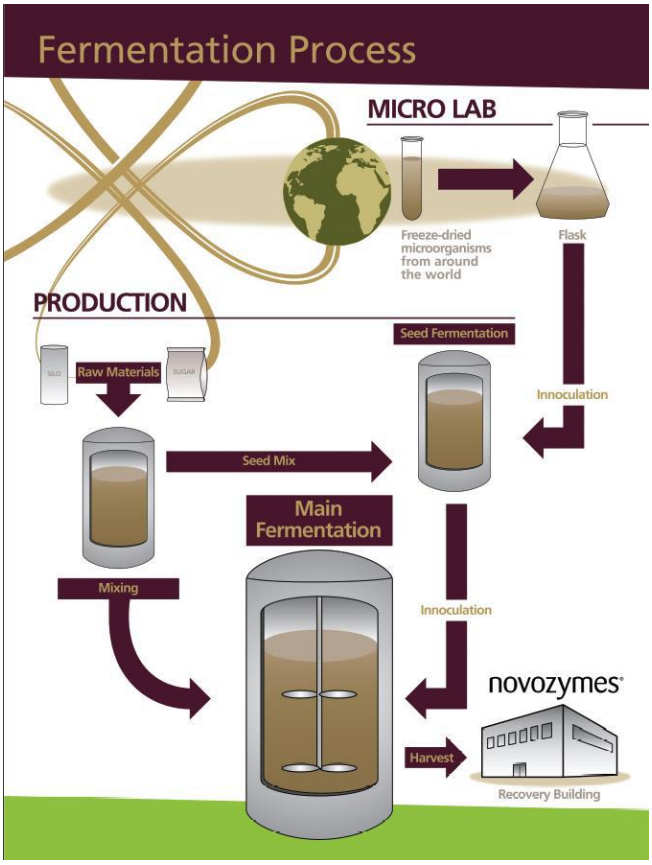


Figure 3.2 Novozymes Fermentation Process. Image sourced from a slideshow presentation given to me by Novozymes during my tour of the biorefinery (August 2018).

After a full health and safety briefing and a PowerPoint presentation about both Novozymes and Cargill, I was instructed to put on a hard hat, a white lab coat, and ear defenders. The biorefinery was a multi-sensory experience. Aside from the all-over sensation of deep vibration from the pressurised pipes, reactors, mixers and refiners, the deafening noise of whooshing steam and deep base of industrial hum, there were also a succession of smells. At first my nostrils were confronted with the sweet smell of corn, then the tangy pungency of yeast cells hard at work producing various scents as the product was first fermented and then refined, and refined again, washed, and separated from waste 'spent biomass'. The final product was then put into tanks and containers where trucks lined up waiting to receive the loads. The tour included the entire production process, and I was led through a disorienting amount of factory floors, chambers, up and down ladders, stairs, restricted walkways, into operation and observation rooms, following networks of pipes as they weaved their way in and outside of buildings and gigantic vats. It was impressive. What struck me is how few people were actually to be found on the factory floor. Workers sat in enclosed observation rooms surrounded by screens and buttons. Aside from one man on a walk-through safety check of tank pressures, the factory floors we passed through where devoid of people[24].

I was told not to record or quote anything I was told during the tour. However the biosystems professor who was a biorefinery expert gave a basic overview of the operations:

> So let me explain a little bit about the Blair campus what I know of it, what I've observed. What you have is a corn wet mill. So without getting into the details of what a wet mill does, basically it takes corn and it splits it up in a bunch of stuff, so your protein, your fibres, your oil and then the starch, and the starch is 65 to 70% of the dry weight of corn. So we got a lot of starch then you can break that starch down into glucose so that's what they do, then they can take the glucose they can make ethanol out of it, they could make high fructose corn syrup…[25]

[24] Novozymes representative told me there were 115 people employed at the Blair plant.
[25] Personal communication (ref. 20). University of Nebraska, United States. 20/08/2018

Or, he explained, they could make it into stevia, describing this abundant 'supply of carbohydrate-rich glucose' is the raw material that is attracting synthetic biology companies like Evolva who've invested USD $2 million in the plant in search of reliable feedstocks for their microbial cell factories to ferment into new products. He elaborated;

> Now, if we can ferment glucose to produce the same compound [from the stevia leaf] not only is that going to help on the corn front but it's also going to help the price because I can't imagine that growing stevia leaves is going to be a real cheap extraction process (laughing) now the other thing is about whether that's going to replace stevia.... [he gets distracted by the time] …to be honest it's basically just expanding, I think the people that are using stevia if they could use this product, and we could show it's chemically identical and it's still being made by a fermentation process, not like we're doing a bunch of chemical reactions, well the microorganism is, but you know - it's a natural product.[26]

An article published after I was there, described the production of biosynthetic stevia taking place on Cargills biorefinery in Blair as a $50 million 10,000 square foot plant (Watson 2019). The ability to replicate 'chemically identical' natural products lies at the heart of the commercial excitement about the limitless possibilities offered by this production method. Cargill brands its biosynthetic Stevia EverSweet™ framing it as both a cutting edge 'next-generation stevia sweetener' in its opening strapline - 'the future is here and its sweeter than ever' – on the one hand emphasising the novelty of the product, and on the other, describing it as nothing new at all. 'Our secret? The age-old technique of fermentation - with a modern twist' (Cargill 2021b).

Building a Cell Factory

Not having an interview or tour from Cargill doesn't seem to matter in the end. In an email from Cargill's Global Stevia manager I receive links to further information online and a video link of a seminar on Cargill's sugar replacement strategy. In the following I extrapolate what exactly it means to 'put a modern twist on this centuries-old practice of fermentation'. I start by quoting the story Cargill tells on its website:

> It all began with the stevia leaf. Our scientists studied the sweet components of the stevia leaf called steviol glycosides. They learned that a single leaf produces more than 50 different steviol glycosides, each with a different sweetness profile. In the meantime, our partner [Evolva], was working on unlocking the secrets around how the stevia plant turns sunshine into the very sweetest steviol glycosides in its leaves (Cargill 2021c).
>
> [O]ur team determined the specific enzymes the plant used to create the sweetest steviol glycosides called Reb M and Reb D. Once our scientists understood which enzymes the stevia plant used to make steviol glycosides, they looked for genes that control the production of those enzymes that work best in yeast. The genes used include genes from the stevia plant and other plants, such as lettuce, tomato, blackberry and rice. The genes perform the same function as the genes in the stevia plant, but more efficiently. This enables our

[26] Personal communication (ref. 20). University of Nebraska, United States. 20/08/2018

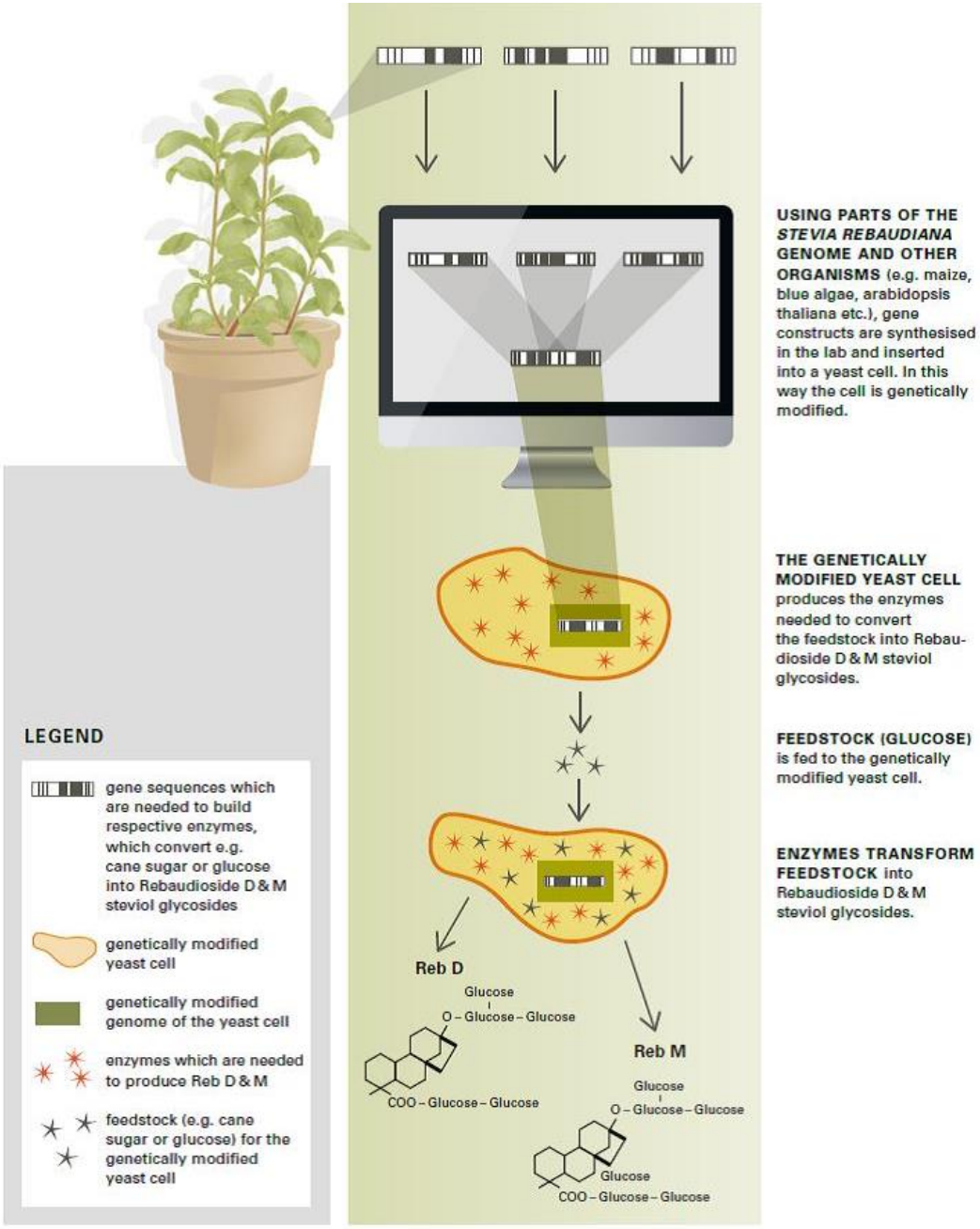
> yeast to become a mini-factory, converting simple sugar into Reb M and Reb D far more efficiently and in much greater quantity than a stevia plant (Cargill 2021).

The idea of yeast as a 'mini-factory' or a 'microbial cell factory' as it is more commonly known, is fundamental to not only the biosynthesis of stevia, but the entire technoscience of biosynthesis and the expansive possibilities of (re)producing natural compounds from plants or animals biosynthetically. There are thousands of species of yeast in the world, representing approximately 1% of the entire fungi kingdom (Kurtzman & Piškur, 2006). As a *eukaryote,* yeasts are considered 'higher organisms' much more closely related to animals and plants than other unicellular organisms such as bacteria. Referred to as the 'trustworthy workhorse' of bioscience, the world's most studied and utilised yeast species is *Saccharomyces cerevisiae* (hereafter *S.c*) denoting sugar-eating fungus, or more colloquially Brewer's or Baker's yeast (Evolva 2019). *S.c* yeast metabolises sugar to reproduce itself at the same time fermenting the sugars into alcohol or carbon dioxide that leavens bread, or creates different flavours in beer and wine, as well as into moulds that ripen cheese or that produce antibiotics. In 1996 *S.c* yeast was the first ever 'higher organism' to be genetically sequenced, enabling new scientific insights into the functions of each of its 6000 different genes. This step expanded public and commercial attempts to influence and change the way *S.c* yeast behaves and the molecules it produces. Coaxing yeast to perform new tasks is not entirely new. However, since synthetic biology as a technoscientific field in its own right began to emerge around 2005, prominent scientists and publications began documenting unprecedented ways to engineer yeast, describing it as a cell factory with new and potentially limitless manufacturing possibilities (Spector 2009). In a review article in the journal *Microbial Cell Factories,* the authors note this transition:

> The yeast *Saccharomyces cerevisiae* is one of the oldest and most frequently used microorganisms in biotechnology with successful applications in the production of both bulk and fine chemicals. Yet, yeast researchers are faced with the challenge to further its transition from the old workhorse to a modern cell factory, fulfilling the requirements for next generation bioprocesses. Many of the principles and tools that are applied for this development originate from the field of synthetic biology and the engineered strains will indeed be synthetic organisms (Kavšček et al. 2015).

What exactly is meant by the term synthetic organism? Is this what Cargill means when it refers to 'specially crafted' baker's yeast? Figure 3.3 offers a visual representation of the of techniques employed by Evolva and Cargill, though the authors do not specify which synthetic biology company it is drawn from.

Figure 3.3 'Production of Steviol Glycosides by a Synthetic Biology Process' (Source: Meienburg et al. 2015)



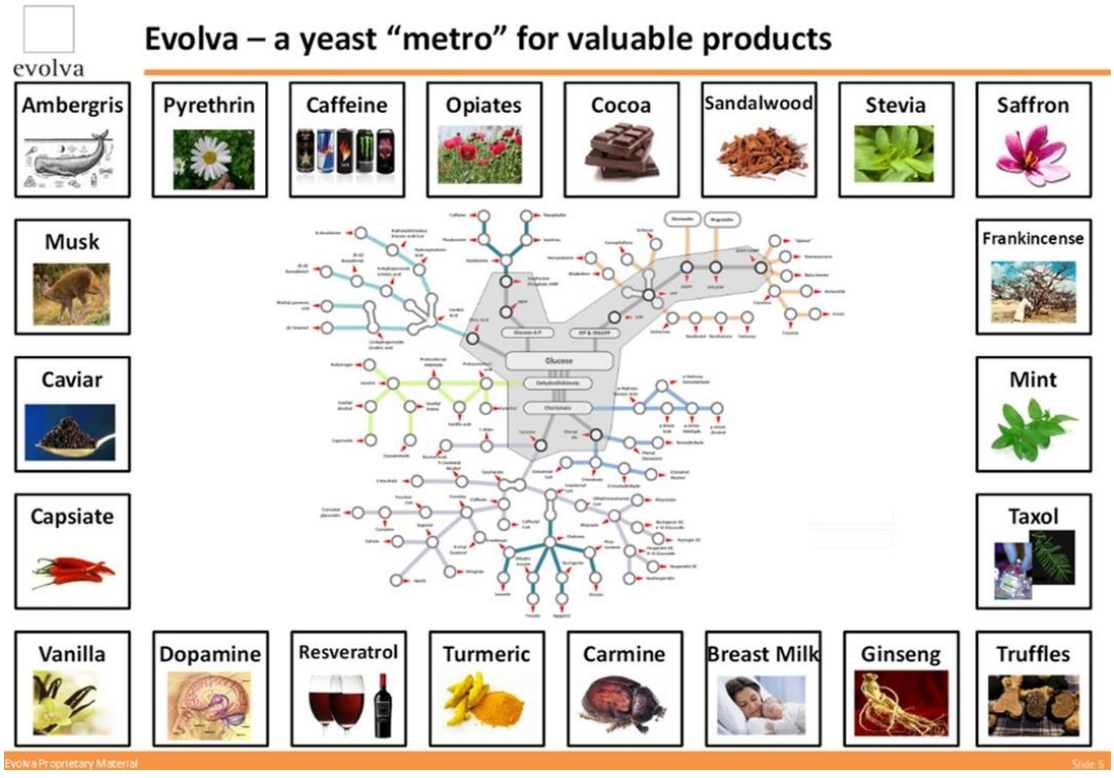
As a relatively new field, synthetic biology is characterised by a range of narratives and descriptions. At the most fundamental, synthetic biology can be defined as a field combining advanced tools of genetic engineering, genomics and systems biology as well as increasingly bio-informatics and automation technology 'to programme and control a biological organism or system and to create new behaviour previously not found in that organism or system' (Kavšček et al. 2015). As a contested field, on the one hand narratives claim that 'synthetic biology differs from anything that has come before' (Morton 2019) in its aims to 'redesign life' with products – such as engineered yeast – described as a hybrid between synthetic organism and living machine (Deplazes & Huppenbauer 2009), or to 'create life from scratch,' for example, in a project currently underway to create a fully artificial *S.c* yeast genome (Synthetic Yeast 2.0 2021). Revolutionary narratives of novelty, on the other hand, are played down by those who see the field as a convergence

and continuum of modern technosciences, and who want to avoid 'unnecessary regulatory burden' (Marris 2015). While metabolic pathway engineering in yeast was an established practice before synthetic biology, its new tools are more powerful, enabling breakthroughs in what was before thought impossible, as described in *The Economist*'s Technology Quarterly 2019:

> Being able to write DNA from scratch allowed metabolic pathway engineers to bring together genes from a number of different pathways, thus offering the prospect of making molecules beyond the reach of chemistry and for less than the cost of harvesting them from plants (Morton 2019).

Advances in DNA sequencing and synthesis (the reading and writing of genetic code) as well as increasingly gene-editing enables scientists to engineer the metabolic function of yeast to produce tailored enzymes that digest sugars into chemicals and compounds it would never naturally be able to produce. As Cargill explained in the quote above, this involves selecting genes derived from various other organisms or species for their specific traits and inserting or editing them into the genome of the yeast cell. Cargill claims it uses genes from the stevia plant as well as genes from lettuce, tomato, blackberry and rice, among others. Genes are not always selected from other plant species; the yeast engineered to produce biosynthetic vanillin for example, includes genes from the vanilla vine as well as of human, bacterial, and fungal origin (Hansen et al. 2009). Projects underway to sequence every gene on Earth are predicted to increase the range and possibility for biosynthesis through metabolic pathway engineering. On its website Evolva declared 'in the future, baker's yeast will be viewed like a Metro railway network from whence thousands of useful ingredients can be accessed—via fermentation' (Evolva 2013, see figure 3.4). Offering potentially lucrative business opportunities, the past decade alone has seen dozens of start-up enterprises and established corporations develop capacity in biosynthesis to produce multiple new 'natural' compounds that are traditionally harvested from plants, trees or animals (ETC group 2016).

Figure 3.4 'Evolva - a yeast 'metro' for valuable products (Source: Evolva Half Year Report, 2013)



As a relatively new technology, many of these ingredients are still being developed. Only a few are fully commercialised on the market. Getting approval for a new ingredient through a novel production method such as biosynthesis takes time. Patents need to be secured, regulatory bodies, such as the FDA, need to approve that they are 'Generally Recognised as Safe' (GRAS) for human consumption and not harmful for the environment, and production needs to be scalable and cost effective to compete on the market. Due to setbacks and delay in scaling up, Cargill only started selling 'EverSweet' (its biosynthetic stevia) a few months before I arrived in Nebraska (March 2018), despite plans to bring it to market by 2016. The journey - from successful experiments by a synthetic biology start-up company in Switzerland to large scale manufacture in Nebraska to global marketing and commercialisation of EverSweet - was far from seamless. As depicted in the timeline below, bringing EverSweet to market involved a series of investments, mergers and acquisitions, strategic partnerships, patent applications, and even significant changes in the way a company describes itself.

Table 3.0 Bringing EverSweet® to market. A timeline of Evolva and Cargill R&D.*

2004	Evolva founded as a **synthetic biology** company, headquartered in Switzerland.
2011	Evolva acquires US company Abunda, another company focusing on biosynthesising stevia.
2013	Evolva partners its 'stevia programme' with Cargill. Under the agreement, Cargill is responsible for the manufacture and commercialisation of stevia, whilst Evolva obtained a 45% stake in the business. Green cans of Coca-Cola Life and Pepsi Next are launched, sweetened by leaf-derived Stevia.
2014	A patent application is made for production of rebaudiosides M and D, stevia compounds. In another business deal Evolva launched 'Always Vanilla' biosynthetic vanillin in collaboration with IFF.
2015	Evolva acquires competitor US company Allylix, to 'strengthen Evolva's stevia franchise' The stevia programme is described as Evolva's key asset, accounting for 47% of its valuation on the Swiss Stock Exchange. Cargill and Evolva unveil that stevia products will be sold under the name EverSweet™, and a dedicated website for the product is launched. Evolva's company description is now a **'Biosynthesis company'**
2016	Evolva is granted a pivotal patent for the commercial production of 'fermentation-derived steviol glycosides'. In June, EverSweet is issued with a US FDA GRAS (Generally Recognised As Safe) certificate. The launch of EverSweet™ was delayed due to 'a combination of factors, including strain characteristics; fermentation and downstream processing costs; facility conversion costs, production scale, and current customer indications on pricing' (Evolva 2016).
2018	By March, Cargill declared it had 'secured its first-mover advantage' and had officially started producing EverSweet™. By 2018 three other companies announced they were developing biosynthetic steviol glycosides. Several months after EverSweet™ was launched Dutch company 'Royal DSM' announced it had produced a 'non-artificial' Reb M stevia sweetener using fermentation to be sold commercially under the brand name Avansya.
2019	Cargill enters into a 50-50 joint venture with competitor Royal DSM to 'leverage their strengths' in commercialising biosynthetic steviol glycosides. DSM's product name Avansya becomes the name under which the joint venture will produce the EverSweet stevia sweetener. EverSweet will continue to be manufactured at the Blair Biorefinery in Nebraska, but Royal DSM will be the main distributor for EverSweet for the food and flavour industry.
2019	Evolva completes building and operates a new bioprocessing facility on adjacent land leased from Cargill. This facility was said to come online in 2019 and manufacture Evolva's other main biosynthetic products nootkatone (grapefruit flavour/fragrance), valencene (citrus oil) and vanillin.
2020	Evolva now describes itself as a **'high-tech fermentation company'.**

2021	Evolva is completely re-branded with a strapline 'Nature Sustained'. Its website contains no mention of EverSweet™, and now calls itself a **'Biotech company researching, developing and commercialising nature-based ingredients'**. The new Avansya website to market EverSweet™ describes the DSM-Cargill partnership values of 'doing well by doing good' and that 'our strategy is aligned with the United Nations' Sustainable Development Goals (SDGs) – which in the case of EVERSWEET™ means 'good health & wellbeing' (SDG no 3)' (Avansya 2021)

*All the data sourced in Table 3.0 are derived from Cargill and Evolva shareholder reports, company press releases, and the Edison Group Investment Research Firm (see: Evolva 2016 & 2021; Edison Group 2021; Cargill 2021f; Avansya 2021).

While my physical following of biosynthetic stevia stopped short at the next-door neighbour processing plant at the Cargill biorefinery, it didn't stop connections and pathways being followed into how Cargill and other synthetic biology companies are marketing their bioeconomic commodities through carefully crafted and targeted narratives on sustainability, economic efficiency, and authenticity. It is such promissory narratives around (biosynthetic) stevia that start to form a thread through the thesis, to which I now turn.

A promissory bioeconomy commodity.

Sustainability and efficiency.

One of the key promissory narratives Cargill promotes is that biosynthetic stevia is more sustainable than 'producing it via leaf' (Cargill 2021). Cargill do not make publicly available the figures or calculations used to make such 'preliminary estimations'. However, defining sustainability solely in terms of CO^2 emissions and land-use is simplistic and potentially misleading. At a basic level the claim overlooks the societal pillar of sustainability. As this thesis will describe, the societal role of stevia has been at the heart of established promises over agricultural stevia in its recent history as a 'sustainable livelihood' cash crop. Moreover, Cargill's sustainability claim obscures important complexities involved in comparing which exact stevia molecule they are describing with which exact variety of stevia is being grown in the field, and under what kind of agricultural system including factors such as water use and agrochemical inputs. Also overlooked are the indirect impacts of land-use change replacing established assemblages of leaf production with alternative crops, for example soy in Paraguay, or indeed impacts of the spread of corn monoculture as feedstock vis-à-vis increasing stevia cultivation. The following chapters will further unpack the complexities behind Cargills simplistic messages by illuminating the diversity of the 'worlds' of stevia that exist.

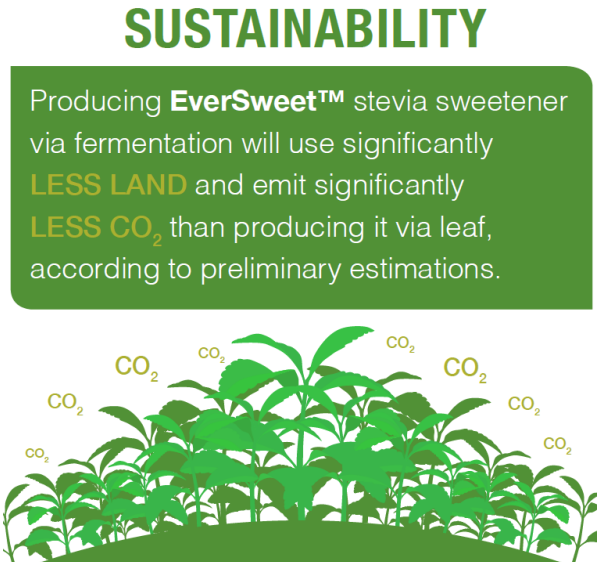


Figure 3.5 EverSweet® sustainability 'infographic' (Cargill 2021f)

Since 2019 Cargill is no longer the only company heralding the sustainability of biosynthetic stevia, and while this thesis focuses primarily on the EverSweet® brand of biosynthetic stevia as it was the first to hit the market, table 3 highlights that since fieldwork took place Cargill partnered with its main competitor Royal DSM, and in 2019 and 2021 two other versions of biosynthetic stevia reached the market (Amyris 2019; NutraSweetNatural 2021). The degree of dynamism in the market demonstrates the level of commercial excitement over what one synthetic biology company called 'just a new way of making natural ingredients' (Amyris 2020). A fundamental dimension of the sustainability narrative is economic sustainability and the overarching drive toward 'efficiency'. This dimension is found less on consumer public-facing sites and more towards those targeted within the biotech and food industry sector themselves, narratives around economic sustainability and efficiency mobilise imaginaries and expectations over profit margins, market control and reliable supply chains in the face of uncertain futures (Watson 2019). Biosynthetic products are framed in terms of cost efficiency and securing supply chains in the context of increasing uncertainty over climate change and societal and economic stability (WEF 2015; Quon 2013). Consolidating supply chains from diverse producers across multiple global regions to a single geographically fixed industrial site promises to mitigate fluctuations in price, quality and supply – volatile factors in some agricultural production – to offer reliable, stable alternatives. In one such appeal to manufacturers, biosynthetic stevia is framed as 'purely better for business' asserting 'using our sweetener in your products costs roughly the same as sugar and the lowest cost stevia products. And since crop yields aren't an issue, goodbye supply uncertainty!' (Amyris 2021). Amyris aims to compete with Cargill as 'the lowest cost producer of the world's leading natural zero calorie sweetener' in order **'**to take meaningful share of the stevia market' (Amyris 2019). Despite having been denied an opportunity to interview Cargill directly, the company's global lead on stevia is quoted in food industry reports declaring the efficiency and sustainability of biosynthesis over the leaf, asserting 'our approach is infinitely scalable – you just add more fermenters, this initial volume is enough to service the largest food and beverage manufacturers in the world' (Andrew Ohmes quoted in Watson 2019).

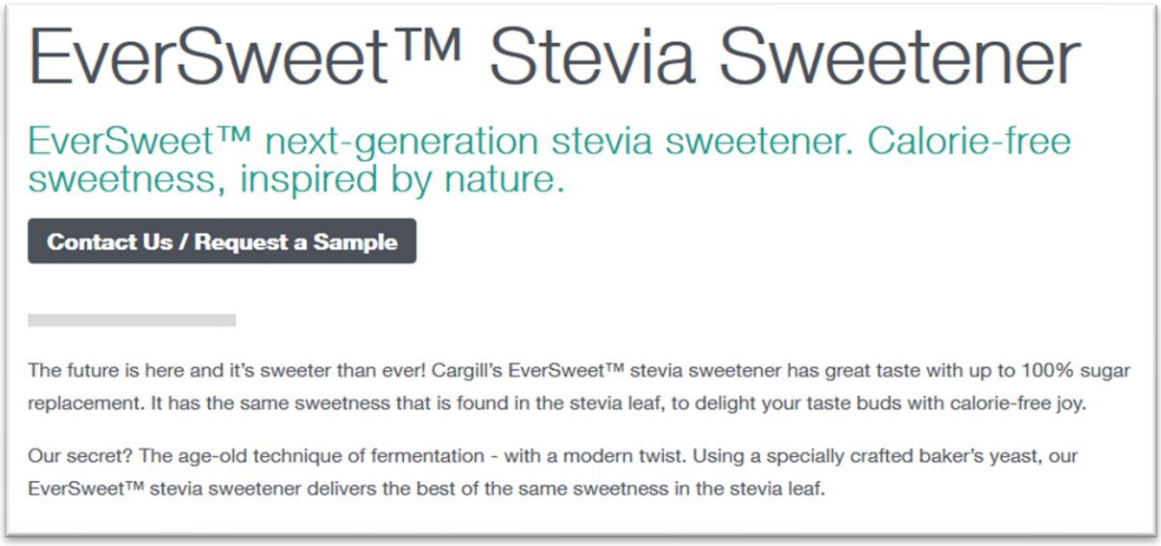


Figure 3.6 Extract of the EverSweet® webpage (Cargill 2021b)

Authenticity & naturalness.

The Cargill lead on stevia asserted 'while fermentation-based reb D and M cannot be labelled as 'stevia leaf extract' because it's not from the leaf, it can be labelled 'stevia sweetener' [...] Ultimately it's up to consumer-packaged food companies to decide what to put on the label, but we feel this is the best way to communicate what it is to consumers. The molecule from the fermentation is identical to what's in the leaf' (Andrew Ohmes quoted in Watson 2019).

This idea of biosynthetic stevia as 'nature identical' highlights the second area of promissory narratives targeted at industry, regulators and consumers. I call it the 'authenticity narrative', as it builds on the idea that biosynthesis produces a purer, cleaner, higher-grade natural product equivalent. Cargill and competitors not only use part of the botanical name to describe their product as 'stevia sweeteners', they adopt images of the distinctive raggy-edged stevia leaf, one even goes as far as obscurely describing its product '100% natural' with a strapline '*keeping* nature *natural*' (NutraSweetNatural 2021). Authenticity narratives summon metaphoric language, mobilise historical connections and associations from the plant, entangling the biosynthetic product within imaginaries of socio-ecological origin. Cargills conception of naturalness is clearly a molecular understanding based on the equivalence of isolated compounds under the microscope. However, as the chapters unfold the concept of naturalness proves much more complex, and the concept of 'naturalness' is contested at multiple stages as one of the key threads weaving sites of this study together. A second part of the authenticity narrative for Cargill and its competitors is to normalise and 'naturalise' the production process of biosynthesis itself, through forming associations with fermenting bread, beer and cheese, as part of an historic and 'age old process of fermentation' using 'baker's yeast' (Cargill 2021c). Evolva, the original developers of EverSweet™ mobilise images of the ancient Egyptians' use of fermentation in a promotional video to create associations of historic equivalence (Evolva 2014). Amyris adopts the same language, asserting their production method 'depends entirely on natural fermentation', explaining in a Food Industry news site that 'the idea of fermentation resonates with people, because it's a natural and millennia-old process for converting sugars into finished product' (Schoup 2019; Amyris 2021). The narrative downplays the novelty of the technique and amplifies naturalness ultimately aiming to convince GM-wary consumers. Indeed, Cargill and competitors claim biosynthetic stevia is 'GM free', because 'once our yeast completes its steviol glycoside production, the mixture is heated, inactivating the yeast cells. At that point, the yeast is removed through a filtering process similar to the carbon filters you might find in a water purification system' (Cargill 2021c). While Cargill's yeast is genetically engineered with an entirely synthetic genome enabling it to convert GMO corn sugars into steviol glycosides, the final product contains no GMO ingredients, allowing Cargill to claim that 'whether produced by the stevia leaf or our specially crafted yeast, the result is the same' (Cargill 2021c).

Cargill and their competitors seek to shape novel understandings of naturalness for some discernible reasons. Until the commercial launch of biosynthetic stevia, the predominant global understanding of stevia was as the only natural zero-calorie sweetener as a 'green alternative to sugar' shown in analyses of social media interactions about stevia between 2017-2018 that 30% of 'chat' was based on stevia's 'naturalness', and a further 28% was based on its healthiness and safety especially for those struggling with obesity and diabetes (ISC 2018). Without a naturalness association, EverSweet™ would be regarded as an artificial sweetener like aspartame and saccharine. Negative associations of artificiality in food is a trend that continues to grow alongside consumer preferences for local, sustainably-produced, natural ingredients, signalling consumers are seeking more accountability and authenticity in where their food comes

from (Askew 2019). Nurturing public associations of authenticity and naturalness is key for the success of EverSweet® and the emerging biosynthesis industry. In the past 5 years synthetic biology firms and research centres have noticeably begun distancing themselves from the word synthetic or even biosynthetic, and describing their practices in terms of bio-design, biological engineering or high-tech fermentation. The latest 2021 biosynthetic stevia launched without any mention of fermentation: 'NutraSweetNatural™ was created by isolating only the sweetest, purest parts of the stevia leaf and incorporating them into a proprietary blend to create the taste of sugar without the calories'. Summoning notions of purity has been central for Cargill and its competitors as part of what they call a trend in 'clean ingredients', which exudes subtle and obscure connotations of lab-grown being somehow cleaner than farm-grown (Cargill 2021; Amyris 2021 & ManusBio 2021)

On top of purity, naturalness and age-old production processes in the pervasive authenticity narrative used to sell biosynthetic stevia sweeteners is a third dimensions which relies upon associations with the plants geographic and socio-ecological origin, provenance and indigeneity. Cargill makes stark assumptions about the original knowers and growers of stevia, to both create associations of traditionality and to distinguish their companies scientific prowess in innovating EverSweet®.

> For thousands of years, the people of South America knew about the sweetness of stevia plants. They knew it was extremely sweet, so only a small amount was needed to sweeten their favourite foods and beverages. What they didn't know was that stevia leaves contain tasty little treasures called steviol glycosides, which delight our taste buds by reacting with the sweet receptors on our tongues – and contain zero calories! (Cargill 2021d)

The appropriation of the indigenous Guaraní peoples' knowledge of the stevia plant to sell biosynthetic stevia is not new. As leaf stevia was commercialised, stories of 'ancient use by native American Indians' have been mobilised as part of an established promissory narrative promoting the safety and authenticity of stevia (Meienburg et al. 2015; Coca-Cola 2015). I follow stevia to these so-called indigenous origins in the next chapter to unpack why the communities themselves are contesting these narratives and authenticity associations as a form of cultural, spiritual and biological misappropriation and exploitation.

In sum, Cargill and its competitors are circulating a multitude of promissory narratives aimed toward a variety of audiences, whether consumers, manufacturers, farmers, regulators, investors, or indeed bioeconomy policy makers. The ways in which the concepts of sustainability and efficiency, and authenticity and naturalness are being interpreted and mobilised within 'other' worlds of stevia however, reconfigure, subvert, and contest the corporate image of green, wholesome, ethical stevia the companies seek to promote.

Figure 3.7 EverSweet® production process 'info graphic' (Cargill 2021c)

Conclusions.

This chapter has traced some of the historic, political economic, techno-scientific, industrial and political ecological factors that have coalesced in making the biosynthesis of stevia viable and desirable in the United States. From the premise that 'it all starts with corn' I consider the political ecology of corn feedstock as a central yet overlooked part of what biosynthesis implies. With Cargill's EverSweet® brand of 'stevia' - the first of its kind – as a lens, this chapter considers how corn was transformed from indigenous staple, to the feed, food and fuel of colonialism and capitalism, becoming a powerful and strategic commodity, contributing to the dominance of the US, as the world's no. 1 producer and patent owner. In summarising this history, I situate stevia within a historical process of appropriation, commodification and politicisation of agriculture. The chapter follows stevia to a vast industrial biorefinery in the 'golden triangle' of the US Midwest Corn Belt, finding stevia simultaneously 'present' in multiple forms: physical imported stevia leaves, strands of stevia DNA inserted into self-replicating yeast cells, and 'nature-identical' steviol glycosides fermented, packaged and exported. I also find stevia in the pride and imaginaries of those with vested interest in the success of the biorefinery.

Abundant and low-cost feedstock is fundamental to the viability of biosynthesis. Starting with the feedstock illuminates how biosynthesis is less a disruptive innovation to the status quo (as it is repeatedly framed), and more an offering of a means to support and expand the existing agro-industrial complex of corn in a region where demand and price of corn has been decreasing. Corporate descriptions of 'fermentation' obscure the origins and politics of feedstock by referring to them as 'simple sugars'. Non-descript notions of 'feedstock' or 'simple sugars' give the impression that a number of different agricultural sources could be flexibly drawn into biosynthesis operations. While this is technically possible in the future, in reality the science, intellectual property, micro-organisms, and fundamentally the geographical and physical infrastructure are optimised and located for either corn or sugarcane feedstocks. Cargill's established

infrastructure and corporate dominance in the corn supply chain provide the perfect conditions for one of the world's first commercial biological 'cell factories'.

This chapter has shown that biosynthesis supports the public-private sector drive in the US to 'increase production, increase demand and expand uses of corn' - the motto of the Nebraska Corn Board and described by research participants themselves. For farming families supplying Cargill in the US Midwest, any use increasing the value of corn is welcome relief in the face of rising costs of agricultural investment and debt. Yet biosynthesis is only viable due to the structural viability and profitability of low-cost surplus feedstocks. Indeed EverSweet® biosynthetic stevia did not get commercialised until it was cost-competitive with leaf stevia. Hence it can be concluded that the biosynthesis of stevia is conducive to the industrial agricultural system from which it emerges. EverSweet™ expands the use and demand of corn that helps reproduce this system. Likewise corn underpins the very viability of biosynthesis technology. The agro-industrial complex (from which biosynthesis emerges) is also conducive to Cargills reproduction, enabling the corporation to expand its dominance in both stevia *and* corn markets. The R&D history of EverSweet® (as seen in table 1) demonstrates that bringing a biosynthetic product to market is a feat logistically and financially feasible through the most established of agricultural systems and actors. Cargill as an influential actor across research sites traversed in this ethnography highlights how integral multinational companies are to the very viability of biosynthesis. Cargill are in a unique position to benefit from both processes of expansion and reduction. Rather than disrupting the status quo of industrial agriculture, EverSweet® as a bioeconomy commodity promises expanding uses of US corn and signals lucrative horizons for broad portfolios of natural ingredients and compounds that can be produced from corn at the single site of the Nebraskan biorefinery. As Cargill adopts synthetic biology techniques into its own global operations and aspirations, it also provides the conditions for other, smaller synthetic biology companies to lease land on its Nebraska biorefinery 'to plug in' to its so-called 'dextrose stream'.

I am not the first to question the long-term sustainability of intensive agriculture underpinning immediate and emerging biosynthetic futures (Smolker 2008; ETC group 2010; WEF 2010; Ribeiro & Shapira 2019). Corn not intended for direct human consumption, but rather as an 'industrial feedstock', implies that monocultural systems which comparatively use more agrochemicals and resources, also expand what is considered the already least-sustainable elements of corn agriculture in the United States. Herbicide-tolerant (GMO) corn has been connected with biodiversity loss, poor soil health, water pollution (Schütte et al. 2017; Soil Association 2017; USGS 2019). Life cycle assessments considering environmental performance of intensive corn agriculture to produce stevia sweeteners vis-à-vis stevia fields are still to be published by Cargill despite announcing in 2018 'plans to conduct a complete Life Cycle Assessment (LCA) once production is fully up and running' (Cargill 2021e). Life Cycle Assessments however notoriously overlook socio-economic and cultural factors so often fail to offer a complete picture or 'holistic assessment of sustainability', nor are LCA's able to capture the societal desirability of certain production or business models, or on-the-ground complexities of different types of agriculture, as well as omitting how 'value and ethical judgements' play into what does or does not get considered such as long term impacts upon inequalities (Ribeiro & Shapira 2019:317; Mathews et al. 2019). An important factor that becomes apparent through this research are the difficult-to-measure indirect implications, including land-use change and socio-economic consequences, which like the obscured politics of

feedstocks, remain unaddressed by Cargill and others in the biosynthesis industry. Very few in the biosynthesis industry have addressed, let alone questioned what is implied by replacing diverse smallholder crops with monocultures of feedstock.

Promissory narratives surrounding the new commodities of biosynthetic stevia simultaneously emphasise accounts of sustainability alongside narratives promising to secure precarious commodity chains for more reliable profits. Within these narratives, imaginaries of stevia's endemic indigeneity and naturalness are played up, while the wonder of conjuring DNA from multiple species is played down. This is problematic as attempts to normalise and historize natural product biosynthesis both obscures and defines the very contours of what it implies. As Jasonoff (2004:2) put it 'the ways in which we know and represent the world (both nature and society) are inseparable from the ways in which we choose to live in it'. Investigating what is implied in the process of technological emergence is not a straightforward task, yet 'things' do not emerge in isolation, they are part of processes or trajectories, as this chapter has shown through attention to the increasing dominance of industrial and corporate controlled agriculture in the United States, a trajectory enabling the prospect of biosynthetic futures to be realised. The historical trajectory of leaf-derived or farm-grown stevia however is another major factor in considering what biosynthesis implies. The only pre-defined tracks to follow to grasp this are those leading to the knowers and growers of stevia itself, in whose direction I now turn.

Finally, I close this chapter with a commercial interlude – a translation of 'Stevia speaks' a German advertisement by *Coca Cola Life (2015)*, one of the most influential and recognised global companies using stevia. The advertisement offers a somewhat absurd portrayal of the plant – anthropomorphising, racialising and gendering 'stevia' as a 'Latina' celebrity, rooted in the plant's historic exoticism. The advertisement also demonstrates how the food and drinks industry has long acknowledged and mobilised elements of stevia's human and geographically-located socio-ecological story to sell products, framings of stevia that biosynthetic and industrialised stevia has noticeably distanced itself from over the past five years.

Commercial interlude.

Stevia Speaks! (*for Coca-Cola*)

Coca Cola Life was launched in many countries in 2014 as a green, healthier cola containing 30% leaf-derived stevia sweeteners. The following advertisement and containing images below were copy and pasted and translated from German from the Swiss Coca-Cola website in 2019. (See original German language version in annex document 10.1)

Figure 4.0 Stevia Speaks!

"Hola amigos. My name is Stevia. I am the sweetest Latina in the world. Okay, maybe apart from J-Lo and Shakira. I admit the two have longer legs, can dance better than me and have smarter dresses. But I'm not so much on bling bling anyway. At first glance I am a robust being and rather small and stocky. I don't mind that. I am not a lily or orchid. I am the uncomplicated girlfriend for everyday life. But I make no compromises on one point: I don't open my flowers until it's bright for at least 16 hours a day.

My homeland is Paraguay. There I grew up, in the middle of the tropical rainforest, near the Parana River, surrounded by wild fruits, huge snakes, rare parrots, tapirs and pumas. About 200 relatives of mine bear similar names, but only in my leaves flows the sweet juice, which the Guarani Indians have known and appreciated for centuries. "Ka'a He'ê", the sweet herb.

Hey, you might think, who speaks Indian? You think. In my own country, Guarani is the second official language, and even the name of my country, Paraguay, is Guarani and means 'water that goes to the water'. It probably comes from the fact that we have magnificent rivers, but no coast.

The Guarani use my leaves for their mate tea and as a remedy, for example against stomach and digestive problems, skin problems and tooth inflammation, or to lower blood pressure. Even today I am used in Paraguay for sweetening teas and making sweets. Because we Paraguayans like it very sweet! We live in harmony with nature and do not have to pinch ourselves. Perhaps that is why we keep calling ourselves the happiest people in the world in surveys.

In the wilderness, you hardly meet me anymore. Like many tribes of the Guarani, I have lost my original habitat due to the destruction of the rainforest. I am a conservationist and I have to be grown.

My family is international. As a basket-flowering artist, I have relatives all over the world, such as your sunflower. But compared to it, my white, star-shaped flowers seem downright graceful. If you want to harvest my leaves, you have to do so before I bloom. Otherwise, all my jungle power goes into the flowers and seeds that the wind later sows into the earth.

In Europe, I was first mentioned in the 16th century; when the Spanish conquistadors reported in their homeland that the South American natives use the leaves of a plant to sweeten their herbal teas. Sugar was still weighed in gold at the time.

Photo from the homeland: here Stevia was discovered.

Alone in the jungle - only with me!

A first scientific study of me was published at the end of the 19th century by Moisés Santiago Bertoni, a botanist and naturalist who emigrated with his family from Switzerland to Paraguay. For years he lived in the middle of the jungle, just to explore me! Unique, this passion! I owe my Latin name to him and his friend, the chemist Ovidio Rebaudi: "Stevia *rebaudiana* Bertoni".

Although they spent years exploring my inner life, they were unable to completely isolate my sweetener. This does not surprise me, I say quite indiscriminately, because they don't call me Stevia Wonder for nothing. Even my music, these are samba and cumbia! You can't explain that in the lab. You have to experience me!

It wasn't until the 1970s that Asians living in Paraguay took me to Japan. Yes, that's the way it is: I was big in Japan first. I have been famous and very popular there for many years. Today, in addition to Paraguay and Japan, my sisters are also grown in South Korea, Malaysia, China, Mexico, Canada and Kenya.

My Sweet Secret? In order to extract the stevioside from my powerful leaves, a procedure that is as gentle as possible is required. As I said: Samba and Cumbia. If you do it right, I taste full-bodied sweet with a slight liquorice taste – but never bitter. Only whoever treats me well, I give to him my whole secret.

And this stevioside is a natural product. It has an outrageous number of advantages over sugar and artificial sweeteners. It is very stable and wanders through your body almost unchanged. I have virtually no calories and I don't affect blood sugar levels. In addition, I do not instill your craving for sweets, nor do I harm your teeth. On the contrary! My ingestion inhibits plaque formation, which is why dentists love me. Even to make toothpaste you want to use my magic powers. After all, I know how important a radiant smile is. And I'll also give you a cosmetic tip from the Guarani: After a bath with the green powder from my leaves, your skin will soften velvety like our Paraguayan milk caramel cream.

If you don't get enough of me, I'll come to your home and live on your windowsill or balcony. Remember: I need a lot of sun and balanced moisture. Cold feet are abominable to me, in winter you should put me in the greenhouse. The effort is worth it. For I am sin without repentance. Promised.

** for Coca-Cola 2015*

Chapter Four.

Ka´a he´ê is our Aunt: Indigenous Origins of stevia.

'The Tekoaruvicha [spiritual leaders] here gathered confirm the sacred origin of this plant created by the grace of Ñande Ramoi Jusu Papa (Our Eternal Great Grandfather) and Ñande Jari Jusu (Our Grandmother) on this land passed down to their children, the Paî Tavyterâ and Kaiowá people, for their use and care. The Ñande Jari kuera (wise women) here gathered confirm the use of this plant in our sacred ceremonies, for its abilities to strengthen the body, the spirit and our peoples with its sweetness. We Tekoaruvicha and Ñande Jari Kuera reveal to the world the sacred name of this plant that the white people call stevia: ka´a he´ê.'

Declaration by the Guaraní Paî Tavyterâ and Kaiowá peoples on the knowledge of the ka´a he´ê plant and its uses.

(quoted and translated in Gaberrell et al. 2016)

The Declaration.

Between 3rd - 5th August 2016 over 100 participants including spiritual leaders, wise women, political and community leaders from dispersed Guaraní communities of the Paî Tavyterâ and Kaiowá Peoples came together at Jasuka Venda, a sacred place in Amambay, North Eastern Paraguay. The coming together was a momentous occasion to rekindle kinship, reaffirm beliefs, unite and organise around what was collectively declared as '(t)he usurpation of our knowledge and biodiversity by multinational companies, who use, sell and profit from ka´a he´ê *(Stevia rebaudiana)* without us Paî Tavyterâ and Kaiowá, who it truly belongs to, having been consulted' (quoted and translated in Gaberell et al. 2016). As part of the declaration the communities denounced '(t)he conditions of poverty that we've historically been subject to through the loss of our territory, biodiversity and knowledge.' And '(t)he genocide that has been practised on our lands, affecting our communities, families and leaders, causing much pain and fear amongst our people'. The declaration lists four demands:

1. [We demand;] The respect of our territory, our world view, our autonomous regions and our authorities, principally Paî Tavyterâ and Kaiowá, as well as the other indigenous peoples of this continent.
2. The restitution of rights for the use of our knowledge related to *Stevia rebaudiana* through benefit-sharing.
3. Respect of the rights consecrated in the constitutions of the nation states that our ancestral communities lie within, as well as international agreements in force that guarantee the rights to life, autonomy, biodiversity and the right to a free, prior and informed consultation on the use of our knowledge.
4. That the relevant nation states guarantee us lands of sufficient quality and quantity within our traditional territories to live a dignified life in line with all the values of our culture.

The declaration was translated from Guaraní into English and Spanish and published in a follow-up report to an initial investigation subtitled the 'Commercialisation of Stevia-derived sweeteners by violating the rights of indigenous peoples, misleading marketing and controversial SynBio production' by a 'coalition' of NGOs and academics (Meienberg et al. 2015). The report focused on companies using leaf-derived stevia compounds including Nestle, Coca-Cola, Pepsi and others, as well as companies biosynthesising stevia compounds, and how all companies utilising stevia ought to comply with legislation developed at the UN CBD under its Nagoya Protocol on *Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization*, which came into force in 2014.

Two years after the Paî Tavyterâ and Kaiowá made the declaration and two *months* after Cargill and Evolva commercialised the bio-synthetic stevia EverSweet®, my family and I arrived in Paraguay. Paraguay is widely recognised the centre of origin of ka'a he'ê, which is the native Guaraní term for stevia, translating as 'sweet herb'. Guaraní is spoken by around 90% of the population alongside Spanish, as the second national language.

This chapter is the first of three chapters examining the significance of stevia in Paraguay. It focuses on the origins and changing relationships between the Paî Tavyterâ, the Kaiowá and Ka'a he'ê, and how ka'a he'ê became known outside Paraguay as stevia. In what follows I interweave ethnobotanical records and documentary and archival information with my ethnographic diary of staying in the 'Itaguazú Indigenous Community' of the Paî Tavyterâ People with the community leader's family, and other semi-structured interviews and informal conversations I had with community members as well as Paraguayan activists working on Indigenous issues. Unearthing the roots of stevia's changing relationship with its indigenous origins exposes a continuing struggle to maintain Paî Tavyterâ and Kaiowá way of life and territory. My account reveals a familiar story of accumulation by dispossession of America's Indigenous Peoples with the eventual transfer of a valuable 'genetic resource' from South to North. Yet it also tells a story of defiance and the capacity of the Paî Tavyterâ and Kaiowá to nimbly work across opposing worldviews, summoning both their cultural identity and legal rights in an attempt to reclaim capitalist and governing narratives about traditional knowledge and to reassert ownership and autonomy. Whether this nimbleness serves to meet their demands for justice however, remains to be seen.

I recognise that in focusing on relationships around a particular plant, I am not able to fully account for the historical injustices or conflicts Guaraní Peoples endured and continue to face nor can I account for the broad, in-depth knowledge and relationships between the Paî Tavyterâ and Kaiowá and multiple other plants, species and ecologies (for more on this, see the work of Reed 1997; Neolli 1998; Glauser 2010; Zanardini & Biedermann 2019). One of the limitations in attempting to describe the histories of marginalised groups is that largely they themselves are not the authors of their own histories. While there are a small collection of anthropological studies of Guaraní groups and specifically the Pai Tavyterâ published in Spanish (Glauser 2010; Zanardini & Biedermann 2019), there are very few accounts specifically written on the relationship between Guaraní groups and ka'a he'ê (Bertoni 1927; Soejarto 2002). While I draw on some of this literature, in order to avoid misrepresentation or only recalling accounts written under the colonial or western scientific gaze, I have decided to focus on what I directly experienced and what I was told by the Pai Tavyterâ themselves as well as those working alongside them.

Meeting the Paî Tavyterâ.

Figure 4.1. My own photo of the entrance of the Pai Tavyterâ community. The sign reads 'Itaguazú Indigenous Community. Supported by the Programme for Inclusive Value Chains, Indigenous Component, funded by USAID'. [27] Next to the text are 3 images of Indigenous men wearing clean white overalls selling vegetables and artisan products in a market, and another of a man in a white bee-keeping suit attending a beehive. Note that electric wires pass by the entrance, but the community had not yet gained access to electricity in 2018. The mountain in the distance is 'Ita Guasu'.

It was 3am on the second day of being in Itaguazú when I was awakened by a torrential downpour. As the rain eased, a gruff yet melodic rhythmic chanting resonated through my tent canvas. The voice was that of the 62-year-old Leader of Itaguazú praying as part of his daily morning ritual.[28] With my 9-month-old daughter undisturbed next to me I lay awake absorbing the sounds of the forest and the leader's family quietly preparing for daybreak until the dawn chorus signaled it was time to get up.

My host was eager to talk to me at first light. I was accompanied by a Paraguayan anthropologist[29], fluent in Paî Guaraní, Spanish and English, and familiar with the Itaguazú community and the leader's family. These vital ties enabled much of my conversation, especially in more formal semi-structured interviews with community members. Around 6am

[27] Translated from Spanish: Comunidad Indigena Itaguazú. Apoyada por el Programa Cadenas de Valor Inclusivas componante Indigena, financiada por USAID.
[28] The Paraguayan anthropologist explained the leader's morning prayers; 'sometimes he prays because he is worried, or just to make sure something is successfully achieved. For example, they may pray to ask to protect a visitor, or the even to heal some pain. A very common prayer is called 'torypa', literally translated it means 'to make everybody happy'.
[29] While I automatically anonymised all my research participants, Marcos Glauser the Paraguayan anthropologist who accompanied me as translator and mediator requested his real name be used.

Marcos beckoned me into the cindered palm-roofed hut where food was prepared on a central hearth that seemed to burn day and night. The blackened walls allowed the smoke to escape through wooden slats. The leader sat on one side of the hearth, his 98-year-old twinkly eyed mother on the other. On the hearth a sooty kettle simmered to refill the smoky tasting 'yerba mate' that delicately burned the tongue as it was sucked through an ornate metal straw called a 'bombilla'. It is custom for the 'guampa' (a mate cup traditionally made from wood or horn) to be shared between everyone in the group, and it is the guampa-holder's responsibility to keep topping up the thick green soupy herbs with hot water and to know whose turn it is to drink. Contrary to my inclination, Marcos informed me it was not to be sipped slowly, but rather sucked up in one go until a bubbly slurp sound signalled it was finished and passed back to the mate distributer. No thanks must be paid upon each serving until you have had enough by returning the guampa to the distributer with an affirmative Aguyje (or gracias – thankyou in Guaraní or spanish), who then knows to exclude you from the next round of mate sharing.[30]

The air inside the hut was heavy with smoke and humidity, the yerba mate, highly caffeinated, gave a dizzying rush to the senses. I clumsily fumbled for my voice recorder and turned it on. A cockerel, the sound of tree-top whistles and squawks, the whirr and hum of insects, clunking as the Great Grandmother pottered with tin pans between streaks of shadow and smoky light.

Figure 4.2 Map of Paraguay's current borders and the pre-war borders depicting the extent of land lost and the border region cutting through Pai Territory. The mount Cerro Cora marked on the map is very near the Itaguazú community (source: The Economist 2012)

The leader of Itaguazú, alert but unfazed by my presence, calmly began to recount how the Paî Tavyterâ in Paraguay and the Kaiowá over the border in Brazil are in fact one People. 'We are all Paî Tavyterâ' he explained, living across what was once a vast territory stretching from the Amambay mountain range to what is now Mato Grosso do Sul Brazil[31]. Most Pai Territory had been claimed by the Spanish during the early colonial period, however due to their remoteness from the sea and being situated between two expanding empires, the Paî Tavyterâ Peoples had not been devastated by colonization like other Guaraní indigenous groups of the period (Liaudat 2015). Under the Paraguayan state which gained independence from Spain in 1811, the Paî Tavyterâ had been given the option to become Paraguayan or to continue being 'Indian', which had allowed a greater degree of co-existence between early missionaries and settlers. This changed dramatically with the Triple Alliance War waged against Paraguay by Brazil, Argentina and Uruguay (subsidized by the United Kingdom) between 1864–1870. The War was considered the 'worst military defeat ever inflicted on a modern nation state', some now consider it a

[30] Drinking yerba mate (or tereré, an ice-cold version of the drink) was a ritual performed with almost every research participant I met in Paraguay, as a central part of Paraguayan culture across social divides.
[31] Personal communications (ref. 28). Itaguazú, Amambay, Paraguay. 25/09/18

genocide, by 1870 Paraguay had lost 90% of all men over 14 years of age, in sum 60% of the population (Lambert & Nickson, 2013; Economist 2012). On top of this, Paraguay lost one third of its territory, especially to Brazil, re-drawing the border directly through Paî Tavyterâ lands, as seen in figure 4.2, splitting in two what before the war was referred to as the Tierra de los Indios (land of the Indians).

On the Paraguayan side of the new border, the disseminated population and the widespread use of Guaraní as a second language meant better conditions for Indigenous communities to survive (Lambert & Nickson 2013). The Paî Tavyterâ on the new Brazilian side of the border however, became known as the Kaiowá in response to increasing encounters with colonisers in which they identified themselves as ka'aguy gua meaning *people of the* forest (Almeida & Mura 2018). Throughout the 20th century, the *people of the forest* lost the forest, Mato Grosso do Sul became a frontier to be colonised and many Kaiowá were enslaved and subjected to state sanctioned policies of missionization, acculturation and concentration (FIAN 2013). Successive waves of deforestation pushed agricultural frontiers further and further into Paî Tavyterâ and Kaiowá land on both sides of the border. Indigenous groups were increasingly divided and contained within reserves, no longer able to practice traditional lifestyles of hunter-gathering and swidden agriculture which demanded open territories.

The new economic orientation of neoliberal capitalism since the 1980s further expanded large-scale mechanized monoculture and livestock, particularly for export commodities of soy, beef and sugarcane. The dispossession of land for industrial agriculture has been disastrous for the Paî Tavyterâ and Kaiowá, whose life cycles, culture, identity and way of being is inextricably tied to 'Tekohá', the land of their ancestors (Mendonça & Sanches 2011; Tusing 2016). Since 1996 the Kaiowá in Brazil have been recorded as having one of the highest rates of suicide in the world, recently estimated to be 34 times the Brazilian national average (Survival International 2017). Many Kaiowá now live in over-crowded reserves or are completely landless, surviving in roadside encampments. With few other options, many Kaiowá labour on the sugarcane plantations feeding Brazil's biofuel boom, in what are described as 'extremely precarious' and sometimes 'slave-like conditions', many communities suffering chronic malnutrition and high infant mortality (FIAN 2013; EU 2016; Ioris 2018). Ioris (2019) calls the situation in Mato Grosso do Sul 'a state of low-intensity agrarian warfare between farmers and indigenous groups', with Brazilian landowners, farmers, vigilantes, private militias, and even state officers and civil servants complicit in what has been called a silent genocide against the Guaraní -Kaiowá.

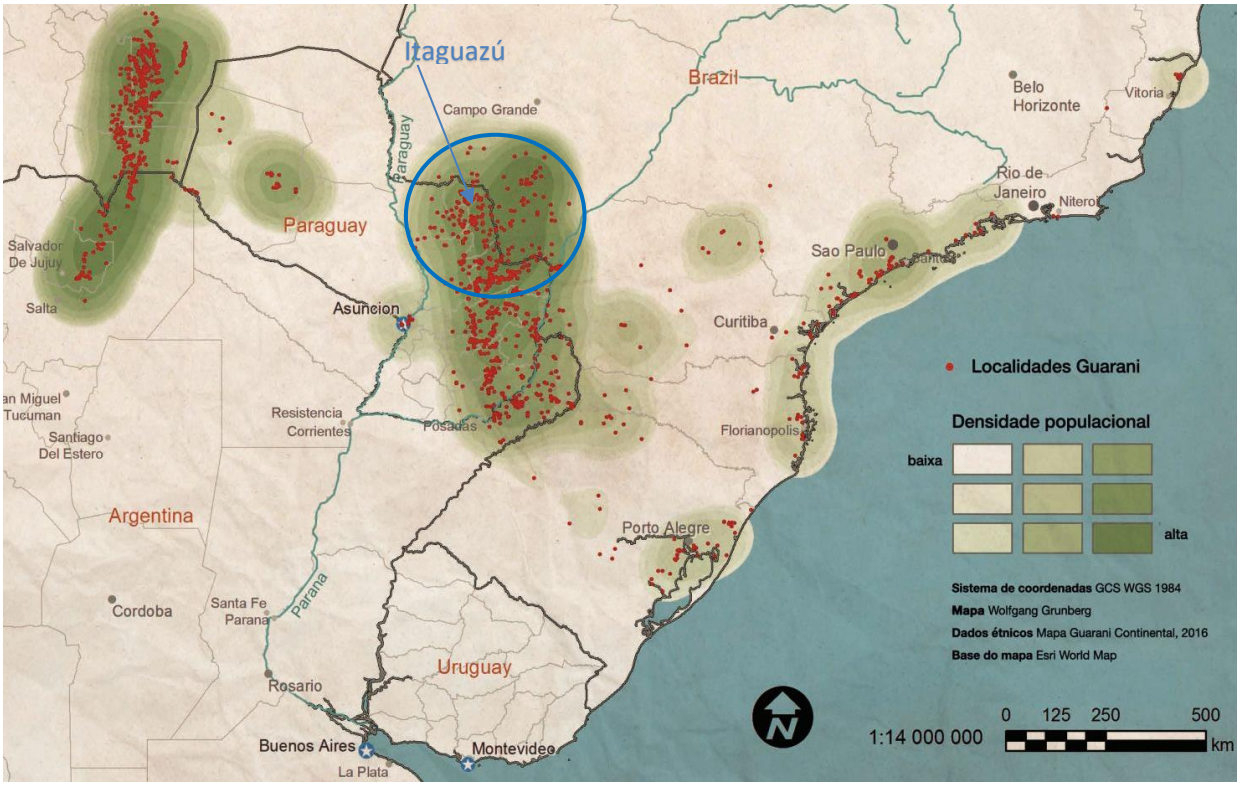


Figure 4.3 Map of Guaraní communities living across Paraguay, Brazil, Bolivia and Argentina (in Portuguese). On the map the red dots indicate Guaraní settlements. The shading represents Guaraní population density from low density (cream) to high density (dark green). The blue circle depicts the general region of Pai Tavyterâ and Kaiowá groups and approximate location of the Itaguazú community. Source: adapted from Mapa Guaraní Continental 2016.

The Pai Tavyterâ population in Paraguay also faced and continue to face difficult circumstances with the expansion of industrial agriculture, as communities have been condensed onto smaller plots of land, and land privatisation and land speculation has rocketed. Indeed Paraguay is consistently ranked the most unequal in Latin America in terms of land distribution and income, by the World Bank (2017). The population of Pai Tavyterâ is thought to be around 15,100 living between 61 communities, 14 of those live in extreme precarity without secure land title (Meienberg et al. 2015). Poverty within communities is high with regular reports of intimidation and violence by drug lords, ranch and plantation owners (Tusing 2016). From a satellite image the indigenous communities appear as small forested and agro-forested islands amid vast expanses of cattle ranches and soy plantations. The reduction of wild habitat and increase in herbicide and pesticide use has reduced the biodiversity that once provided subsistence for the communities, many of whom are now dependant on wage labour provided by the ranches, estates and plantations. It is for this reason, that wild stevia is now thought to be otherwise extinct outside of indigenous lands.

Itaguazú, the community I was staying in, was home to at least 500 people, and is considered one of the more stable Paî Tavyterâ communities, having secured land title in the 1980s (Glauser, 2010). In the leader's smoky forest hut my semi-structured interview is abruptly interrupted by piercing electronic techno music. The leader takes out his phone and shouts instructions to someone. Having no electrical infrastructure doesn't stop technology enabling communications within and beyond the community. The leader explains how since embarking on the campaign to reclaim ka'a he'ê, he has travelled to Brazil and remains in contact with both other Paî Tavyterâ and Kaiowá community

leaders.[32] He rejoiced that, despite the lapse in time since their division, the Kaiowá have retained traditional Pai Tavyterâ customs and beliefs affirming their distinct and united identity despite the border dividing them[33].

Knowing Ka'a he'ê, ecology and culture.

Later that day I have an appointment to meet a shaman and healer in Itaguazú. I am told he is very eager to tell me about ka'a he'ê because he was disappointed that he had not yet had the chance to share his knowledge about the plant with outsiders.

We meet him, a slim toothless elder in holey t-shirt and cap, accompanied by a small crowd of children, women and young men under an ancient tree whose broad branches provide much needed shade from the nearing midday sun. The view from the tree is stunning. Penetrating the horizon overshadowing the community's ceremonial temple (a huge thatched prism) is the sacred square-topped mountain of Ita Guasu after which the community are named. No sooner had we taken a seat on one of two bench-like roots expanding from the tree in opposite directions, than the shaman began chanting. Like the leader at 4am that morning, it was a guttural, undulating sound that reverberated a hypnotic rhythm sending shivers down my spine. He had clearly been waiting to share it, as once he had finished, he appeared visibly relieved. Marcos explained that he could not translate the prayer as it was chanted in a sacred ancient dialect of Pai Guaraní. The shaman explained that in their belief system, Ka'a he'ê was created at the beginning by The Creator who created everything that the Pai Tavyterâ know at the site of Jasuka Venda (a mountain 40km south) as he put it 'where the world was created'[34]. The shaman reiterated what the leader also explained, that the Ka'a ma'te (Yerba Mate) is 'our father' and that Ka'a he'ê is seen as 'the younger sister of our father, she is our aunt, a relative of our creator'.[35] The shaman explained that the Pai Tavyterâ have a specific way to reach the plant or to get closer to the plant, before touching 'her' you have to start with the prayer he had chanted for us. Very seriously the shaman recounted the three stages of the prayer, the first allows you to touch the Ka'a he'ê and to cut it, then the second part is to heal the plant after you see it is hurt from the procedure, then once you see that the plant is ok you say the third part of the prayer in gratitude as you leave. Marcos translates his warning; 'because it is a very powerful plant this is the procedure you *must* follow'. I ask how he knew the prayer, Marcos translates his response:

> Most of our useful plants have these sacred chants. These chants were taught to us by The Creator, my grandfather taught them to me, and I am sharing them with the next generation because I am weaker and weaker every day so I hope the new generation will learn from me, because what I share with you today is exactly as I learnt it from my grandfather.[36]

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[32] In the first meeting on Stevia 18 Kaiowá leaders came to Paraguay, and the second meeting 13 leaders came. The Itaguazú leader also attended a Kaiowá gathering of women in Brazil.
[33] Personal communications (ref. 28). Itaguazú, Amambay, Paraguay. 25/09/18
[34] The heritage of the Pai Tavyterâ is thought to date back over 5000 years, after archaeologists discovered some the of worlds earliest evidence of 'man' in a Jasuka Venda cave (Survival International 2009).
[35] The reference to Ka'a he'ê as a spiritual Aunt, can also be found in audiovisual recordings of the Jasuka Venda Conference of spiritual leaders and women of wisdom 15-17th August 2018, also titled in Pai Guaraní as 'Pai Tavyterâ omboaguera ojoupe teko' translated as '*The Pai Tavyterâ remind each other of their way of being'* which took place at Jasuka Venda. The archive of recordings by the Paraguayan NGO Grupo SUNU (who support intercultural cooperation in Paraguay) have published on YouTube some of the Pai Tavyterâ prayers, chants and rituals relating to ka'a he'ê and other important plants.
[36] Personal communications (ref. 29). Itaguazú, Amambay, Paraguay. 25/09/18

The leader had also explained to me the importance of intergenerational knowledge transfer as he sat, gesturing toward his 98-year-old mother, who had far surpassed the average Paraguayan life expectancy.[37] He lamented how with ka'a he'ê, for many communities it is now a matter of 'recovering our knowledge'. Today fewer families follow traditional practices, he said, or have the opportunity to share knowledge across generations. Having their great grandmother still alive, he went on, allowed his family to, as Marcos translated 'listen to this knowledge and to talk about this knowledge now and that's how I know, that's how we know'[38].

Every adult I met in Itaguazú knew Ka'a he'ê. Most of the various uses described centred around the plant's defining property, its sweetness. The leader explained one important use is for women to infuse their hands with ka'a he'ê to ensure 'sweet handling' in the ritual preparation of the 'chicha' (a fermented maize alcohol), a 'sacred drink' for adolescent boys undergoing initiation ceremonies into manhood.[39] In other conversations and interviews I was informed it was used to sweeten foods and yerba mate, for bathing, to make medicines more palatable as well as a medicine in itself. Despite the multiple uses described to me there wasn't actually ka'a he'ê growing in Itaguazú. Another community member explained, 'you cannot find ka'a he'ê here because it is not where it naturally grows […] plants have their own very specific place where they grow'[40]. The shaman and two others told me about near-by communities where it grows wild and remains regularly used. I am surprised, contrary to my prior research in accounts I read that ka'a he'ê in the wild is virtually extinct (Liaudat 2015; Coca-Cola 2015). The shaman looks at me sincerely 'it is a plant that will never end because it is always growing again and again'[41]. He described the ecological conditions and locations he goes to harvest wild ka'a he'ê, explaining he occasionally takes cuttings to be used for ritualistic and healing practices. I do not disclose this knowledge. During my first interview upon arrival in Asunción, a Paraguayan academic cautioned 'I really beg you not to share the exact location of the wild varieties, not even to your colleagues'[42]. The academic explained that this knowledge remained a guarded asset in the process towards producing a Community Protocol on ka'a he'ê. Hopes are pinned that this knowledge - now being recorded for the first time - will lead to Guaraní groups gaining recognition and possibly 'benefits' for their historic role as guardians and reproducers of the biodiversity in which wild ka'a he'ê thrives.

While today's secrets of exact locations of wild ka'a he'ê are closely guarded, ethnobotanical records from the early 20th century describe the species growing wild across a specific region stretching between the mountain ranges of Amambay to the Sierra de Mbaracaju crossing into Brazil. This area almost exactly coincides with the territories of the Paî Tavyterâ and Kaiowá Peoples seen in Figure 2. What these maps don't show however is how the ecology and land-use of this region has changed over the last century, and whether the apparent rarity of wild ka'a he'ê corresponds with the enclosure of Paî Tavyterâ and Kaiowá into reserves (Tusing 2016). Although it is difficult to prove cause and effect, a clear correlation can be distinguished. The reduction of Pai and Kaiowá territory as a consequence of clear-cutting and

[37] Paraguayan life expectancy is 73 years (New Internationalist, 2018).
[38] Personal communications (ref. 28). Itaguazú, Amambay, Paraguay. 25/09/18
[39] Again this use came up in a devotional song to purify the chicha recorded at the Jasuka Venda Conference of spiritual leaders and women of wisdom 15-17th August 2018, Another reference was that the woman must wear Ka'a he'ê at the time of her menstruation.
[40] Personal communications (ref. 30). Itaguazú, Amambay, Paraguay. 25/09/18
[41] Personal communications (ref. 29). Itaguazú, Amambay, Paraguay. 25/09/18
[42] Personal communication (ref. 25). Asunción, Paraguay. 15/09/18

deforestation throughout the 20th and 21st centuries can be seen as a process of mutual co-reduction of wild Ka'a he'ê habitat and traditional use and knowledge of the plant.

It was during this same period however that Ka'a he'ê was 'discovered' by the West and given a Latin taxonomic classification *Stevia rebaudiana* Bertoni. Since then, ethnobotanists, scientists, bioprospectors and businessmen from Paraguay, Brazil, Japan, China and the USA ventured into Pai territory seeking knowledge from Guaraní groups about this promissory 'ancient herb'. Hence the reduction of ka'a he'ê's endemic relations has explicitly coincided with the co-production of stevia as a plant of western scientific interest and capitalist expansion.

Turning Ka'a he'ê into Stevia.

Of the three European men[43] for whom ka'a he'ê is botanically named, it is Swiss-born Moises Bertoni (1857-1929) who the British Consul in Paraguay credits with the 'discovery' of stevia just over a century ago. Bertoni became a prominent botanist and anthropologist in Paraguay, publishing on flora and fauna as well as the habits of the Guaraní Peoples. The first ka'a he'ê Bertoni encountered were the dried remnants obtained from a 'yerbatero' (herbalist), labouring on the Northern yerba mate plantations (Bertoni 1918). Most of Bertoni's publications on Ka'a he'ê occurred after he became director of the Asunción School of Agriculture. In these works, Bertoni regarded Ka'a he'ê as a 'rare and unknown plant' (Bertoni 1905:1). It is difficult to corroborate the extent of its rarity, but Bertoni certainly struggled to obtain either dried or living specimens. Historians documented how between 1903-1904 adverts appeared in the University paper*, El Agricultor,* offering reward money for samples of Ka'a he'ê (Chesterton and Yang 2016). Bertoni was thought to have acquired his first living specimen of ka'a he'ê through Indigenous mediators and Priests in contact with Northern Guaraní groups in what is now the San Pedro province (Liaudat 2015). In 1905, Bertoni published the first in-depth study of ka'a he'ê describing its botanical and chemical features, as well as estimating its economic potential (Bertoni, 1905).

Bertoni was the first of many scientists and entrepreneurs to enthuse about the potential of ka'a he'ê and to prophesise about the plant as a means of economic development and health. In 1904 the front page of *El Agricultor* argued that the Paraguayan government 'more than anyone else has the obligation to make this interesting plant known to the outside world' and that samples should be sent abroad to better ascertain its potential uses (*El Agricultor*, 1904, quoted in Chesterton and Yang 2016: 261). Bertoni went on to actively pursue his dream that ka'a he'ê would be a 'step in the right direction down a path of progress' for Paraguay, publishing and sharing his knowledge not just about its sweetening properties but importantly as I examine in more detail later, for its medicinal uses, especially for diabetes, for which he stated 'beyond a doubt, that in whatever form the diabetes presents, my Stevia Rebaudiana, the Kaáhee [sic] of the Indians, is useful' (Bertoni 2008: 228; *El Agricultor*, 1904, quoted in Chesterton and Yang 2016: 261).

[43] The other two men, first, Petrus Jacobus Stevus 1500–1556, was a Spanish botanist who classified the genus Stevia as a part of the Asteraceae family representing around 240 other stevia species found native between the Northwestern United States and South America. The second man, Ovidio Rebaudi (1860-1931), was a Paraguayan-born chemist who in 1900 published the first chemical analysis describing the compounds that distinguishes *Stevia rebaudiana* Bertoni from any other stevia, its sweet glycosides, referred to as rebaudiosides and steviosides (Rebaudi 1921).

Bertoni's 'discovery' can be seen as the turning point where ka'a he'ê was translated into an object of western science. Its new taxonomic classification as *Stevia rebaudiana* Bertoni disaggregated its chemical, botanic and economic properties through the language of molecularised science, rendering it legible as an exploitable resource to the centres of mercantile capitalism (Daston, 2000). News of the plants 'discovery' and potential can be found in the British journal of the Royal Botanic Gardens, Kew in 1901 (RBG 1901). Despite its emergence as a new object of science, the 'ancient' origin and use of ka'a he'ê by the Guaraní Peoples of Paraguay remained a central part of a developing authenticity narrative and imaginary that began to be circulated about stevia throughout the 20th century. By the 1920s, articles on stevia appeared in US newspapers, one in *The Washington Post* entitled 'The sweetest plant in the world' described 'kaahee [sic]' use by natives 'down in Paraguay' who 'sip it through curiously carved gourds sucked through silver tubes' (Washington Post 1928, quoted in Chesterton and Yang 2016: 263).

Until the 1960s, experimental plots of stevia had largely not been attempted commercially outside of Paraguay. When Japanese researchers began seeking alternatives to what were increasingly considered carcinogenic sweeteners - saccharine, cyclamate and dulcin - popular during sugar shortages following World War II, stevia was seen as a solution not just for its sweetness, but also as a plant with less geopolitics (Liaudat 2015). Geopolitically sugar and artificial sweeteners were dominated by Western (former) colonial plantations and scientific institutions (de la Peña 2010; Richardson 2009). Between the 1950s and 1971 when the Japanese company Morita Kagaku Kogyo Co. Ltd eventually produced the first commercial sweetener from stevia, various accounts[44] document Japanese researchers travelling in Paraguay to study ka'a he'ê cultivation, collecting seeds and samples (May 2003; Chesterton & Yang 2016; Morita Kagaku Kogyo Co. Ltd. 2019). It is documented that in just two 'expeditions approximately 500,000 wild plants were excavated in the area of origin and brought to Japan' (Meienberg et al. 2015). Indeed, some argue that this mass removal of plants is one of the key reasons for the near-extinction of the wild population of stevia in Paraguay (anonymous at the Union of Ethical Biotrade conference 2017).[45]

The leader of the Itaguazú community remembers the Japanese researchers searching for wild ka'a he'ê plants. He tells me, 'I was young, around 12, now I'm 62, I remember these Japanese people were coming and were looking for ka'a he'ê. I remember the plants in this area here, and another area over there, and they took these plants'[46]. Other elder community members also remembered Japanese people coming to collect wild plants, one explained that it was Paî Tavyterâ guides that showed them where the plants were[47]. The shaman recalled the Japanese but also recounted memories of others arriving to find ka'a he'ê too:

> I know, I remember people from the government looking for the plant and taking many samples, they were doing this not only here but also in San Pedro and in Concepcion, and also people from Brazil came and also

[44] Various accounts and oral histories document different dates and exact locations. But all accounts are between these dates.
[45] In June 2017 I attended the Union for Ethical Biotrade (UEBT) Conference in Paris, and observed a closed 'informal dialogue on issues and opportunities around Stevia and fair and equitable benefit sharing' that the organisers described as a dialogue to 'bring together, *by invitation only,* companies working with stevia or derived products, non-governmental organizations looking at the stevia case, representatives from the holders of traditional knowledge and experts on access and benefit sharing (ABS). Its objective is providing an informal platform to constructively engage on how ABS applies to stevia and what concrete measures could be taken to advance fair and equitable benefit-sharing'. The event occurred under Chatham House Rules, so all statements are anonymised.
[46] Personal communications (ref. 28). Itaguazú, Amambay, Paraguay. 25/09/18
[47] Personal communications (ref. 30). Itaguazú, Amambay, Paraguay. 25/09/18

> took some samples, and these people thought that nobody would remember but now after some years there is this process of recovering this knowledge and that's how everything started again to be refreshed, because as people talk about it, more is remembered.[48]

Since the 1970s and the period of intensive in-situ research on stevia, with the removal and translocation of thousands of seeds and plants from Guaraní lands, the global consumption and demand for stevia sweeteners has steadily increased, and commercial plots expanded in Japan and consequentially China, which is today the world's largest stevia producer. I ask community members what they think about foreign interest in ka'a he'ê. The leader responds,

> One of the bad things about this interest is that we were not consulted and we were not being told what or why the outsiders were interested, and what were they going to do with the plant and that was a bad thing. They just arrived, found one Indigenous man who knew where the plants were and then took plenty of plants away and afterwards they were using these plants and the seeds of these plants in their countries and not coming back. If it was going to happen again now they would have to sit down and explain and consult officially because we are the owners of the plants.[49]

I ask what ownership of a plant means? The leader clarifies 'this plant does not belong to Itaguazú, its belongs to the whole Paî Tavyterâ and Kaiowá Peoples, mainly because it is a sacred plant not just any plant'.[50] This notion of collective or cultural ownership of ka'a he'ê being 'our plant' was repeated and reiterated to me. After waves of dispossession, it appears that although historically the Guaraní did not consider nature as something that could be privately owned, in the struggle to defend and reclaim rights, territory and cultural artifacts they are co-opting capitalist conceptions of ownership (Smis & Inman 2018). Though their conception of ownership was explicitly collective as opposed to financial or private forms of ownership. On more than two occasions, community members likened the fight to reclaim stevia to the fight to reclaim Jasuka Venda, after Pai Tavyterâ communities were evicted during the 1940s. According to Pai cosmovision, the land and mountain of Jasuka Venda is the place of creation. As the leader explained 'it is a sacred place, where everything started, everything was created from this point, just south from here'. During the 1970s Jasuka Venda 'was being deforested' the leader recalls, 'we didn't know, it was only because some people from Asunción came and told us, we were able to know that it was happening, they told us that we had the rights to claim and to fight for that piece of land and it is similar to what is happening now with ka'a he'ê'. I later realised it had been the Paraguayan anthropologists' parents among others, who had been such people from Asunción supporting the land expropriation and legal transfer of Jasuka Venda to the 'Asociación de Comunidades Indígenas Pai Reta Joaju'. Other community members joked in seriousness that once they had gained justice over stevia they would have another fight on their hands over Yerba mate, which represents their most sacred father, the older brother of ka'a he'ê.

I ask what community members know of what happened to ka'a he'ê since it was taken. The shaman states simply; 'yes I know that some people are making money out of what they took from here and that they are not sharing anything

[48] Personal communications (ref. 29). Itaguazú, Amambay, Paraguay. 25/09/18
[49] Personal communications (ref. 28). Itaguazú, Amambay, Paraguay. 25/09/18
[50] *Ibid.*

with us'.[51] Most respondents were unaware of the commercial plots of ka'a he'ê in foreign countries let alone the smallholdings of local Paraguayan campesinos growing it just kilometres away. The leader of Itaguazú only learned about Paraguayan and foreign uses of ka'a he'ê after he was invited to Asunción earlier in 2018 to participate in a forum titled 'Ka'a he'ê threatened by synthetic biology and patents' organised by two Paraguayan NGOs (BASE-IS 2018; Conamuri 2017). He told me this was the first time he had seen images of ka'a he'ê grown on a large scale:

> [I was] shocked to see how the current use of the plants look like because that is how I realised that they are modifying the plant, they are playing with the plant, the leaves were much longer and thinner and the plant was much higher than the original wild plant.[52]

I asked what he thinks about the idea of ka'a he'ê being biosynthesized? Marcos said biosynthesis is probably a concept the leader could not comprehend. So I re-worded it, what do you think of ka'a he'ê been made by man's hand, rather than been grown from the earth? 'That is not ka'a he'ê, it is something else' he replied sternly. 'Ka'a he'ê is the plant, it is the leaf, it is the whole plant and it is the plant in our culture that is ka'a he'ê. If you add other things, you don't have the leaf anymore, then it is not ka'a he'ê'. He goes on, 'if they are selling it and saying that it is ka'a he'ê then they are just using the Paî Tavyterâ and just using our culture. The best thing would be if they came here and had a consultation so they could know what Ka'a he'ê is'.[53]

The 'use' or exploitation of Guaraní People's culture to sell stevia products has persisted as one of the framing narratives established since the plant was first described by Bertoni. As mentioned previously in chapter three, imaginaries of the 'ancient', and 'indigenous origins' of stevia-derived products are a part of a broader authenticity narrative conjuring notions of purity, naturalness and mystery, as a means to both entice and reassure consumers of stevia's long history of consumption (Coca-cola 2019; Meienburg et al. 2015). Cargill has reproduced this narrative in both its leaf-derived products and its new biosynthesized stevia (Cargill 2021b).

A case of biopiracy?

My experience with the Pai Tavyterâ clearly demonstrate that their understandings of the plant go far beyond Cargill's assumption that they knew it as a sweetener and nothing more. Cargill's marketing message both historicizes their knowledge and reproduces colonial tropes about indigenous ignorance of scientific complexity that Bertoni was guilty of over a century ago. Bertoni, like many naturalists of the colonial era, was praised as being the 'discoverer' of the plant, despite it having been in use for thousands of years. The legacy of such assumptions persist that only once something has been described by western science can it be truly 'known' (Daston 2000). A decolonial perspective today might see turning Ka'a he'ê into stevia as a form of dispossession, and certainly the Pai Tavyterâ talked about it in terms of ka'a he'ê been taken from them.

The characteristics of what is termed 'traditional knowledge' as ancestral, communal, cross-border, and shared, essentially not ownable, make it a form of intelligence less compatible with the global order of financeable knowledge

[51] Personal communications (ref. 29). Itaguazú, Amambay, Paraguay. 25/09/18
[52] Personal communications (ref. 28). Itaguazú, Amambay, Paraguay. 25/09/18
[53] *Ibid.*

in the terms stipulated by intellectual property systems. In the prevailing scientific culture success is often measured in terms of patents, and traditional knowledge has been frequently rendered less or non-scientific. The role and significance of 'traditional knowledge' became increasingly recognised since the signing of the UN Convention on Biological Diversity (CBD) in 1992. Under this global treaty, parties committed to the principle that access or utilisation of sovereign 'genetic resources and/or associated traditional knowledge' of 'Indigenous Peoples and Local Communities' should be subject to rules on 'fair and equitable benefit sharing' (CBD Treaty text 1993). The access and benefit -sharing or ABS objective as it is commonly referred to, essentially implies that all the people who contribute to the discovery, knowledge or innovation of a thing, or the country in which it was discovered, should share in benefits that arise from its utilisation or commercialisation.

However, as bioprospecting increased throughout the 1990s with pharmaceutical, cosmetic and biotechnology companies looking to the botanical knowledges of Indigenous Peoples as a source of innovation, so did accusations of biopiracy (Robinson 2010). Biopiracy was a concept coined to contest the exploitation and patenting of Indigenous and Local Communities' (ILC) knowledge of plants, crops or natural remedies without adherence to access and benefit-sharing rules (RAFI 1994; Shiva 1997; Dutfield 2004; Oldham 2007).

Globally loose compliance to the ABS rules fuelled many years of further negotiations at the CBD on a stricter legal mechanism for ABS, culminating in 2010 with the signing of the *Nagoya Protocol on access to genetic resources and the fair and equitable sharing of benefits arising from their utilisation* that entered into force in 2014. ABS has flourished as a policy concept central to incentivise the preservation and protection of biodiverse habitats, oceans, forests and jungles, and the rights of Indigenous Peoples as 'traditional knowledge holders' and 'environmental stewards' (Muller 2015).

While the Guaraní peoples themselves do not use the term biopiracy, the NGO coalition supporting their ABS claim argue stevia represents a clear case of biopiracy, where the marginalisation and discrimination of Kaiowá and Pai Tavyterâ has coincided with dramatic loss of the wild Ka'a he'ê habitat and the virtual extinction of plants in the wild. In their report, they support the Guaraní claim that knowledge was obtained and wild plants taken without 'free, prior or informed consent' or 'mutually agreed terms' during the 1960s, pointing out the spike in patent activity since the 2008 US and EU evaluation of safety for steviol glycosides (Meienberg et al. 2015). Significantly, the report presents statistics that since 2009 there has been an increase in the number of patents filed 'focusing on ways of producing steviol glycoside molecules as opposed to using them' coinciding with the R&D on biosynthesis production techniques (Meienberg et al. 2015:14). The NGO coalition argue that because so much commercial activity on stevia has occurred since the signing of the Nagoya Protocol, companies producing and using leaf-derived stevia as well as those digitally sequencing and synthesising stevia's gene sequences are equally in violation of the law.

'Stevia' understood in terms of a functional genetic code may be beyond ontological comprehension for the Pai Tavyterâ, who argue that biosynthetic stevia should not be considered ka'a he'ê, and any association between the two is exploitative of the Paî Tavyterâ and their culture. As the shaman insisted sitting under the tree overlooking Ita Guazú.

> We do not think what these people are doing is good. [We] really hope and think it could be a very good thing if we can get access to some benefits because our people need it, we did not know that this was happening

but now we are slowly understanding there are factories making money and this money should also flow back.[54]

Fair and Equitable benefit-sharing and the future.

As part of the Jasuka Venda Declaration on Ka'a he'ê in August 2016, the Paî Tavyterâ and Kaiowá made the following three decisions to guide future action in their pursuit of a 'fair and equitable' share of the benefits derived from Ka'a he'ê.

We decide the following:

1. That the here present, members of the Paî Tavyterâ and Kaiowá people, will form a permanent assembly to monitor the claim for a fair and equitable sharing of benefits arising from the utilization of stevia and its derivatives.
2. That from this moment on we shall act in a manner guided by our own world view as we continue along the path we have started.
3. That we will no longer permit the usurpation of our sacred knowledge and the use of the biodiversity present in our territories without the due process of free, prior and informed consultation.

(Quoted in Gaberell et al. 2016)

Two years after the Jasuka Venda declaration on ka'a he'ê, when I arrived in Asunción in September 2018, a Paraguayan member of the NGO coalition assisting the Guaraní communities to draft their community protocol explained that the whole process was experiencing significant setbacks. Firstly, after the industry had 'space to talk' about the ABS claim, their representatives had come back to the NGO coalition arguing that there was nothing in EU law that required them to enter into negotiations with the Guaraní Communities[55]. Instead, a financial contribution was offered by a global trade association representing companies that produce and use stevia products (including Cargill) to help the Paî Tavyterâ and Kaiowá establish stevia farming, 'so they could be integrated into the stevia boom'. The Paraguayan NGO respondent laughed in irony, 'these companies just don't get it, benefit-sharing is not about turning Indigenous Peoples into capitalist farmers, it is about respecting their traditional knowledge and compensating them for their intellectual contribution'.[56] Even the synthetic biology company Evolva, the inventors of the biosynthetic stevia EverSweet®, who initially had declared '[Evolva is] willing to engage in discussions regarding benefit-sharing with the Guaraní as per the spirit of the Convention on Biological Diversity' had backtracked, and now declined to discuss benefit sharing at all (Evolva quoted in Gaberell et al. 2016: 6). This backtracking coincided with corporate restructuring at Evolva, as the founder and CEO was replaced by an ex-Cargill executive. Industry are united and acting as one in attempt to close down this process, 'to stop it in its tracks', the Paraguayan NGO respondent explained.

[54] Personal communications (ref. 29). Itaguazú, Amambay, Paraguay. 25/09/18
[55] This was the 2018 outcome of the 2017 invite-only 'informal dialogue on issues and opportunities around Stevia and fair and equitable benefit sharing' (that I attended and observed) – between companies working with stevia or derived products, NGOs looking at the stevia case, representatives from the holders of traditional knowledge and experts on access and benefit sharing (ABS) – that took place during the Union for Ethical Biotrade (UEBT) Conference held in Paris under Chatham House Rules.
[56] Personal communication (ref. 17) SUNU HQ. Asunción, Paraguay. 5/09/2018

Another setback alongside the retreat of Industry, was the retreat of the Brazilian government whose delegates in a side event at the 2016 CBD COP13 had asserted their intentions for supporting the Guaraní in what they had excitedly proclaimed might be the first ever case of trans-boundary benefit-sharing. Under the incoming Bolsonaro government by the end of 2018, the prospects of these intentions looked unlikely, the government agency for Indigenous Peoples known as the National Indian Foundation or FUNAI, had undergone significant reform, cutting half the number of staff. One ex-employee of FUNAI that I met through following stevia, explained confidentially that the team working on ABS procedures was now dominated by industry. Bolsonaro since appointed a former police officer with connections to agribusiness as head of the agency (Phillips, 2019).

Other setbacks were the logistical and political challenges of bringing together representatives from 61 Paî Tavyterâ communities in Paraguay, and the dispersed Kaiowá in Brazil to co-ordinate a consultation process to build a Community Protocol,[57] the vital procedure before any negotiations could begin. One of the explanations the NGO respondent had explained was down to the pervasive culture of corruption In Paraguay, rumours and distrust between communities over how much benefits are at stake was hampering progress. Logistically and politically, he also explained the situation for the Kaiowá in Brazil remained dire. Kaiowá leaders had welcomed the benefit-sharing efforts and the invitation to participate in the community protocol, however they regretted that all their energy and resources were taken up on the front line of land occupations and evictions. The Kaiowá continue to face what they call a daily 'fight for survival' against a genocidal force of land grabbing, poverty, malnutrition, agro-chemical attacks by landowners, vigilante violence, murder, and a lack of state protection (Ioris 2019). The situation was deemed so dire for the Guaraní-Kaiowá, that in 2016 the European Parliament passed a resolution condemning the violence against them (EU, 2016).

The setbacks of industry's and governments' retreat and the complex local-level challenges over coordination and participation were putting pressure on the benefit-sharing coalition's 'low budget and limited resources' needed to facilitate the Community Protocol. As the Paraguayan NGO respondent explained, a Community Protocol must be established democratically and transparently, it will be an important legal document setting guidelines for stevia but could also act as a guide for future encounters between Guaraní Pai and Kaiowá traditional knowledge and/or ecological resources. He cautioned 'we are proceeding despite the turmoil, but we have to be mindful all the while not to raise the community's expectations, because they might not get anything at the end of this process'.[58]

I was mindful of this warning not to raise expectations during my stay at Itaguazú. However, I thought it was important to consider – what if the benefit-sharing case *did* eventually fail after such a long process first initiated in 2008?[59] What would be the implications? In closing my semi-structured interviews with Pai Tavyterâ community members, I asked, 'what if eventually you don't gain any recognition or benefits from all this?' One respondent showing me around the community's vegetable allotments and medicine garden asserted 'nobody asked for permission to take these plants

[57] Community Protocols were conceptualised during the Nagoya Protocol as an instrument to encompass Indigenous Peoples and Local Communities (IPLCs) worldviews, principles, values, rules, codes of conduct, and established practices in interactions with their ecosystems, between IPLCs themselves, and in their interactions with external actors (UNEP 2013).
[58] Personal communication (ref. 17) SUNU HQ. Asunción, Paraguay. 5/09/2018
[59] Academics at the University of Hohenheim, Germany, first pointed to stevia as a potential case for benefit-sharing in 2008 (see Kienle *et al.* 2008)

and nobody explained why they were interested in these plants, and what we are asking now is that the companies using ka'a he'ê should consult us'. He went on:

> We have the knowledge of how to use many other plants, but we are not feeling happy with how we have been treated and we are now going to focus on reproducing these plants that we have available, we know some particular plants are used to heal that some Paraguayans are coming here to buy and we know that these plants could be interesting for medicine in the future.[60]

The same man describes the fibres of a native vine the community use for its healing properties, which he asserts outsiders have started coming to buy in large quantities, likening it to the situation when the Japanese first came to find ka'a he'ê. Failure of the benefit sharing process would – as other community members agreed – make them less willing to share information about useful plants with outsiders. The Shaman added, 'it would be wrong, it should not end like that, it is wrong that someone is appropriating or taking something that does not belong to them. Maybe they do not want to share now but at one stage they will have to, because it is very clear this is something that belongs to the Paî Tavyterâ'.[61] The leader said '[It] would be wrong if they deny these benefits', though he acknowledged that 'this will be a long process', but he is defiant to 'continue to work on this', adding that he 'hopes that the government also get involved and support their claim'.[62]

Despite the challenges, the Itaguazú respondents remain positive and defiant. Their experience fighting for their goals, such as the occupation and struggle to reclaim Jasuka Venda from loggers and ranchers eventually achieving an inter-community land title has inspired hope and determination in their ability to confront historical injustices. The community's defiance to 'recover ka'a he'ê' rests on what the leader described as their 'double strategy':

> One part is the law, we know our rights and know we have the right to be consulted, and the other part of our strategy is our culture because ka'a he'ê is not just any plant but it's a particular plant created by The Creator and she is our plant, by using sacred chants and sacred songs we can also fight for recognition and benefits.[63]

Conclusions.

The Pai Tavyterâ understand ka'a he'ê as much more than a sweetener, cash crop or steviol glycoside molecule, for them the plant is a spiritual aunt, a family member central to medicines and life's ceremonies. Physically staying in the home of the Pai Tavyterâ gave me a unique snapshot perspective on the spiritual and ecological relationship this community have with the living world. It opened up a deeper, richer picture of the stakes in a community where livelihoods seemed to fluctuate between the pushes and pulls of tradition, culture and spirituality and modern-day economy, work, and Christianity accentuated by strategies of US aid programmes to integrate them into '*Inclusive Value Chains*' as the signpost read upon their entrance. During my stay, unprecedented changes loomed over the Itaguazú community, the leader was frequently on the phone pre-occupied with logistics over a government

[60] Personal communications (ref. 30). Itaguazú, Amambay, Paraguay. 25/09/18
[61] Personal communications (ref. 29). Itaguazú, Amambay, Paraguay. 25/09/18
[62] Personal communications (ref. 28). Itaguazú, Amambay, Paraguay. 25/09/18
[63] *Ibid.*

development project to bring electrification and build roads and replace traditional wooden dwellings with formally designed concrete homes. My short experience staying in the community cannot account for the complex dynamics of development facing them. Yet ka'a he'ê, which was passionately described as so rooted in the history and culture of the Pai Tavyterâ, seemed to represent one such juncture with the outside 'modern' world as a channel through which encounters and understandings between worldviews were being forged. *Through* stevia the community attempted to work within legal structures of rights and property, and their actions meant that multinational corporations were being forced to consider culture, history and social justice.

Members of the community framed ka'a he'ê within a history of things being taken from them, likening their claim over ka'a he'ê to previous struggles against dispossession, such as reclaiming their sacred mountain Jasuka Venda. Perhaps this achievement and experience working across cultures and worldviews is what inspires such confidence in their 'double strategy' summoning both international law and their unique culture and customs. While the leader clearly understood his community's rights as 'Indigenous Peoples' and 'traditional knowledge holders', the mobilisation of their culture was of equal importance, through prayer and ceremony, the re-affirmation of Pai and Kaiowá shared history, beliefs and perhaps most significantly, their memories of appropriation. They repeatedly and firmly asserted that ka'a he'ê belonged *to them*, inciting the plant as a form of property.

Their defiant claim of ownership over the plant struck me for its juxtaposition to the institutional commercialised forms of ownership assumed through intellectual property, patents and trademarks fundamental to the innovation of biosynthetic stevia. I later heard the notion that 'ka'a he'ê belongs to us' reiterated by small farmers I met following stevia across Paraguay. Interpretations of ownership by both Indigenous and local farming communities manifested themselves through physical, cultural and historical connections to the materiality of the plant rather than through the notion of owning intelligence, as imbued by intellectual property rights. Their expressions of ownership expose a trajectory whereby non-capitalised or non-capitalisable intelligence has increasingly been rendered expendable in industrialising processes which understand only institutionalised, disaggregated, and molecular types of knowledge of over plants and agriculture as ownable and *(financially)* worth protecting. The Convention for Biological Diversity was pioneering in being the first global institution to formally recognise the contribution of 'other' forms of knowledge, yet it has been critiqued on one hand for incentivising commodification of 'traditional' or non-capitalised knowledge, drawing it in to financialised innovation processes, and on the other for its legal loopholes and weak legislative power to enforce Access and Benefit-Sharing considered contradictory to the strictly enforced WTO TRIPS (McAfee 1999; Pant & Ramisch 2010; McManis & Burton 2018) (I come back to some of these critiques in Chapter Seven). As the earliest written accounts show (Bertoni 1905; Kinghorn 2002) stevia as it is known around the world today, wouldn't exist were it not for people like the Shaman I met in Itaguazú openly and generously sharing their knowledge.

Between the world forming around stevia as a bioeconomy commodity, and the world where stevia is a spiritual family member, 'ownership' shone out as a key dis/connect. Ownership (of nature and knowledge) between these worlds began to emerge as a thread connecting the diversity of paths following stevia. Meanwhile the promissory narratives of authenticity, efficiency and sustainability fundamental for Cargill to sell its biosynthetic stevia, highlighted in the previous chapter, played out in the livelihoods of the indigenous community both implicitly and explicitly. The previous

chapters described how imaginaries of stevia's 'indigenous origins' play into the 'authenticity narrative' amplified by companies such as Cargill and Coca-Cola to reassure consumers of the plants 'ancient' and historical use by 'Peoples of South America' within conjured landscapes and mindscapes of natural wilderness, health and purity. Paradoxically those at the heart of the ethnobotanic and endemic authenticity narrative, deeply contest the 'usurpation of their knowledge' the appropriation of their plant and the 'use of [their] culture' by such companies (Gaberell et al. 2016). This paradox demonstrates how attention to the disconnects or frictious zones within powerful conceptions such as 'authenticity' bridge and have effects and affects across worlds. As I travel on, more dis/connects within an authenticity narrative emerge, illuminating a more granular understanding of the shifting dynamics behind biosynthesis.

Alongside authenticity, sustainability and ownership, a fourth central frictious dis/connect emerged in this chapter central to the stevia story: the promise of justice. While the concept of justice was far from explicit in the previous chapter following biosynthetic stevia, the synthetic biology scientists, start-up companies, and incumbents like Cargill are inescapably drawn into debates over fairness, equity and justice in the use and ownership of nature and knowledge through global governance regimes on Access and Benefit-sharing (ABS) and the public campaign launched by the Pai Tavyterâ, Kaiowá and the coalition of NGOs and academics accusing the companies of biopiracy. The demands[64] of the Pai Tavyterâ and Kaiowá demonstrate that ka'a he'ê is not only important to them as a spiritual herb, the plant is a means to gain recognition, respect, and ultimately justice in securing their way of life.

Beyond the local-level setbacks in Paraguay and legal loopholes affecting the Guaraní groups' ABS claim, stevia has been drawn onto the front line of even bigger battles in a decade of global dispute over regulating tools and techniques in synthetic biology, and the access and editing of genes. These disputes engulf the frictions over authenticity, ownership, sustainability and justice, and the promise of ABS policy remains in limbo (Laird et al. 2020). I come back to developments in the stevia benefit-sharing case in Chapter Seven. I also revisit the prospects of the Guaraní groups gaining the benefits they call for in the Conclusion.

For now, I stay with the process of following. The stories of ka'a he'ê in Pai Tavyterâ history and culture stand in stark juxtaposition to the latest manifestations of stevia described in the previous chapter in the cornfields and biorefinery fermentation tanks in Nebraska. But stevia's indigenous origins also stand in juxtaposition to the next part of the plant's story, as ka'a he'ê became a promissory cash crop for rural sustainable development and poverty alleviation in Paraguay. As the Itaguazú leader confessed, since memories of Japanese collections, he had been oblivious to the journey ka'a he'ê had undertaken as it was domesticated in Paraguayan campesino fields and later as it became globalised into the cash molecule for which it is renowned today.

[64] Demands include the respect of territory and world view through legal 'rights to life, autonomy, biodiversity', and the 'restitution of rights for the use of our knowledge related to *Stevia rebaudiana'*, by companies and nation states in order to guarantee 'lands of sufficient quality and quantity' within traditional territories 'to live a dignified life in line with all the values of our culture' (quoted from Gaberell et al. 2016).

Photo-ethno-graphic interlude.

No sooner had we left the Itaguazú community, than I shouted stop!

I got out of the car and took a photo.

The majestic mountain of Itaguazú was out-shadowed by a billboard (Figure 4.4)

The billboard depicted a military-style operation of what looked like soldiers dropping from a helicopter into a soy plantation with capitalised words in bold 'The team to save your soy'. The billboard by Syngenta, one of the largest multinationals in the crop chemical and GMO seed business, was advertising fungicide. Initially I was struck by the contrast of the giant agri-business billboard on the border of an Indigenous community, and the two's opposing relationships to plants. It later dawned on me how poignant a symbol that billboard was as a turning point of my research and the issues I was about to confront in the next part of my journey following stevia. Not only did the billboard reflect the militarisation of the area I was entering as an ongoing legacy of rural conflict and corruption in Paraguay, but it reflected the stories I was about to encounter over stevia's struggle to live up to its prophesy as a cash crop for campesinos on the frontline of Paraguay's soybean boom.

Chapter Five.

Ka'a he'ê killed my father, Soy kills communities: Paraguay's cash crop promise.

Figure 5.1 Earthened hand holding guaraní, Paraguay's currency. This image featured on one side of a business card given to me by a director from the world's largest Stevia company, the same image also features on the companies' promotional video 'This Leaf' transcribed below.

This Leaf.

This leaf is stevia, it's green, it's small, it's sweet, but it is also so much more.

When this leaf is dried in the sun, steeped in water, filtered and purified it adds a sweet taste to the food and drinks you love, and that's not all, this leaf is powerful.

(on screen: ***This leaf is powerful.)***

It can reduce our impact on the environment through sustainable farming techniques.

(on screen: ***This leaf saves enough water to bathe 5.5 million people. This leaf saves enough CO^2 to light a million homes)***

and it replenishes the air through the planting of thousands of seedlings.

(on screen: ***This leaf protects millions of wildlife habitats***)

It can help with those with few options start profitable businesses

(on screen: ***This leaf improves the lives of 25,000 farmers***)

and gives their children the start they deserve.

(on screen: ***This leaf educates thousands of children***)…

It touches thousands of foods you probably already know

(on screen: ***This leaf improves 5000 products around the globe***)

and millions of people you've probably never met.

(on screen: ***This leaf reduces 500 billion calories worldwide***)

Yes, it is a small leaf with a simple purpose, but it has the power to move the world!

Pure Circle Stevia, 2014.

'This leaf' as a 'powerful' cash crop for sustainable development and small farmer livelihoods is a promissory narrative about stevia that has travelled from Paraguay around the world. This narrative has encouraged thousands of smallholders, subsistence and peasant farmers in African, Asian and Latin American countries to invest in establishing plots of stevia. Nowhere has this sustainable livelihood promise been more prophesised, and arguably more needed, than in Paraguay, stevia's centre of origin. Rural poverty rates and land inequality in Paraguay are among the highest in Latin America. Many Paraguayans refer to stevia as Ka'a he'ê[65], because Guaraní – spoken by 90% of the population – remains a first language for many, especially outside of cities. The Paraguayans were the first to domesticate wild ka'a he'ê, establish commercial plots, and adopt it into their daily diets. Ka'a he'ê has become woven into the cultural fabric and aspirations of Paraguay.

The next two chapters continue the ethnographic journey charting the transformations of stevia that began 50 years ago as the plant was uprooted from Pai Tavyterâ territory and entered capitalist circulation. In juxtaposition to the 'worlds' where stevia is perceived as a bioeconomy commodity, or related to as a spiritual family member, this chapter follows the spaces, places and people whose worlds gravitate around ka'a he'ê as a Paraguayan cash crop.

First, I unearth the roots of a promissory narrative that sprouted with the domestication of stevia as a cash crop for campesinos and rural development in Paraguay. Then – told through the stories of campesinos, traders and businesspeople that I encountered travelling across Paraguay, as well as interviews with government officials and trade associations – I explore how the promissory narrative has been reproduced and plays out on the ground through the meanings, livelihoods and benefits derived from ka'a he'ê. The stories in this chapter expose the stakes riding on what I discover is a long-time 'promise-in-the-making' that – despite diverse struggles – continues to direct individual, collective and national aspirations.

The multiple meanings, livelihoods and stakes riding on stevia as a 'campesino cash crop' feed further frictious dynamism into the four bridging zones of dis/connect that emerged in the previous two chapters over authenticity, ownership, sustainability, and justice. This 'world' in particular challenges biosynthetic stevia's claims of sustainability and authenticity. These challenges are further confounded by struggles over ownership and justice in the subsequent

[65] I use stevia and ka'a he'ê interchangeably depending on which word is preferred by the respondent or setting in which it is understood. I use stevia if I am referring to the plant in a general sense as this is how it has largely come to be known outside of Paraguay.

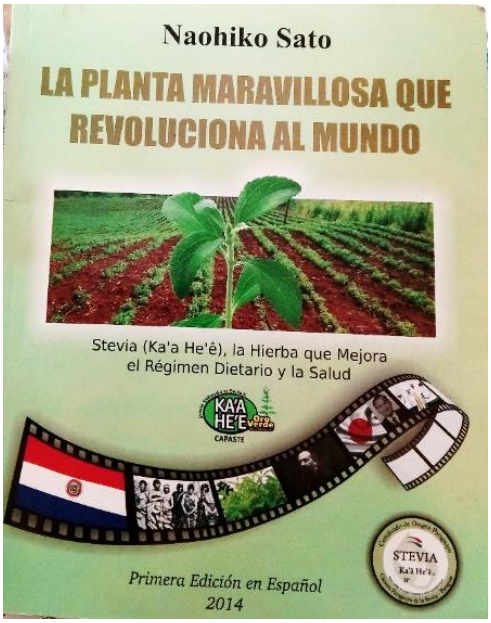
chapter that follow the next stage of stevia's commodification. This next stage sees stevia globalised and reconfigured as a cash molecule to rival the power of sugar as a 'high intensity sweetener'.

Promissory roots.

In Paraguay, the term 'campesino' refers to a smallholding farmer or peasant from the social working class. It is not as derogatory a term as peasant implies in some cultural interpretations, and many campesinos in Paraguay hold much pride in their identity as independent rural pioneers (FAO 2018). The first 'campesino colonia' I visit is like many 'colonias' or settlements in Eastern Paraguay, the result of widespread agrarian reform during the 1960s and 70s under the military dictatorship of Alfredo Stroessner who, reacting against the tide of Marxism and peasant revolt sweeping Latin America, implemented the *Programa Alianza para Progreso* to encourage rural 'colonisation' into the dense forests and enclaves of Indigenous Peoples. The establishment of private property was an important symbol of rural modernisation and thousands of campesinos were allocated minifundios (smallholdings) of up to 20 hectares along newly constructed rural roads (Villagra & Acero 2017). These roads connected colonias through a government-directed programme of export-oriented cotton production (Hetherington 2013). Like corn 'pioneers' in the American Midwest, the campesino frontier in Paraguay was shaped by cotton, yet production has steadily declined since the 1980s (Hetherington 2013). The primacy of cotton as a 'rentier crop' relied on farmers purchasing external inputs and had the effect not only of taking up more land for cash crop production than for family subsistence, it also created greater dependence on the external market for food and survival (Villagra & Acero 2017). Following cotton, the government promoted other cash crops for campesinos, including tobacco and sesame, however these cash crops have largely not proven economically or environmentally sustainable to campesino livelihoods, and since Stroessner's first push at land reform, campesino colonias have been in rapid decline (Baer & Birch 1984; Lopez 2017).

Paraguay is the least urbanised country in South America. Around a third of Paraguay's population live below the poverty line and the majority of the poor live in rural areas where poverty is twice as high as in cities (IFAD 2020; World Bank 2017). Two thirds of the rural poor – disproportionately women and indigenous peoples – are considered to live in 'extreme poverty' reliant solely upon subsistence agriculture (IFAD 2020). Paradoxically Paraguay has experienced rapid economic growth over the last decade averaging a rate of 4.8% GDP, faster than its regional neighbours, due largely to agricultural exports, most notably soybeans (World Bank 2017). Ironically the wealthiest and poorest in Paraguay rely on agriculture.

This has created what has been described as a 'two-tier model of agriculture' between large-scale industrial or capitalised agriculture and smallholder or campesino agriculture. The conservative Colorado Party which has largely held power in Paraguay since emerging from dictatorship has incentivised large-scale industrial farming with tax exemptions, access to credit, and low environmental and labour regulations, yet has not offered the same incentives and support to small farms and farming families (Oxfam 2014). Between 1991 and 2008, Paraguay's Agricultural Census showed the number of farms of less than 100 hectares declined, while plantations up to 500 hectares rose by 35%, and farms over 500 hectares increased 57% (López 2017). Today Paraguay's land distribution is the most unequal in Latin



America and is considered one of the main factors perpetuating rural poverty, with 90% of the land belonging to just 5% of landowners (OHRCR 2016; Oxfam 2020).

At the heart of struggles over land is what can be produced from it. Long before the green leaves of soybeans began to carpet rural Paraguay, Moises Bertoni's 'prophesy' of stevia as the original 'oro verde' (green gold) cash crop, has formed a part of a promissory national imaginary of the perfect campesino cash crop.

Figure 5.2 *'The marvellous plant that revolutionizes the world'* (translated from Spanish). Source: author's photo of a report presented by one of the farmers interviewed. Image depicts timeline of significant people from ka'a he'ê history.

Ka'a he'ê becomes a cash crop.

Driving just a few hours west from Pai Tavyterâ territory in Amambay along Ruta 5 into the province of Concepción, we pull over in front of a concrete farmhouse not far from the town of Horqueta, a region home to the highest concentration of campesinos in the country.

I will refer to this family as the Horqueta Family to preserve their anonymity. The Horqueta family home is dilapidated, and while clearly a far from wealthy household, the family appear on their roadside veranda and greet us with great generosity, offering shelter from the sporadic hot humid downpours and customary refreshments of Yerba mate tereré and chipa (corn bread). They have been waiting for us. With eagerness rivalling that of the Itaguazú shaman, the 70-something-year-old head of the Horqueta family – renowned in the area for committing over 50 years to cultivating ka'a he'ê – barely allows us to sit before he starts relaying his story of stevia in a mix of Spanish and Guaraní. He doesn't ask any questions about who I am or why I'm interested in Ka'a he'ê[66], despite his tired body, his eyes are wide and intent, his speech passionately rapid. My translator has to ask him to pause repeatedly, to ensure I'm following what could be described as a legend of ka'a he'ê.[67] Between my translator's explanations in English, and the transcript from the recording, I retell his story.

> The discovery and study of ka'a he'ê by foreigners is much older than Bertoni, in fact Bertoni himself first encountered tales of ka'a he'ê in the early Jesuit missionary manuscripts. These stories recounted the first Spanish conquistadors that arrived from Buenos Aires up the Paraná and Paraguay rivers, where they encountered the Guaraní Peoples who received them and showed them great kindness and hospitality. It didn't take the Spanish long to notice that the Guaraní Peoples were all using utensils of gold and silver, yet there was no gold or silver to be found in the area. Eventually the Guaraní revealed the 'exchange relation

[66] In a phone call to arrange my visit, I had explained to the man that I am a social science researcher from the UK looking at stevia cultivation in Paraguay. After he stopped for breath, he also received a research information and consent form.
[67] I have not corroborated the respondent's story with different historical records.

they had with another Kingdom'. The kingdom, the Guaraní told the conquistadors, was located towards the sunset following 'El Ruta del Sol' (road of the sun) it is the tropic parallel 38 and this direction goes on to connect Peru to California 'between two flowing rivers'. This was the Guaraní's 'exchange route', but what did they take to exchange? They were taking something that was then not called ka'a he'ê, they took 'Ka´ao toryra, una hierba para alegría' (a herb for happiness). The herb was important at parties and festivals, and encounters between chiefs along this 'exchange route'. It sweetened drinks and alcohol in particular, as it was thought to relieve the toxic effects of inebriation. Ka'a he'ê was thought of as an herb to soften and soothe, in contrast to the ka´avopo syra (Coca leaves) also traded along this route as an herb to enrage and to fight. Coca and ka'a he'ê, alongside gold and silver were among the valuable natural compounds that drew the first 40 conquistadors led by Juan de Ayolas along the Ruta del Sol. However, in order to keep this important route secret the Guaraní followed and murdered the conquistadors upon their return through the Chaco. Their murder was documented in historical manuscripts but the Guaraní's motive remains a legend. [68]

The old campesino, stops for a slurp on the tereré. During his tale, two 30-something-year-old men had pulled up faded plastic Coca-Cola seats, they sat serious and silent alongside us on the veranda. 'Now, I tell you the second part of the story' he eyeballs me. He fast-forwards 430 years and begins his story about the first domestication of wild ka'a he'ê by a Paraguayan entrepreneur by name of Señor Luis Enrique de Gásperi. The name 'de Gásperi' makes my ears prick, I had heard this name mentioned as an important figure in the history of Paraguayan stevia.

In 1963, the old man recalls, Luis Enrique de Gásperi received a letter from his brother living in California that research was emerging on possible carcinogenic effects of artificial sweeteners, and that a substitute was needed, a natural substitute, he wrote, that could be ka'a he'ê. De Gásperi, a Paraguayan graduate, businessman and entrepreneur quickly gathered an expedition to Amambay to seek out ka'a he'ê growing in its endemic wild grasslands between patches of forest in the higher altitudes surrounding Cerro Kuatia and the River Taracá, not far from Jasuka Venda, the sacred mountain of the Pai Tavyterâ. From there Gásperi began taking wild plants and domesticating and reproducing them on his coffee plantation he owned in Horqueta.

'We were there from the start' the old man exclaims, some family members worked alongside De Gásperi. Later the Horqueta family established a separate family stevia business. Only upon later research in Paraguayan newspapers, do I realise that this old man, is one of the infamous four Horqueta brothers who were responsible for Paraguay's first ka'a he'ê nurseries and productive plots since the 1960s, and who have invested their life's work into establishing ka'a he'ê as a cash crop for campesinos (ABC colour, 2003).

The old man continues his story. With ka'a he'ê domesticated, De Gásperi began seeking markets and clients for his new business, the first of these, he says were 'the Japanese', who were interested in researching the viability of ka'a he'ê as an alternative to artificial sweeteners. 'The Japanese' he explained, took samples from De Gásperi's farm and with permission from the Paraguayan government, went on further expeditions into Amambay and San Pedro seeking

[68] Personal communications (ref. 31). Horqueta, Concepción, Paraguay. 26/09/18

wild plants.[69] Japanese researchers are reported to have uprooted and transplanted 20,000 wild plants from the land surrounding Cerro Kuatia to the first commercial test plot in Paraguay, before seeds and cuttings were reproduced and new plantations were established (Sugii 1977 in Soejarto 2002). The first export of live samples from Paraguay to Japan were reported between 1967-69, and the first large-scale harvest was shipped to Japan in 1974 (Soejarto 2002).

By the late 1970s the Horqueta family, among others, had set up a small company to cultivate and sell dried leaf and liquid stevia extract in Paraguay and beyond. Farming families and small businesses in Paraguay worked together to establish a producers co-operative to collectively support production and promotion of Ka'a he'ê, which later became the Paraguayan Chamber of Stevia known as CAPASTE (Cámara Paraguaya de la Stevia),[70] an organisation still active today. Paraguayan production steadily expanded with the first mass export of dried leaf to Japan in 1977. The initial goal was to reach 10,000 hectares of stevia, so that Paraguay would be exporting around 20,000 tons of leaves with an annual revenue of US$50 million (Kinghorn 2002). By the mid-1980s, over a decade of scientific research on stevia consumption in Japan concluded that crystalized stevioside sweeteners were safe for human consumption with no side effects. The early 1990s saw stevia's popularity expand globally (Bonvie et al. 1997).

The old man reminisces over the excitement of forming producer cooperatives and broadening export horizons in Japan, the US and Europe, then he stops and sighs, 'but it doesn't work' not only does the domestic demand not grow, but 'those octopuses' he spits, 'Monsanto - they get what they want'.[71] Monsanto at the time was the leading US chemical company producing 'NutraSweet' an aspartame artificial sweetener.[72] By 1991 stevia was totally banned in the US. Monsanto allegedly lobbied the US Food & Drug Administration (FDA) for stevia to undergo the same long period of safety tests that aspartame underwent to gain its GRAS (generally recognised as safe) certificate (Jones 2006; Bonvie et al. 1997). The FDA, not willing to consider non-US based research, concluded there was inadequate toxicological information on stevia to demonstrate its safety (Jones 2006). At the time, stevia was a plant representing the interests of a patchwork of small businesses and farmers globally. Unlike the chemical sweeteners which could be owned through patents enabling profits to channel back to the company, stevia was not yet a plant captured by a single dominant financial interest or corporate actor, and so funds to pay for US-based toxicological testing did not exist. The US stevia ban was controversial among the American herbal association, Lipton tea and other users of the plant who petitioned the FDA, fuelling speculation about why stevia was being 'suppressed by the FDA' (Bonvie et al. 1997:4).[73] It took another 23 years before the FDA issued a 'no objection' approval for GRAS status to a highly refined stevioside used in Cargill, Coca-Cola, and PepsiCo products in 2008. However, unrefined 'stevia leaves or crude extracts obtained from stevia leaves' curiously remain 'considered unsafe food additives' in 2020 (FDA 2020).

[69] Personal communications (ref. 31). Horqueta, Concepción, Paraguay. 26/09/18

[70] CAPASTE remains an integral and active reproducer of the cash crop promise, organizing 9 International Stevia Symposiums in Paraguay over 10 years, the last one, however was held in 2016, and there have been no more since.

[71] Personal communications (ref. 31). Horqueta, Concepción, Paraguay. 26/09/18

[72] Ironically during 2018 a synthetic biology company called ManusBio acquired the NutraSweet company and its US manufacturing facility from Monsanto and began transforming it to manufacture biosynthetic stevia – I elaborate on recent developments in the conclusion.

[73] The ban bolstered an ongoing distrust of the FDA by the US public that arose since publications such as James Turner's *The Chemical Feast* which exposed powerful food lobbyists and showed that the FDA pursued 'minor transgressors while failing to tackle the giant corporate frauds' (Turner 1976).

The old man was certainly convinced over the allegations about the role chemical sweetener companies and the sugar industry played in slowing stevia's ability to compete as an alternative sweetener. One of his sons emerged from the farmhouse carrying a foot thick pile of paperwork which he dumped on a plastic chair, before he and his father began siffling through it. Pulling out glossy flyers, newspaper articles, brochures and conference proceedings all recalling the benefits and successes of stevia (one of which I photographed in figure 5.2), until… 'Aha the law!' the old man exclaims, pulling out what he had been looking for. The opening paragraph of the dog-eared document read (I translate);

> The Congress of the Paraguayan nation sanction into force this law. That declares a national interest in the agricultural development of the cultivation of ka'a he'ê (Yerba dulce or *Stevia rebaudiana* Bertoni) and empowers the executive to dictate rules for its promotion, conservation, renewal and national exploitation (Paraguayan Congress 1970. copy of original document in annex 10.2).

He explains this legislation passed through the Paraguayan congress on May 8th 1970, yet never received approval by the executive and so was never transposed into law. The old man vigorously thumbs through the documents, pointing to the 12 articles of the legislation, reading aloud the second and third articles that state any person making capital investments 'for the cultivation, conservation and exploitation of Ka'a He'ê (Yerba dulce) will enjoy the following releases: of customs duties; of change surcharge; of the previous deposit: and from sales tax'. Article 9 states; 'the Executive power will promote a credit plan to the country's producers, long-term and low interest, and will transmit the financing of a national exportable production program'. Article 7 prohibits both 'the destruction of Ka´a He´e (Yerba Dulce)' and 'the export of seeds and plants of said species' (Paraguayan Congress 1970).

I can see why the Horqueta family are visibly exasperated over the failure of this legislation to pass in 1970, it marks a pivotal and decisive moment in Paraguay's agricultural and ecological trajectory. Had it been transposed into law, stevia cultivation would have received the same tax-free status granted to soybean agriculture, and possibly set in motion a very different rural trajectory to that of industrial soy. Since then, Paraguay has witnessed an exponential rise in soy monoculture steadily deforesting and replacing the once mega-diverse Atlantic Forest and wreaking socio-ecological destruction to wild ka'a he'ê habitat and Pai Tavyterâ territories (Richards 2011). The existence of this draft law, as the Horqueta family point out, demonstrates that Paraguay has for some time recognized Ka'a he'ê a matter of national genetic sovereignty and something worth protecting and promoting. The reasons why the Executive did not enact the 1970 law remain unclear, it is clear however that had it been enforced a greater proportion of wealth and other benefits generated from the plant would have had a chance of remaining with the people who first knew it and grew it.

Cultivating the promise.

Despite the failed support by the Paraguayan government in the 1970s, competitive Chinese cultivation beginning in the 1980s and set-backs of import bans in the 1990s, the promise of stevia has surged throughout the 2000s. Between 2004 and 2017 various government and development agencies, agronomists, businesses and NGOs around the world promoted the benefits of cultivating stevia for small farmers in Paraguay (USAID 2004; Bamber & Fernandez, 2012; World Bank, 2014; Fundación Granular, 2016; Oxfam 2017). The 21st century promissory narrative of stevia now

includes the added dimension of environmental sustainability and reproduces discourses about rural development, sustainable livelihoods and combating poverty, perhaps most overtly reflected in Pure Circle's 'This Leaf' video transcribed in the opening of this chapter (Pure Circle 2015 & 2016). During my time in Paraguay, it was clear to see how the promise of stevia continued to incentivise farmers, campesino organisations and small businesses to invest time, energy and resources in cultivating a livelihood around stevia. In the following discussion, I group the multiple claims of stevia's benefits into 10 key promises reproduced about stevia for sustainable development and small-scale farming in Paraguay which I found in literature but also heard across the testimonies of Paraguayan farmers and businesses people.

1. Paraguayan stevia is in high demand.

Since the 1970s demand for stevia has steadily increased. After 2008 however, when the US, the UN joint WHO/FAO committee on food safety in 2010 and the European Union in 2011 officially recognised steviol glycosides as safe for human consumption, global demand began to skyrocket (BBC 2013). News headlines appeared in Paraguay stating that the world demanded Paraguayan stevia (ABC 2015). Authenticity narratives emerged around Paraguayan stevia as farmers were promised a competitive advantage in 'the birthplace of stevia' (Bamber & Fernandez 2012).

2. Stevia offers the highest income for small farms.

Central to the stevia promise is that the plant provides the highest income per hectare compared to other viable smallholder crops in Paraguay (Granular 2016; El País 2016)[74]. One hectare of stevia in Paraguay can produce up to 4,000 kilos of leaf per year, fetching between G$8 – 10,000 guaranís per kilo ($1.2 – 1.5 USD). One hectare can therefore generate an average income of about $5,000 USD a year, while stevia which can be certified organic or fair trade can fetch an even higher price G$13,000 guaranís per kilo (Fundación Granular 2016; Oxfam 2017; Giménez & Lehner 2017). Once harvested, stevia is dried in the sun giving it a longer shelf life, a significant factor enabling farmers' flexibility in obtaining the best prices (Bamber & Fernandez 2012).

3. Stevia provides socioeconomic benefits for farming families.

The typical plot set aside for stevia that is manageable for a campesino family in Paraguay ranges from one quarter of a hectare to two hectares. For this reason, stevia is said to be well suited to campesino families who can profit even from small parcels of land. Just one quarter of a hectare of stevia is said to provide a significant financial contribution to a campesino family. Harvested 3-4 times per year, stevia generates income at regular intervals, as opposed to one lump sum annually, making family finances such as schooling, transport and hospital fees easier to manage and reducing the risk of falling into debt (Fundación Granular 2016). Bamber & Fernandez (2012:14) assert that 'Increased family income [from stevia] has extended education for children'. Other socio-economic benefits include the usefulness of the plant itself within typically diverse farming systems of campesinos where the stem can be used to enrich the food of animals as well as to fertilize the soil and the leaf can be sold locally as well as exported.

[74] This information was also corroborated across all the interviews I carried out with farmers and businesspeople in Paraguay during September and October 2018.

4. Stevia requires relatively low inputs and investments.

Stevia does not necessarily require expensive agrochemical inputs or externally purchased seed. Initial investment to establish stevia cultivation is said to be a relatively minor investment compared to other crops. To establish half a hectare with an irrigation system, an investment of around G$13 million is required. Half a hectare produces at the lowest G$13.5 million per year, meaning that within one year the whole investment can be earnt back. However, repaying the full amount requires a few years, as the income is spread across family expenditures. This means that small farmers require fair access to credit in order to invest in an irrigated plot.

5. Paraguay has superior climate and ecological conditions for stevia.

It is widely reported that Paraguayan stevia is among the sweetest, best quality and most productive in the world due to the richness of its soil, supportive climate and ideal ecological conditions (Pure Circle in *El País,* 2016; ADN 2016). In Paraguay a plantation can last up to 5 years with 3- 4 annual harvests before new seedlings must be replanted, unlike other parts of the world such as China where stevia plantations only produce one harvest per year and must be replanted annually.

6. Stevia farming is environmentally sustainable.

Smallholder stevia farming in Paraguay is said to 'complement 'climate smart farming' to reduce negative impact of agricultural activities on the local biodiversity, help preserve water resources, practice forest conservation and restore degraded soils' (Fundación Granular 2016). Compared to sugar production, stevia requires four times less land area and less water resources, and has far lower carbon emissions (Fundación Granular 2016). In some regions of Paraguay, such as its centre of origin in Amambay, stevia can be rain fed and does not require irrigation, however with climate change, irrigation is said to offer farmers more resilience. Stevia grown by conventional plant breeding methods such as cross-pollination and other non-genetically modified processes does not necessitate use of agrochemicals, especially when aligned with agricultural techniques such as rotation and farm-produced fertilizers and can be grown organically (Oxfam 2017a).

7. Stevia increases rural employment and decreases rural-urban migration.

Stevia cultivation is non-mechanised and is labour intensive; one hectare typically provides 5 workplaces. Rural unemployment is high and labour is in demand in Paraguay. Bamber & Fernandez (2012) assert that 'encouraging children to view the cultivation of stevia as an important opportunity' is 'helping to alleviate migration out of rural areas to urban zones' (p. 19). Stevia has been widely promoted as a crop which helps farming families stay on their land (Pure Circle 2015). Community stevia nurseries and seedling 'collection centres have become important hubs for employment in different parts of [Paraguay]' (Bamber & Fernandez 2012:19)

8. Stevia 'empowers' small farmers.

Once established, stevia farmers can reproduce their own stevia plantlets after one year. This is said to enable farmers to gain 'self-sufficiency' and 'a self-sustained income' accredited with 'empowering disadvantaged smallholder farmers and their families, integrating them into the rural economy' (Fundación Granular 2016:16; Pure Circle 2015 & 2016;

Coca-Cola 2016; USAID 2004). One particular project by Oxfam (2017) set out with the objective to specifically 'empower women' through cultivating ka'a he'ê. Organised growing co-operatives have been associated with increase community cohesion and support networks, enabling communities to make joint investments in local infrastructure (Oxfam 2017). The idea of shared capacity-building in agricultural knowledge has been described as contributing to the social assets of communities (Oxfam 2017). Other NGO projects assert that 'stevia provides the farmers with a sound cash crop, a dignified occupation and a sustainable source of income' (Fundación Granular 2016: 4).

9. Ka'a he'ê leads the fight against poverty.

USAID (2004) was one of the first to describe stevia as 'a tool for poverty reduction' in Paraguay. Since then, many public, private, and NGO development projects have pumped thousands of dollars into stevia projects in Paraguay. In 2012 the Interamerican Development Bank funded Duke University (US) researchers to improve 'the volume and quality of stevia production in Paraguay to expand supply, upgrading into the higher extraction stage of its value chain, and ultimately raise small producers' incomes' as part of a drive across Latin America to link 'small producers with high-value agricultural markets' (Bamber & Fernandez 2012: 2). In a separate project the World Bank co-funded a project alongside the Paraguayan government promoting stevia to 'sustainably reduce extreme poverty' (World Bank 2015; ADN, 2016). Oxfam's stevia project not only aimed to empower women, but also to achieve sustainable livelihoods and build resilience to poverty (Oxfam 2017). This promise of poverty alleviation has been disseminated perhaps most widely by the world's largest stevia leaf company, Pure Circle (2015a; 2016b).

Figure 5.3 Oro Verde del Paraguay (Green Gold of Paraguay) logo and moto (Source: FAO 2016).

10. Stevia will save the country!

Despite the Paraguayan government failing to enact the 1970 law declaring a national interest in ka'a he'ê, the Paraguayan Chamber of Stevia-Ka'a he'ê (CAPASTE) has kept the goals of the agenda alive. The organisation has been instrumental in pushing the idea that Ka'a he'ê is both a matter of national pride for Paraguay as a symbol of 'national genetic heritage' and as 'oro verde' or 'green gold' of Paraguay, symbolising the long-prophesised fortune from ka'a he'ê, a promise reproduced in Paraguayan mainstream media (El País 2016; ADN 2016; ABC news 2003). The nationalist, egalitarian sentiment that stevia is beneficial for all, underlines the Paraguayan Chamber of Stevia's stated aim: 'we seek that ka'a he'ê be the flag for the fight against poverty, as well as the pride of the present and future Governments of our country, regardless of the parties or the colours, most important is that society and peasants live in the same conditions economically, educationally and especially in health' (President of CAPASTE quoted in ADN News 2016). 'Stevia will save the country' was a statement made by a business-owner in Asunción in 2018 in the context of

the national importance of 'a family crop that can be grown alongside crops that also feed the family'[75]. The promises, imaginaries and expectations circulating around a sustainable and truly Paraguayan cash crop are leading to ambitious targets, with a plan to overtake China by 2030 with production exceeding 100,000 tons and over 50,000 hectares under cultivation, under CAPASTE's ultimate goal; 'We want our country to be the largest producer of ka'a he'ê in the world' (ADN 2016; El País 2016).

Figure 5.4 Poster for the 8th International Symposium for Ka'a he'ê Stevia hosted by CAPASTE in Paraguay. Note the accompanying narrative translates from Spanish as: '*Ancestral Past, Natural Present, Healthy Future. For a more green and responsible economy'* (Source: CAPASTE 2016).

The 10 key elements listed here make up what I call the 'campesino cash crop' promissory narrative of stevia / ka'a he'ê in Paraguay. This narrative emphasises the environmental sustainability of cultivating stevia as a crop that can be grown organically or requires few external inputs. The most notable element of the cash crop sustainability narrative is that it is rooted in the social and economic dynamics of production promising increased wellbeing, education, development and poverty reduction, a crop *for* small farmers. The amplification of the socioeconomic dimensions in the cash crop promissory narrative stands in stark contrast to Cargill and other biosynthesis companies who amplify the superiority of biosynthesis in reductionist calculations on carbon emissions and water use with no reference to the models of social- or agro-ecosystems it supports. I come back to the emergence of this zone of dis/connect in concluding this chapter. While the promises of ka'a he'ê have become well-known as part of an (agri)cultural imaginary in Paraguay, the way they play out on the ground are complex and entangled with both local and global political economic and rural struggle.

[75] Personal communication (ref. 42). Asunción, Paraguay. Paraguay 9/10/18

Ka’a he’ê Campesinos.

Following stevia across Paraguay led me to encounter livelihoods formed around stevia stemming from two different agricultural models: there were those that grew and traded ka’a he’ê independently cultivating publicly available varieties and employing organic methods, and those that grew a proprietary variety of stevia under a contract model for a global company. This chapter focuses on the former, and it is to those families I now turn.

The Horqueta family.

The Horqueta family are among the few families in Paraguay who have remained committed to the promise of stevia since the 1960s, despite significant ups and downs. The stern 30-something-year-old men who had silently joined us on the veranda are two of the old campesinos’ 11 children. Though the sons no longer live in the family home, they still work the 20-hectare land, a situation typical of their generation of Paraguayans born in the 1980s neoliberal era of land concentration and population growth where acquiring land has become unaffordable for many young campesino families. The brothers don’t need asking, they lead me across the farm explaining their families’ livelihoods, eagerly educating me on Ka’a he’ê cultivation. As we trudge over the earth and past the chickens and pig, the brothers come alive with their passion for plants. Of the 20 hectares owned by the family, one hectare is currently dedicated to ka’a he’ê. It is the first time I have ever seen a field full of ka’a he’ê! I have arrived in flowering season, row upon row of small green bushy plants are decorated in delicate white star-shaped flowers, one brother hands me some seeds and then uproots and proudly presents me with a bouquet of stevia flowers! Immediately I pop a leaf into my mouth. Even though flowering season is the time when the leaves are at their least potent, it is incredibly sweet followed by a mildly bitter medicinal taste that some compare to liquorice. I naïvely put a stalk of ka’a he’ê in my diary to make a flower pressing. I receive a wary glance and it suddenly dawns on me how the stealing of seeds and genetic information has been a controversial issue in the development of commercial ka’a he’ê. I quickly reassure the brothers of my strictly ethnographic intentions, flicking through montages of other cuttings and stickings in my diary.

The brothers start to explain their practices of ka’a he’ê cultivation, constantly referring to their practices within the context of the wider campesino colony, and what other campesino families have done, do now or could do in the future. For this family at least, ka’a he’ê cultivation is seen as a community undertaking not simply an individual enterprise. The younger brother explains ka’a he’ê is labour intensive so is well suited to community farming, where work is needed and labour is in good supply. Depending on the size of their land, a typical family would put around 1 hectare of land to grow a cash crop like ka’a he’ê because the rest of the land has to feed the family and the animals if they have any. One hectare of ka’a he’ê ‘can generate 5 workplaces’ the older brother exclaims, ‘imagine how many you could multiply for 100 hectares!’. The brothers explain that ‘after the first harvest you get 400 kilos of dried leaf per hectare, and then if you cultivate for one year you can harvest 3000 kilos of dried leaf’. You see, he explains, ‘during the first harvest you cut the plant here’, he says pointing to a stalk, ‘then it multiples like mint!’.[76]

[76] Personal communications (ref. 31). Horqueta, Concepción, Paraguay. 26/09/18

In this region, the older brother went on, we have perfect growing conditions, 'you plant it once, and it lasts for 5 years', most crucially it can be harvested 3 to 4 times per year, rather than just one harvest season like many crops, this means that 'families have income' multiple times per year. He went on, 'it's a very good product […] because people can remain in their communities, in their family, and get some economic benefits to be able to send kids to school and to university in order to improve their lives'. 'And you don't need to buy seeds each time?', I ask. 'We grow La Criolla,' the brothers assert proudly. La Criolla is the variety acknowledged as endemic to Paraguay, bred from the original wild plants taken from Amambay in the 1960s: 'We are not buying seed because there are no companies selling Criolla seeds because all the companies are interested only in the sweetness'. The family have bred their own seeds for 50 years, but other farmers only need to buy their seed or plantlet just once, 'then they can reproduce, it's not complicated, but you have to know at the beginning if you're not used to this plant as you would not know how to manage, how to collect the seeds, but then it's not so hard.'[77]

The brothers proudly show us their new investment, an irrigation system, lines of black plastic pipes perforated with holes weave up and down the green rows of plants. Next, we visit the nursery where ka'a he'ê is reproduced by either a 60-day seed germination or by replanting cuttings, replicating a genetic copy of the mother plant. As we walk towards the family's allotment, the older brother pulls out a small bottle of brown liquid from his pocket, dabbing some on my finger, he explains proudly 'this is miel de ka'a he'ê' which translates as ka'a he'ê honey - a refined extract of ka'a he'ê. One tiny drop bursts my whole mouth with miraculous sweetness. It is one of the products the family sell, made by soaking leaves, then boiling, and re-boiling depending on the density required. The little bottle I'm given is only 5% density, but the family sells extracts of 60% density, allowing people to make their own brown sugar-like ka'a he'ê crystals at home in an oven, or drop into foods and drinks.

The over-50-year history of cultivation in the Horqueta region has meant ka'a he'ê been widely consumed with local people developing diverse uses for the plant beyond a simple sweetener. The brothers enthusiastically explain some uses by people in their community including putting it in children's milk before they go to school as an appetite suppressant. Families who have dental issues use it to replace sugar because it doesn't cause tooth pain or decay. Families feed stalks to their animals, while chickens fed on ka'a he'ê, they exclaim, produce cholesterol free eggs, citing Japanese research in the book photographed in Figure 5.2. Excitedly the younger brother pulls a ripe red pepper from a vine, 'you can put the extract into a spray or irrigation system' and it makes fruits like melons or peppers or tomatoes supersweet.[78]

[77] *Ibid.*
[78] Personal communications (ref. 31). Horqueta, Concepción, Paraguay. 26/09/18

Figure 5.5 The two most common publicly available varieties of ka'a he'ê in Paraguay. The native la Criolla (on the left) and Eirete (the right). The campesino pulled these out of the ground to show the differences between them. Source: *authors own photo.*

The Horqueta family remain one of the few families that continue to grow and sell ka'a he'ê locally. Beyond their community they sell to two Paraguayan businesses, one is a small dealer in Asunción paying G$12000 guaranís per kilo, and another is a small yerba mate tea company in Itapua who pays G$16000 guaranís. They explain that they have less options to sell because they only cultivate the Criolla variety, and buyers seek varieties bred to contain more of the sweeter steviosides, such as Eirete (pronounced ay-re-tay), a national variety grown in Paraguay. Despite this the family staunchly believe based on their years of experience working with 'la Criolla', that this variety remains the best for ka'a he'ê's most important uses as both a sweetener and a medicine. Moreover, they explain that la Criolla is better for the farmer, it has stronger roots, is more resilient, and is more fertile than Eirete and other varieties, enabling it to be grown from seed (see Figure 5.4).

Returning back to the farmhouse, we pull plastic chairs into a circle between the shade of two trees, and the family rejoin us. My horticultural education complete, they are intent on explaining the stakes. Without any prompting or need for my questions, they explained how vital ka'a he'ê is for the community. The elder farmer explains that the campesino colonia makes up 1000 hectares either side of the highway, and most crucially the land remains in the hands of small farming families. Regionally, the department of Concepción is home to the highest concentration of small family farms in all of Paraguay, a number that is reducing every year due to increasing land acquisition by wealthy soy growers and ranchers (Villagra & Areco 2018). Aware of this asset, the Horqueta family and their local community have made a collective decision not to allow transgenes or chemical agriculture in their colonia, as the elder farmer explains 'we are restarting [ka'a he'ê] again here in the north, because here is the only place in Paraguay that is not contaminated, the transgenes are not yet advancing our side of the Ypane river'. This collective decision, they enthuse, allows them to pursue a high-value organic cash crop that does not require expensive machines, chemicals and can absorb the high demand for labour. The family and their local community are staking their livelihoods on their ability to isolate themselves from agro-chemicals, which as I later observe is an increasing challenge for small farmers nation-wide.[79]

It really is the 'perfect cash crop' for this area both brothers agree. Their expressions change as they describe the darker stakes resting on ka'a he'ê's success, the only alternative crop that can generate a rival income for smallholder farmers, the older brother says, is marijuana. Many young campesinos seeking income have few options, either they migrate to the cities, or they find work on the marijuana plantations that run along the Brazilian border. These plantations are operated by what have been described as mafia-style cartels who have infiltrated local police and government (TNI 2016). The trouble is, the younger brother explains, while working there 'they also get involved in drug consumption and it destroys their families and communities'. Despite having one of the lowest consumption rates of marijuana,

[79] Personal communications (ref. 31). Horqueta, Concepción, Paraguay. 26/09/18.

Paraguay is South America's largest producer, with the estimated value of marijuana exports rivalling that of soy (TNI 2016). 'It's because small farmers have no other options', the younger brother adds.[80]

I was surprised. I expected to hear campesino problems associated with expanse of soy cultivation (Hird 2015; Hetherington 2020), but I didn't expect to hear that one of few options for young people to maintain rural livelihoods would be cultivating cannabis for criminal gangs. My local friend and translator corroborated the brothers' accounts, 'it is something Paraguayans and Indigenous Peoples don't talk about, but everyone knows'. The under-acknowledged problem is put starkly in a report published by the Transnational Institute in 2016;

> Contradictions in productive structures, the lack of agrarian policies, poverty and the absence of perspectives for the rural population led to a gradual, and progressively more blatant, adoption of cannabis cultivation by the young. Over time, growing cannabis became one of the few viable economic prospects for large sectors of the population (TNI, 2016).

Over the 50 years working with ka'a he'ê the Horqueta family described a cocktail of political and ecological success, challenge and disaster, yet despite the ups and downs they remain committed and confident about the promise of stevia. But they admitted this push was taking everything they had, and that this time it would be their last attempt.

The Diciembre Family.

We leave Concepción for the province of San Pedro. Driving at walking pace down a road of Paraguay's iconic red earth snaking like a vein through lush green countryside and what appears to be a flood plain, with lagoons and fields of bulrushes either side of the road. The occasional man on a motorcycle slaloms around huge potholes, overtaking us. It feels like our vehicle will never make it. We pass farm after farm, land is divided up into small plots, there are barely any amenities, it appears to be a place where it is difficult to eke out a living and clearly dependent upon subsistence agriculture. Despite this, everyone, even those most remote, know each other. After several pauses to ask for directions, we find the family home of the Diciembre family (not their real name).

The head and mother of the Diciembre family, Sofia[81] is 48 years old. She explains her responsibilities caring for her elderly parents, her husband who has a blood condition, and her youngest of five children, who has been bedbound for two months following an operation and who the mother insists I come inside the house to see. The teenager looks mortified as her mother tells me how intelligent she is and her worries about the girl's inability to attend school due to lack of money and transport. Other family members sit silently around the house including two tiny children toddling around shyly in worn-out clothing. As the first female head of the household I met, this family epitomises the dismal statistic that calculates 'for every 100 rural households living in extreme poverty [in Paraguay], 34 are headed by women' (IFAD 2015). The family speak only Guaraní.

We get back into the truck with both Sofia and her husband and drive a short distance to the 5-hectare land her family shares with 10 other families. We walk past subsistence crops including 'maize, peanuts, beans, mandioca (cassava), a lot of mandioca to feed the family, the chickens and the pigs' she explains, until we reach a scraggly looking one quarter

[80] Personal communications (ref. 31). Horqueta, Concepción, Paraguay. 26/09/18
[81] Not her real name.

of a hectare of what is left of the communities' ka'a he'ê boom. 'For 15 years we depended on Ka'a he'ê, that was our main income', there were 15 families in this community growing it, receiving G$1000 per kilo. 'They were the best years,' Sofia reminisced, 'every 2 months a big truck was coming to take 10000 kilos from families here, we were so happy!' She explains how it benefited the community:

> It was a completely different atmosphere in the community because everybody knew that they had this *esperanza* – 'hope', every two months there is money which means if someone needs something they will get it in credit, because they know they will have money in two months, and they can pay back. There was a lot of exchange and reciprocity and we were able to pay for labour to weed the ka'a he'ê so it created more jobs.[82]

She goes on, 'I'm proud because all my children studied thanks to ka'a he'ê, one finished university and one is working in Asunción'. Not far from the family house a painted sign on the side of a building symbolises the pride and promise of ka'a he'ê for the community, now faded and chipping away it read: *Comité de Productores de Mujeres de Ka'a he'ê* (Ka'a he'ê Women's Producers Committee). Before ka'a he'ê, she recalled, 15 years ago, with five small children, and a husband too unwell to work, 'I had to buy everything, the government was not even giving notebooks for school, it was really difficult, ka'a he'ê was such an important thing for us'. I ask about the sign, she said that was a long time ago, we got some government funding to buy a community freezer, some chairs, and materials for fixing roofs. I ask why the central role of women, she replied bluntly, that was the government's decision, that's just how the government works.[83]

We walk around the abandoned plot of green bushy ka'a he'ê in white flower, weeds disrupting the straight lines. The husband, quiet and seemingly weak with his blood condition, explains 'this is all we have left, no-one is buying at the moment, so we just leave it', he says his sons have collected seeds, and 'if someone is willing to buy we are ready to start again'. Interestingly the Ka'a he'ê, which was originally the Eirete variety, has its own evolutionary agenda. In the few years of being left untouched, the plant is reverting back to the characteristics of its wild relative. Sofia's husband quietly shows us two branches, whose leaf shape and size are completely different.

Why is no-one buying? I ask eventually. They shake their heads unsure, Sofia suggests there are two possible reasons. They were told that ka'a he'ê was been produced cheaper in other countries, but falling demand also coincided with an incident. Instead of weeding by hand, one community member had sprayed Monsanto's Round Up herbicide, which contaminated the entire harvest and was later detected in a lab after export to France. 'We don't use chemicals or fertilisers' she insists, 'and for the fungal infection, we just use ash'. Whatever the reason the demand disappeared, the family have since been struggling. Sofia explained she recently had to undergo an operation, now she said 'we just don't have enough money, it's very difficult, everything's tough'. She explains 'the reason why we are not growing tobacco or sesame or cotton here is because he cannot be exposed to chemicals because he is sick', gesturing to her husband, 'so that's why we keep the ka'a he'ê'. Others in her community also cling on to the hope of ka'a he'ê, she explains, setting aside plots waiting in hope to restart production.[84]

[82] Personal communication (ref. 38). Diciembre, San Pedro, Paraguay 30/09/18
[83] *Ibid.*
[84] Personal communication (ref. 38). Diciembre, San Pedro, Paraguay 30/09/18

On our way back to the family home the sombre air of struggle hangs over us all. Although I make it clear to Sofia I am merely a researcher learning about stevia's story in Paraguay, she clearly hopes I am something more. She approaches me, the main problem she says is we don't own our own land, and we don't have money to buy land. Her eyes light up, 'our neighbour is selling 1 hectare of land for 15-20 million guaraní' (approx. £2000), she asks if I want to support small farmers, 'the land costs nothing in terms of what we can produce selling ka'a he'ê'. She bargains if I could buy this land, the family would repay me, 'we have been working for 15 years with ka'a he'ê but we don't have nothing that is ours, if we finish now we will end up without anything.' I feel sad and awkward upon our farewell and leave the family a small donation towards their dream of regaining the stevia promise.

It was becoming increasingly clear that the promise of stevia in Paraguay is far from reached. Despite this, most small farmers I met clung to this promise with passion, symbolic in so many of my experiences, but especially in the small amount of land this particular family continued to sacrifice to this promise, despite the uncertain outlook and their need to make use out of what few assets they had.

Like many of the campesinos I met, Sofia held little regard for her government;

> I trust more foreign people than my own. The government in Paraguay is not supporting the poor families they are just benefiting their own friends and relatives. I have two options I can work hard and sweat, that's what I've been doing all my life, the only other option is that a foreigner comes and has a particular interest in ka'a he'ê.

Ka'a he'ê companies.

The hopes and frustrations I heard travelling through the countryside meeting farmers were echoed by those I met in Asunción operating small businesses from the capital. I was lucky enough to meet, interview and be shown around the operations of five of the less-than-a-dozen small businesses that connect small stevia growers, domestic production and international buyers. Amongst the operations, one small business uses leaf directly in their products to make teas; one focuses on exporting organic leaves to Sweden; another is a native and medicinal plant trader who presses and grinds dried leaf and stalk; another focuses on investigating medicines derived from Ka'a he'ê; and the fifth produces a range of branded products from stevia including organic fertilizer and medication. For all five businesspeople, ka'a he'ê was not merely a job or a commodity, it was a passion. This enthusiasm seemed to run in the veins of virtually everyone I met in Paraguay who had some form of working relation with ka'a he'ê.

With a national population of around 7 million, and 550,000 in the capital Asunción, the Paraguayan stevia business community is relatively small. All the businesspeople knew or knew of each other and each other's operations. All five businesspeople understood the intricacies and seasonality of ka'a he'ê cultivation in Paraguay. Three of them started as farmers themselves before moving to the city, three had ongoing agreements with farmers to buy their harvests, and one of them was part of a family-owned plantation and processing facility. All of them preferred the use of the native Criolla or Eirete seed, and most of them sourced from farmers using organic methods, although none of their farmers had yet obtained organic certification. They all knew aspects of the politics and history of stevia from the Pai Tavyterâ origins to De Gásperi and the Horqueta brothers. They all had similar struggles doing business in Paraguay, and had

opinions why China overtook Paraguay, as well as shared frustration over the failure of Paraguay's stevioside refining facilities. Like the farmers, the businesspeople shared a deep-seated belief in the promise of stevia. Similar stories were repeated and reiterated to me.

The Delcampo Family company.

'We have been selling ka'a he'ê for 40 years or so' said the native and medicinal plant trader, whose business card's company name describes stevia as 'the solution'. The family business, based in the Asunción sprawl, is one of the Horqueta family's main buyers. During two separate meetings with the trader and his 97-year-old father who founded the business, I meet the extended family and am shown around their warehouse. The warehouse marked another sensory imprint upon my journey of following stevia. In my diary I noted:

> Chaotic and poorly lit, sack upon sack of kilos of dried whole and milled stevia leaf and stalk are piled precariously high toward the corrugated iron roof, with barely room to move, 3 large pieces of antique-looking industrial sorting, milling and pressing machinery are thickly carpeted in green dust, and the air inside is thick and rich in aroma with dried plant leaf dust, you can literally taste the stevia.

Like many involved in stevia, the family were there from the start of the cash crop promise and have been involved with different aspects of the business. 'First my father planted a little and sold a little bit, right? We lived to the north, where the Ka'a he'ê is planted, harvested, towards Amambay' the trader explained. 'Then, we brought it here and sold it in little bags, about 30 years ago. And we settled here, we buy a molinito about 25 years ago, like that' he pointed to the industrial milling machine, 'and we grind it, we make powder of Ka'a he'ê'.[85] He explained that 40 years ago, very few people knew about it in Asunción, 'only the Indians used it', he said, but 'little by little people were getting to know the properties, which were for health, good for health.' Today, he went on, some people have 'become addicted to ka'a he'ê with mate, with your tea, whatever'. He explains his direct relationship with farmers, and acts not just as a buyer and trader, but an agricultural technician trading in seeds and plant seedlings as well as in agricultural knowledge. He explains the demand for what he calls 'responsible technical advice', which he contrasts to irresponsible advice in which farmers are sold the promise and 'then not supported to realise the benefits'. He has helped establish commercial plots of ka'a he'ê with campesinos across Paraguay as well as in Bolivia, teaching skills and methods in non-mechanised peasant farming systems.[86]

'We have posted seeds to almost everybody,' he boasts, '…Italy, USA, Mexico, Brazil', and he goes on 'I have sent to England, many times, a kilo or two of seed, I don't know what happens after that, I'm sure it is already planted there.' (The trader seems unaware of the international laws protecting seeds as sovereign genetic resources). International demand for milled leaf began increasing around the year 2000. He recalls exporting to Italy, but today most of what he sells is to the domestic market, though one of his international buyers – a Parisian superfood boutique – sell a 50 gram pot of ka'a he'ê *'from the land of origin'* for almost US$10 (184.00 € / kg) (Guayapi 2018). Though difficult to ascertain, the Parisian price tag is not reflected in the appearance of traders' operations, the aging machinery and sacks piled up

[85] Personal communication (ref. 43). Luque, Paraguay. 09/10/18
[86] Personal communication (ref. 27). Asunción, Paraguay. 21/09/18

do not give the impression the business is thriving. He is confident, however, that if buyers demand - as he clearly hopes I might be - his family and his farming contacts stand ready to supply.

The Itapua Family company.

'Stevia has so many uses, it's unbelievable, you've probably read a lot, and the lies on the internet, there are so many uses and we are trying many things!' exclaims the next businessperson I visit in Asunción enthusiastically in English.[87] The company's brand emphasises the naturalness of stevia and unlike most stevia businesses it focuses on products made from stevia *other* than its use as a sweetener. The man neatly arranges an array of products his family produces on the table in front of me. Professionally packaged and branded with images of green stevia leaves, and the red, white and blue flag of Paraguay, a range of organic fertiliser and fungicide and medicinal products, including an anti-acid, antioxidant and anti-parasitic – some tablets in foil pill packets and some in little white bottles. He tells me his family became interested in stevia during the 1970s and have been involved in various aspects of the stevia business since the 1990s. Following similar struggles the previous trader described with export bans and high specifications from foreign buyers, the family made a strategic decision around 2014 to develop the domestic market. However, they face an uphill struggle. 'We are trying to sell but we are going too slow', he explains. The family own an 8 hectare farm and processing factory in Itapua and employ around 20 people. Other local smallholders are contracted in ready and waiting to grow stevia too, but the demand for the products is not there, he tells me:

> The biggest problem is that stevia is not consumed yet the way it should be […]. The problem is we need to sell, if we don't sell we can't promise anything to them [the farmers]. When you need something to work it has to be like a wheel it has to go, and in Paraguay it does not, because you can plant and accumulate [leaf] but you cannot sell, the Paraguayan people do not consume enough so you cannot help the farmers. We are depending on the export and our variety is not good for export. […] They [buyers] are just thinking about sweetener.[88]

I ask what variety they plant? 'we prefer the natural grown from Paraguay because we care about the health and the agriculture', he went on, 'we started with Eirete, that's a good sweetener yes, but there was not any seeds' repeating the Horqueta family's assertion, 'you have to do the cutting which is hard work and high cost, and with time the varieties mix so get the variety 'F1' which is what we have and also the Criolla. So we are working with those two varieties.' He repeats what other stevia businesspeople had told me, that working with La Criolla is best for medicine, that varieties bred solely for sweetness reduce the medicinal potency of the plant, as one put it, 'each stevioside plays a role in the body'.[89]

'This', he shakes the packet of pills, 'we cannot export, cannot enter the US…here in Paraguay this product is approved as a natural medicine, […] but in Argentina they don't have, in Europe they don't have, in Peru they don't have'. He goes on:

[87] Personal communication (ref. 42). Asunción, Paraguay. Paraguay 9/10/18
[88] *Ibid.*
[89] *Ibid.*

> …If we change it to a *dietary supplement* we can export it but we have to change the product itself, so it is very difficult to introduce something new and we need a lot of money to invest to make it grow and we don't have a lot of money to do that. We know that the results are very good. We know diabetic people who have a black leg who recovered the colour and they start to feel again and many other secondary problems of diabetes they get better taking this in one year.[90]

On the family business's website, they describe what they call social and environmental responsibility, by 'working with the base of the pyramid (small producers)' and by pursuing organic certification, and their role as a company to raise 'Awareness about a culture of life. Awareness about the use of all the wisdom we inherit from our ancestors. Awareness that not only do we take care of nature but also that nature takes care of us.' (Translated from Spanish. Stevia Natural 2021).

The Hermana family company.

I meet another businessowner in a huge warehouse on the side of a chaotic Asunción dual carriageway. She is the first woman outside of an NGO I meet in Paraguay in a position of economic responsibility. She has a small family company with her sisters and two daughters making and exporting herbal teas, one of her best-selling blends is 'yerba dulce' (yerba mate with stevia). I enter the all-female office. Right by the entrance is a display cabinet, just like the one I saw at the Nebraska Corn Board, but instead of everything made from corn, it displays everything made from stevia. In centre place, I am surprised to see a large jar of Cargill's Truvia! Across all the Paraguayan supermarkets I scoured for stevia products, both Cargill's Truvia and Coca-Cola Life, at the time the world's best-selling stevia products, remained curiously elusive.

We get seated and I am offered a cup of the best-selling blend. I ask straightaway about Truvia and whether her business supplies any leaves to Cargill. It turns out her display is a general collection of products made with stevia. 'Cargill,' Ramona[91] says bluntly in fluent English, 'here they are big with soy and wheat, everything is GMO, genetically modified soybean' she spells out.[92] From this large warehouse she operates two businesses, her family-operated tea company, and a Swedish stevia firm for which she acts as the Paraguay director. The Swedish stevia company, whose focus is purely on the sweetener, source most of their stevia from China, but have been operating in Paraguay for several years to establish hundreds of organic-certified campesino family stevia farms. The businesswoman's eyes roll, 'it has not been easy…', our conversation follows:[93]

Ramona small farmers are spread around the country and they are very poor and you have to supply everything, we supply the technical assistance, the plantlets, we have to do all of it, so it's pretty expensive.

Molly But is it a good crop for the farmers?

[90] Personal communication (ref. 42). Asunción, Paraguay. Paraguay 9/10/18
[91] Not her real name.
[92] Personal communication (ref. 26). Asunción, Paraguay. 20/09/18
[93] *Ibid.*

Ramona yes, [farmers] work with their family and since they don't need to buy much, the company supplies the plantlets, they just need to plant them and contribute their labour'.

Molly It is labour-intensive?

Ramona 'It is labour-intensive, you need to prepare the soil, and plant, take care of it and take out the weeds […] When the farmers harvest their stevia they cut it with scissors not with machetes, that is because the plant regrows and lasts 4 to 5 years, so you cut and it grows again and again'.

(She hesitates) it depends on water of course, good rain when it is needed… it normally rains but you know our weather is becoming kind of crazy so we can't rely on the same patterns of rain. Sometimes we have two years of drought, and then we have a lot of rain when you don't need rain, so small farmers depend a lot on the weather, sometimes their crops get ruined by either drought or excessive rain so they are not prepared.

Despite the unreliability of a changing climate, she goes on to explain that families sign up to a contract which guarantees them a price of 10,000 guaraní (around $1.50 USD) per kilo of dried leaf, a price a little above the average at the time of writing. The only condition is farmers must exclusively sell the leaves back to the company, and gradually cover the costs of the plantlets over each harvest. For certified organic stevia the average price farmers receive almost doubles. However, the businesswoman complains 'the organic certification process costs a lot of money, and we have been spending a lot for 10 years now'. None of the farms are yet certified organic, she explains why;

> We know [farmers] don't have the money to buy chemicals, but sometimes the samples we send to the German lab which has the capability to detect 600 chemicals and it is very sensitive, some of our samples are rejected because the farmers are surrounded by something in the soil or somebody else's spraying and they get contaminated. In Europe and Germany they are very strict so that is the challenge we as companies face because if we buy and then we can't sell, then we are stuck with leaves here.[94]

The Asunción businesswoman's aspiration towards supporting organic ka'a he'ê reflected the majority of small farmers and small businesses I encountered, indeed most of them already produced organically, though remained uncertified. All highlighted similar problems with contamination in a countryside dominated by intensive farming, particularly heavily sprayed soybean. Like the trader and farming families I encountered before, she similarly spoke of soy agriculture 'sprays carrying in the air' and 'contaminating water-ways carrying the chemicals downstream', and that in order gain organic certification the plantation has to be 'well isolated'. Contaminated environments of soybeans were being amplified as both cause and consequence of the failure to fully grasp the promises of stevia in Paraguay.

The state and stakes (on stevia).

In the second half of this chapter, I turn to the ethnographic encounters which expose the stakes riding on stevia as a cash crop on the frontline of two very different agricultural models in Paraguay. Before I turn to the plant's

[94] Personal communication (ref. 26). Asunción, Paraguay. 20/09/18

contradictory treatment by the Paraguayan state, which faces accusations of corruption and prioritising interests of large-scale foreign-owned soy agriculture over small-scale domestic stevia farmers. The governments national declaration on stevia as sovereign 'genetic resource of economic interest' has arguably come 30 years too late, and frustration and a mounting sense of injustice is emerging over unfulfilled promises, exposing even deeper dis/connects.

Soy kills communities.

As early as 2004, one of the first development projects labelling stevia as a 'poverty reduction tool' described the spread of soybean monoculture in the Northeast as 'not compatible with stevia cultivation' underlining this as a cautionary factor in the project's success and stating 'stevia uses virtually no agrochemicals whereas there is an intensive use of agrochemicals in the cultivation of soybeans' (USAID, 2004:6). 'La soja mata' (soy kills) has become a popular slogan both graffiti-sprayed across the capital and adopted by campesino organisations in rural Paraguay (Hetherington 2013). Every small farmer and many small business owners spoke to me of problems associated with soy agriculture, and its impact on the potential of ka'a he'ê. Wider social and environmental consequences of GMO soybean monoculture on campesinos, Indigenous Peoples and biodiversity in Paraguay are well documented over the past 20 years (Guereña 2013; Hird 2015; Paulau et al. 2019,-Benítez-Leite et al. 2020).

As in Nebraska where it was impossible to engage with biosynthetic stevia without engaging with Industrial corn, the same was true in Paraguay following leaf stevia with industrial soy. Described as one of the few viable cash crops capable of securing campesino land and livelihoods on the front line of soybean expansion, the stakes are palpable. I encountered some of these when I attended a farmers' rally and rural social forum in the North of Paraguay held on the grounds of the University of Concepción. In one of the main events of the day, entitled 'Campesino and Indigenous Agriculture versus Agribusiness', a speaker addressed a packed audience in Guaraní.

> It is a dispute between two models, agribusiness model involving large scale monoculture and the other model of the campesino. We have 3.5 million hectares of soy, not wheat or maize or other grains, only soy. In the period between 2010 - 2014 soy plantations increased 700% in this department of Concepción, today only 21000 hectares are owned by campesinos, the rest is privately owned large-scale properties. It's not just about who owns the land, it's what they do in this piece of land, cultivating soy and using agrochemicals. Paraguay imported 45000 tonnes of agrochemicals this year, this is not only polluting the crops but it is also polluting the land. 13.9 million cows in Paraguay and in Concepción 1.2 million cows. These two models are not coexisting because they cannot coexist. We need to talk about deforestation because this model is increasing deforestation nationwide. When we meet like we do today, we share what we feel about this reality, it's important because we can recharge our batteries in order to resist this model, because this model is eliminating or erasing any kind of future for our children that's why we have to keep persisting.[95]

The next speaker contrasted her dismal picture describing 'strategic campesino agriculture' a holistic production model that would 'not replace job opportunities with more technology because the one thing we have is our labour'. Labour was an asset campesinos repeatedly referred to during the day's event and in many of my interviews. Compared to stevia cultivation which provides employment for 5 people per hectare, only one person is employed for every 500

[95] Foro Social Del Norte recordings of speeches (ref. 35) Universidad de Concepción, Paraguay. 28/09/18

hectares of soy (Bajekal, 2015). Another speaker agreed there was a need for small-scale simple technology 'I'm talking irrigation, shade from the sun, improving the quality of soil'. The discussion soon moved onto the need to 'start processing what we cultivate in order to increase the prices' and 'historically we've just produced raw materials and exported it but why are we not processing why are we not transforming it?' Others recognised the central role of the government 'to intervene in this aspect because obviously we are not going to be able to compete when we produce something in 10 or 20 hectares'.[96] These calls for small-scale appropriate technology chimed with the stories I'd been hearing from a variety of stevia farmers of the need for secure markets, basic infrastructure, fair access to credit, simple technology, processing capacity in Paraguay, and a crop that rewarded their agricultural knowledge and their labour.

A local official stood up asserting while 'soy is driving the whole agribusiness model […] we should not commit this mistake because our model is the combination of different kinds of crops, different kinds of produce and animals, that diversity is our strength.' The smartly dressed man beside me raises his hand; my translator whispers, 'he was a departmental governor during the Lugo government.' The man informs the audience that the current government under Mario Abdo Benítez (2018) have approved the rural infrastructure and development budget, 'but those programs are not focusing on strengthening small-scale agriculture, we have to force them to change and to include *agricultura familia* (family agriculture) otherwise the government policies will kill us, it is a plan to kill us'.[97] The current president, son of dictator Stroessner's private secretary, has maintained the Colorado party neoliberal position advancing policies in the interest of the *latifundios* (large-land owners).

The year I was in Paraguay soy production hit a record milestone of over 10 million tonnes becoming the world's 3rd largest exporter. In celebration the government declared it would double national production by 2028 (Bronstein & Desantis, 2018). Widely considered 'not compatible' and unable to 'co-exist', the State's commitment to large-scale soy is a significant factor impacting stevia's promise-in-the-making. Each year in Paraguay '9,000 rural families' are said to be 'evicted by soy production and nearly half a million hectares of land are turned into soy fields' (Environmental Justice Atlas, 2019). Today less than 13% of primeval forest remains in Paraguay. Stevia is thought to be among 600 medicinal plants used by rural and indigenous communities threatened with extinction (Le Temps 2013)

Ka'a he'ê killed my father.

I come back to another cautionary tale relayed to me by the most committed of ka'a he'ê campesinos. Just before I Ieft the Horqueta family farm, one of the brothers (whose middle name translates into English as 'coming fortune' given by his parents in the height of the 1980s hope) turned to me and said 'I expected you to ask me what I think will happen to ka'a he'ê in one year?' We laugh, 'go on then' I say, 'tell me?' Despite the efforts the family are putting in, he doesn't forecast fortune, he vents his frustrations;

> What I think is that rich people are against ka'a he'ê production in Paraguay so they might get involved in this business, but with the artificial sweeteners, while we are discriminated nationally and regionally, because other people are saying that we already lost land because we are crazy with ka'a he'ê. If international

[96] Foro Social Del Norte recordings of speeches (ref. 35) Universidad de Concepción, Paraguay. 28/09/18
[97] *Ibid.*

> companies or research institutes don't secure some support for this, I think in 1 or 2 years we will be dry without any possibility to continue.[98]

The Horqueta family believe a combination of corruption and lack of government investment, coupled with climate change, drought and crop failure, underline the struggles in achieving the dream of 'oro verde'. I ask, 'why do people call your family 'crazy with ka'a he'ê?' The older brother explains to me, 'we *almost* lost our land' due to lack of buyers, and one of 'our uncles *did* lose his land' over ka'a he'ê'

> Our father's brother re-mortgaged his house to invest in ka'a he'ê production. That was the year of El Niño and the plantlets did not cultivate, so he could not pay this debt, and some sort of legal trick occurred, so one of the bankers took ownership of his land.[99]

Sadly, he says, this is not something uncommon, many people are losing land from agricultural loans and debt. The older brother carries on, 'it was really bad because other families saw, and they say; *you see if you get involved with ka'a he'ê you lose your land.* So our uncle became a reference'. Meanwhile the story of Enrique Luis De Gásperi, the entrepreneur that was at the centre of efforts to transform Ka'a he'ê into a cash crop during the late 1960s, also became a bitter reference. The elder Horqueta father, who had at first been so eager to tell me the full story of stevia, explains how De Gásperi was tricked into breaching his exclusivity contract with a Japanese company, leaving him unable to sell 10,000 kilos of leaf powder. The old man sighed, 'eventually the family lost everything, that's why the son of De Gásperi says that the ***ka'a he'ê killed my father***'.[100]

Every small farmer I encountered in Paraguay who had previously or currently cultivated ka'a he'ê described the importance of a reliable cash crop, and that the success or failure of their cash crop was a decisive factor between managing to stay on their land or losing it. Many complained that other traditional campesino crops such as cotton and sesame no longer provided a reliable income or had left soil infertile. Despite multiple promissory narratives of Ka'a he'ê as a crop for sustainable livelihoods to keep farming communities together, it has also gained the reputation as a risky crop due to repeated structural and political failures, leaving even the most committed ka'a he'ê farmers facing times of crisis.

Even well-funded stevia projects such as that supported by the Inter-American Development Bank stated in the project follow-up report that 'unsuccessful engagement of the small producers in stevia production in the past, led to scepticism and a reluctance of small producers to join the out-grower projects (Bamber & Fernandez, 2012: 15). Cautionary factors underlining the potential problems facing the stevia promise are not new. In 2004 the USAID project warned:

> One of the cautionary factors regarding the Stevia industry in Paraguay is the slow start, even after the push in the late 1990s when more private firms entered the market. The reasons for this slow start include the difficulties of introducing a new crop to small producers without any effective government or international support. The main Stevia cultivation area is located in the regions of San Pedro and Concepción where low-income farmers and small producers dominate the rural economy (p.24).

[98] Personal communications (ref. 31). Horqueta, Concepción, Paraguay. 26/09/18
[99] *Ibid.*
[100] *Ibid.*

Corruption and contradiction.

In a nation with underdeveloped rural infrastructure, public welfare, and health and social care services, farmers spoke of being accustomed to minimal state support and all of my respondents had a low regard for the adequacy or reliability of governmental programmes or even reliable information about the stevia industry. One stark example of this was the contestations I encountered around what is one of the most fundamental questions in understanding stevia dynamics in Paraguay: how much land is cultivated with stevia?

Across my interviews with farmers, government officials, and small and big businesses, none of them estimated the same hectarage, and two respondents accused others' statistics of being a lie. The only official statistics I came across stated that in 2014 there was 2,300 hectares planted in Paraguay (National Directorate of Census and Statistics of the Ministry of Agriculture and Livestock, *in El País* 2016), and more recently the national cultivated area quoting the Ministry of Agriculture and Livestock (MAG) was said to cover 2,370 hectares (Godoy 2019). However, one government scientist who works with stevia angrily told me, 'I believe that in all of Paraguay maximum, *maximum,* there are just 300 hectares.'[101] Three hundred hectares was the lowest estimate I heard. An Asunción stevia businessman estimated between 1000-1500 hectares[102] and an Asunción businesswoman[103] told me that the maximum area planted Paraguay has ever reached was 2,500 hectares. While a representative from Pure Circle Stevia (the biggest stevia company in Paraguay) said Pure Circle accounted for 90% of total Paraguayan production, he claimed (in 2018) this was only 500 hectares[104]. Considering the consensus that the average stevia farm in Paraguay is around 1 hectare per campesino family, whether the total area of stevia cultivated is 300 hectares or 2500 hectares is a significant difference. This basic statistic is vital when considering not just the scale of the industry, but assessing who is benefiting, who is losing out and indeed the prospects of the 2016 goal of expanding production to overtake China (El País 2016). For farmers, reliable figures on crop cultivation are vital to make informed decisions about livelihood strategies or whether to invest in growing a crop such as stevia.

Conversely around the time that global demand began to balloon with big brands replacing sugar and sweeteners for stevia, Paraguayan campesinos reportedly began uprooting ka'a he'ê for lack of buyers. A Paraguayan newspaper article entitled 'Campesinos abandon their plots of ka'a he'ê' reported that the two sweetener industries, NL Stevia and Nativia Guaraní, which invested US $8 million and US $5 million, respectively, had been 'totally paralyzed' (ABC news 2014), a move which initially resulted in stevia farmers lighting fires in protest outside the NL Stevia factory after it stopped buying their leaf (ABC news 2014). I visited the locked factory gates of the NL Stevia extraction facility, still protected by security guards. Once a symbol of great national promise, it was inaugurated in 2009 only to cease production in 2011, remaining inactive ever since. Not only was the factory embroiled in the 'FIFA-gate' corruption scandal following the embezzlement of millions of dollars by its owner Nicolas Leoz through NL Stevia bank accounts, but the factory never got enough investment to achieve more than 90% extract purity, closing off the lucrative US and EU export markets that demanded a minimum of 95% purity (Associated Press, 2017). This meant that Paraguay never

[101] Personal communication (ref. 44). Caacupe, Paraguay 11/09/18
[102] Personal communication (ref. 42). Asunción, Paraguay 9/10/18
[103] Personal communication (ref. 26). Asunción, Paraguay. 20/09/18
[104] Personal communication (ref. 39). Pure Circle, Asuncion, Paraguay. 3/10/18

managed to capture the value-added product of processing the lucrative white ka'a he'ê crystals. The crystallisation factory would have transformed cash crop stevia into the cash molecule steviol glycoside. Instead, leaf stevia grown in Paraguay continues to be shipped halfway round the world for this chemistry to occur.

Sovereign stevia?

Thirty-six years after the failed legislation that would have granted stevia cultivation the same tax exemptions as soybean agriculture, another legal document on ka'a he'ê emerged. In 2006, the Paraguayan government issued a Decree (Decreto Nr. 8392) declaring ka'a he'ê endemic to Paraguay and a plant of national agricultural interest (MAG 2006). Significantly, the decree included a clause stating that *'Stevia rebaudiana'* had been added to the list of critically endangered species in Paraguay (MAG 2006). In 2012, a long time in-the-making, this decree was finally transposed into law asserting a 'national interest in *Stevia rebaudiana* de Bertoni - Ka'a he'ê' and encouraging 'its promotion, investigation, production, industrialization and commercialization' in Paraguay (BACN, 2013).

Across my interviews with businesspeople and farmers in Paraguay many felt that the government's actions and the national decree of sovereignty over stevia were all too little, too late. Patents on stevia rocketed during the period before the decree. Meanwhile internationally Paraguay remained silent on political debate around genetic resources and as of 2020 had not ratified the UN Nagoya Protocol *on access to genetic resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization*. Many criticised the government's use and abuse of the cash crop promise to attract foreign aid money and encourage hope and investment among campesinos when markets and infrastructure were not guaranteed. The results of stevia investments and rural development projects in Paraguay have been patchy and successes have not been sustained. During my time in Paraguay, I visited the state stevia and medicinal plants research centre, I also interviewed three current governmental representatives and one former government minister. It is to their comments I now turn, to make sense of stevia's unfulfilled promises.

The ex-minister heading an agricultural department during the Lugo government (2008-2012) picks me a leaf from a ka'a he'ê plant growing in his garden, proudly presenting it to me: 'this is Amambay, wild ka'a he'ê from a Pai Tavyterâ shaman'. We sit in the shade outside his Asunción home conversing about the history and future of stevia and Paraguay. Eventually I ask him why Paraguay has struggled to fulfill the many promises of stevia for small farmers, as well as the benefit-sharing case of the Pai Tavyterâ and Kaiowá peoples. He sighs, 'if you look at an isolated case of stevia, there is no smoking gun, this is a war with many fronts'.[105] He describes problems Paraguay faces in terms of lack of rights and support for Indigenous Peoples, the rural poor and campesino communities, the strong political influence and low-tax contribution from foreign agro-business such as Cargill, as well as high levels of corruption and vested interests entrenched in the status quo.

He then tells a story I had not yet heard, a story of potentially momentous consequence for the future of Paraguay's long-prophesied cash crop. He explains that during his time in office he witnessed the state's complicity in the covert trade of genetic resources from Paraguay through what he termed '*under the table deals'.* And that these deals on

[105] Personal communication (ref. 25). Asunción, Paraguay. 15/09/18

Paraguayan stevia underpin the genetic basis for what are today the most commercialized and patented stevia varieties on the market. He explains that publicly-funded research on ka'a he'ê at Paraguayan universities and government agronomy programs have for decades been working on developing national varieties of stevia, successfully producing Eirete and Katypyry (varieties I witnessed growing in campesino plots). Some of the most promising varieties produced by publicly-funded research, he explains, were sold controversially to a Paraguayan company, a company that was later acquired by Pure Circle, the largest global stevia company now headquartered in the US. By 2009, the ex-minister tells me, he was working at the plant and seed authority when Pure Circle made a request to export these stevia varieties out of Paraguay. He bangs the table, reliving the discussion he had with his colleagues in government:

> I said well no, these are national varieties we can still fight this, we can tie them to our national interest, and especially if they ask you because they own it, that's not the way we see it, the way we see it is - it is a plant of national interest! There is this operation by the Parliament [2006 decree] that we have to abide by, then you [Pure Circle] can plan the strategy here, with our people, with our raw materials, with our soil, with our germplasm![106]

'People don't understand it,' he sighs, impersonating in Spanish 'pero por que si esta por todo lado ya hay.' He translates, 'if there is so much stevia breeding going on [in other countries] why would you not allow one more or several more to go?'. He claimed that while President Lugo attended Dilma Rousseff's presidential inauguration in Brazil in 2011, the vice-president controversially signed a decree authorising seven varieties to leave the country.[107]

This institutional complicity in facilitating the export of sovereign genetic resources, he claims, has undermined the state's ability to support either the benefit-sharing case of the Pai Tavyterâ in Paraguay, or the ability of Paraguayan campesinos to exploit the comparative-*ecological*-advantage they had from stevia as a cash crop.

The ex-minister's accounts of the covert politics of ka'a he'ê as a sovereign genetic resource were corroborated without prompting during a visit to the Ministry of Agriculture's programme on ka'a he'ê/stevia and medicinal plants at the Hernando Bertoni Research Centre, operated by the Paraguayan Institute of Agrarian Technology.

Figure 5.6 Entrance sign reads: Paraguayan Institute of Agrarian Technology. Hernando Bertoni Research Centre programme on ka'a he'ê/stevia and medicinal plants (translated into English) (Authors own photo)

[106] Personal communication (ref. 25). Asunción, Paraguay. 15/09/18
[107] *Ibid.*

A placard in the research centre's reception describes Hernando Bertoni as the 'grandson of the great student of plants, Moises Bertoni', the man who gave ka'a he'ê its Latin classification. I meet three members of the research centre's staff and these clearly passionate and committed agronomists kindly show me their life's work. The research centre carries out work on genetic improvement, organic production, plant protection, multiplication of the national varieties, and field test plots of new varieties. They also hold 11 materials in gene banks, and they perform in-situ conservation of wild species, as seen in Figure 5.7 of a collection from Amambay.

It is a sweltering day as the three agronomists guide me around their research and conservation plots, buzzing with insects. I am handed different varieties of stevia leaf to taste and as I chew, they explain the different genetic characteristics between rebaudiosides (sweetness) and steviosides (medicine), and between wild, native, Chinese, cross-breeds and trial varieties. It is not long before I pick up on the now familiar sense of hope and frustration I have encountered with almost all my respondents with regards to stevia in Paraguay. The agronomists are quite exasperated. Substantiating the former government minister's story, one describes the covert trade in ka'a he'ê, as the illicit 'theft' of stevia varieties, characterizing it as *'vende patria'* which translates as selling your homeland or being a traitor. They list problems and injustices experienced by smallholders growing stevia. 'Why in the country of origin are farmers punished?,' one asks. Stevia farmers in Bolivia and Argentina get higher prices; 'we compare,' they tell me, 'low price affects everything'. My respondents are aware of the criticisms made about the government's support of ka'a he'ê, and acknowledging their role one says sternly: 'Molly, we are the government right?' arguing, 'but how can we disseminate and promote stevia cultivation if the price is not good?'[108]

A blame game over stevia's unfulfilled promise has developed with the companies and farmers blaming the government, and the government blaming the companies and the international market. Although few of my respondents explicitly mention the word 'corruption' it manifests itself in many of the frustrations over perceptions of truths and lies.[109] Again, the area of land dedicated to ka'a he'ê is particularly controversial. The agronomists argue that they travelled all over Paraguay and 'there is no such surface, it is not true!' one says responding to the various estimates I recount. The agronomists are particularly suspicious of the largest foreign-owned stevia company operating in Paraguay. 'Pure Circle say it produces seedlings to expand the cultivation 300 hectares per year, but that is not seen in the field!'. One goes on, 'if the first part is a lie, how are you going to believe the final part?'. The agronomists say they have observed Pure Circle 'reducing farms and firing technicians, and what's going on then?' and one asks, 'I look from outside, that company is dwindling and why? We need the truth.' The agronomists assert: 'The company that paid better was Pure Circle, they incentivized the cultivation of the PC1 variety, but what happened?' One said, 'I know farmers who [signed contracts] two years ago and now [Pure Circle] say they will not buy more leaf. How?' The agronomists conclude, 'farmers are afraid'. Concerned, one sighs:

[108] Personal communications (ref. 44). Caacupe, Paraguay. 11/09/18
[109] Paraguay is in the top five most corrupt countries in the Americas, listed 137 of 177 countries on Transparency Internationals' 2019 Corruption Perceptions Index (Transparency International 2021).

> All I can tell you Molly, is the current situation of the ka'a he'ê in Paraguay is uncertain. It is not safe for our farmers, it is not safe. In our case, we can do research, we can multiply [plantlets], but none of us are in a position to tell farmers 'do Ka'a he'ê, do Stevia.[110]

The agronomists complain how underfunded their research is, how they lack basic equipment and technology used in Plant Science to analyse, catalogue and protect genetic resources. One claims, 'if I had Eirete's DNA registered, I could sue Argentina, they took our Eirete material and gave it another name.' But instead of public research, they lament, the state diverts funds toward public-private partnerships such as the '*Mil Familias* 70:30' scheme with Pure Circle, which they said had only benefited a handful of families, an assertion farmers will substantiate in the next chapter.

Before I leave, I ask their thoughts on biosynthetic stevia, and the claim that producing the sweet rebaudioside molecules via fermentation is more sustainable than producing it via the leaf. The head agronomist fires back, 'And where is the social part? We are in a country with 280,000 peasant families!' He goes on, infuriated,

> We need a crop to take advantage of and generate income for our farmers. I do not care that Cargill can synthesize the sweet molecule and avoid cultivation... and the farmers? They must wait for another crop to appear to generate income? We have the Ka'a he'ê available! Here what is needed are companies that work on the medicinal part of the ka'a he'ê, not only the sweet for Coca-Cola, but the medicinal part.[111]

The agronomists soften, imagining ka'a he'ê being grown for medicine: 'I have much more faith in stevia as a medicine than for the industry'. They describe stevia as a medicine with multiple health benefits, with the most important part of the leaf for health being the steviosides, the very molecules that companies are reducing in modern varieties of the plant for its bitter aftertaste. They disagree with companies who refer to one sweet molecule as stevia. They repeat what I have already heard, that the native Criolla is beneficial for diabetes sufferers, helping the pancreas produce natural insulin to regulate blood sugar. He complains how underfunded research is into medicinal plants like stevia.[112]

I ask about the future, 'I know that multinationals see 10 to 15 years in front. I know they have that ability to know what will happen.' One says, 'what I see here, first they began to promote rebaudioside A, then they lower price, now they want rebaudioside M, and then lower price. A lot of uncertainty, for me a lot of doubt.' Despite the struggles and somber prospects, I ask the agronomists, do you still hold hope in the stevia promise? 'That's, why we are working' they reply, repeating their belief that there is 'much more future for stevia as a medicine'.[113]

[110] Personal communications (ref. 44). Caacupe, Paraguay. 11/09/18
[111] *Ibid.*
[112] *Ibid.*
[113] Personal communications (ref. 44). Caacupe, Paraguay. 11/09/18

Figure 5.7 Collection of living ka'a he'ê 'materials' from Amambay (authors own photo).

Stevia's unfulfilled promises (conclusions).

Following stevia as an ethnographic object across Paraguay led to encounters with farmers, businesspeople and agronomists, but also led to micro-interactions with taxi drivers, people in cafes, on buses, and journeys through markets and supermarkets. These multiple and iterative interactions conveyed ka'a he'ê as a distinct part of a national cultural imaginary and identity in a country dominated by agriculture.

This chapter follows ka'a he'ê as the plant became understood as a cash crop in Paraguay through processes of physical excavation in Amambay, through to agrarian experiments, crop domestication, iterations of botanical and ecological knowledge, and entrepreneurial endeavors inspired through imaginaries of socio-economic wellbeing derived from the small-scale campesino model of agriculture or *agricola familia* (family agriculture) as it is also known in Paraguay. Long before development agencies and NGOs began targeting the crop as a 'tool for poverty reduction', entrepreneurial farmers were prophesizing rewards from the leaves' sweet, medicinal properties.

Over the 2000s and especially since the surge in global demand for stevia during the 2010s, these promises concretized into a narrative about stevia as a leaf capable of *sustainable* socio-economic development, for its low environmental impact, among other benefits. I saw and heard first-hand what 'this leaf' can do, or indeed *could* do for smallholder livelihoods in Paraguay. Across my encounters with campesinos and small businesses it was clear that the social and ecological basis upon which this promise depends has undeniable potential to succeed. I was overwhelmed by the pride and passion of the Paraguayans who associate themselves with ka'a he'ê. And I witnessed how significant the need is to address Paraguay's rural poverty. All of those I met who were committed to ka'a he'ê defiantly believed that with the right support and conditions, ka'a he'ê the cash crop continued to hold promise for improving small farmers' livelihoods. While for former growers, ka'a he'ê continued to represent a future livelihood pathway 'on hold' waiting to re-start under improved conditions. Many held hope that once the medicinal value of ka'a he'ê became better recognized, there would be a renewed demand for Paraguayan ka'a he'ê.

Despite the passion and hope however, I heard numerous stories of farmers and small businesses who struggled to grasp the promise and faced a number of hurdles, some proving too high for families who were forced to give up on ka'a he'ê, or even lost their land altogether. This has left ka'a he'ê in Paraguay with a legacy of broken promises and a reputation of risk. Challenges were said to include failed legislation and a lack of state support, limited access to credit, poor infrastructure, unreliable statistics, corruption, a need for simple technology such as irrigation, drying and storage equipment, underfunded research on ka'a he'ê beyond its use as a sweetener, as well as challenges of gaining organic certification in contaminated environments.

Stevia's unfulfilled promises are clearly not just a result of any one thing. 'There is no smoking gun' as one respondent put it, but historical and ongoing intersecting factors and imbalances of power both domestically and internationally combined with corporate and economic transformations surrounding synthetic biology becoming a significant factor (which the next chapter explores). An unescapable element, however, encompassing both domestic and international political economy in Paraguay, is the industrial model of soy. The direction Paraguay pursued at the agricultural crossroads of the 1970s away from the potential of stevia and toward industrial soy is both a cause and consequence of the failure to fulfil the stevia promise for small farmers. The few families and campesino projects I encountered that continue to pursue the promise of stevia bluntly saw the stakes riding on their ability to isolate themselves from relentless soy expansion with its proprietary seed regime, heavy use of agrochemicals and mechanisation of labour - a model of agriculture said to be 'incompatible' with the small-scale diverse model of campesino agriculture. The ability of campesino colonias to withstand the pressures of soy expansion (and increasingly climate change) ride on cultivating viable cash crops that sustain community resilience. Ka'a he'ê was repeatedly described by respondents as one of the *few* viable cash crops capable of achieving resilience, enabling campesinos to stay on their land, school their children and offer employment, avoiding the traps of poverty or cartel-controlled cannabis production. It is for lack of viable smallholder cash crops in Paraguay that so much campesino land is converted to soy each year (Transnational Institute 2016; Correia 2019).

In seeking to understand what biosynthetic stevia might imply in Paraguay, the question that emerged through fieldwork for this chapter was 'what are the stakes riding on the viability of stevia for small farmers?' This question illuminates a range of implications and indirect effects through the aspirations, meanings and livelihoods of those who understood ka'a he'ê as a campesino cash crop. The 'worlds' constructed around ka'a he'ê as a cash crop raise questions for future rural socio-economic and sustainable development. This chapters findings feed further frictious dynamism into the four bridging zones of discursive dis/connect forming between worlds of biosynthetic commodity- and sacred herb- 'stevia' described in the previous two chapters over authenticity, ownership, sustainability, and justice.

In contrast to the narrative promoted by Cargill (*and other SynBio companies)* on the superiority of biosynthetic stevia, based solely on reductionist equations of sustainability derived from environmental and economic calculations of efficiency on water-use and less CO^2 emissions in comparison to leaf-stevia (Cargill 2020). The campesino cash crop 'promise' rests on an interpretation of sustainability underpinned and entangled in the 'social', the social-economic and the socio-environmental, derived from calculations, development reports and lived experiences about reduced rural-urban migration, community cohesion, farmer autonomy, diverse benefits of regular income intervals, and ecological

farming methods for reducing poverty and inequality (Oxfam 2017). Without holistic interpretation of sustainability, consideration of (in)direct impacts upon rural communities and land use, such as potential to eradicate small-scale farming, generate social upheaval, and increase land conversion to soybean monoculture, could mean that CO^2 and water-use reductions pail in significance to the sustainability implications of the alternative. Ten years since the 2008 International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) global expert consensus has solidified that smaller, more diverse farms play a pivotal role in maintaining agrobiodiversity and rural development, with small-holders producing 70% of global food production, these agro-ecological systems are recognised as vital to (socio-economic-environmental) sustainability (IAASTD 2008; see especially IAASTD+10, 2020).

The **authenticity** narratives surrounding (biosynthetic) stevia and ka'a he'ê amplify its 'ancient' uses and 'indigenous origins', however the legacy and contribution of agroecological knowledge of peasants and small entrepreneurs central to domesticating the plant and developing uses in farming systems and medicine in Paraguay, are an overlooked, yet important connection. Campesinos themselves described ka'a he'ê as 'their' cash crop, as opposed to the soybeans of the *latifundios* and agribusiness, ka'a he'ê has long being promised to 'them'. This also dis/connects to the discursive zone of **ownership** in terms of who 'owns' ka'a he'ê especially relative to intellectual property rights where patents have encompassed properties and varieties developed by farmers and breeders. Further dis/connects over **ownership** can be identified in the declarations of the Paraguayan state asserting national sovereignty over the plant as an endemic 'genetic resource' (MAG 2006; BACN, 2013). The stakes over genetic resource sovereignty have sparked significant conflict in ongoing politics of synthetic biology over who can access, own and benefit from genetic resources, which I unpack further in the penultimate chapter.

The dis/connects bridging the chapters *so far* on articulations of sustainability, authenticity and ownership reveal diverse implications of biosynthetic stevia depending upon from which worldview one is looking, and lead into very different mobilisations around notions of **justice**, fairness or equity. In this chapter exploring the worlds of those who understand ka'a he'ê as a cash crop *for* campesinos, a mounting sense of injustice was building over the unfulfilled promise of stevia. It's a similar yet different kind of injustice to the one highlighted by the Pai Tavyterâ who seek to reclaim ka'a he'ê as part of a long history of dispossession. The sense of injustice from campesino communities was connected to the lack of development, security and wellbeing, as well as the palpable sense of corruption at multiple levels. During my time in Paraguay, this sense of injustice was mounting with the latest reconfigurations of the cash crop promise in turmoil. Re-framing and refining stevia into a 'cash molecule' has set in motion a trajectory of pushing the promise further away from small farmers and towards industrial agriculture and multinational corporations. I unravel the process of molecularisation in the next chapter following the globalisation of stevia, and the eventual commercialisation of the biosynthetic molecule, and how those in Paraguay are reacting to it.

Ethno-botanic-graphic interlude.

Figure 6.0 A medicine woman's cart of herbs and plants on a street corner in San Pedro Department, Paraguay (source: authors photo).

Before I turn to the molecularisation of stevia, and its interpretive re-definition as an isolated sweet molecule, it is important to introduce the significance of herbal medicine in Paraguay. The use of herbal medicine and its role in Paraquay illuminates a different avenue of consideration over what might be lost in the molecularised approach and biosynthesis of plant compounds.

The passion and faith of campesinos, small businesses and the state agronomists in stevia as a medicine is part of an ingrained and nation-wide faith in plants and herbal medicine across Paraguay. Until the day I landed in Asuncion, I had not been aware that stevia could be *more* than a zero-calorie sweetener. Staying in an apartment in the centre of Mercado Cuatro, I spent my first few days in Paraguay wandering through the capital's biggest and busiest sprawling street-market district. It wasn't long before I found ka'a he'ê among the medicine women that pepper the street corners with tables or cartfuls of fresh and dried herbs, tuber roots, tree barks, and leaves, which they would concoct for customers with large wooden pestle and mortars and infuse with hot or cold water, or prescribe bottles of tinctures or bunches of herbs for patients to take home to cure common ailments such as bowel infections, indigestion, stress, or chronic conditions such as diabetes. According to the Etnobotanica Paraguaya project, around 15% of the 8,000 plant species recorded in Paraguay are used for their medicinal properties (Le Temps 2013). As I travelled across the countryside even in remote towns medicine women with roadside carts would be offering herbal prescriptions, like the one photographed in figure 6.0. Some assert Paraguay's 'GDP-defying life expectancy' – among the highest in Latin America, despite being one of the poorest nations – 'has instilled something of a surety for these ancient methods of medical practice in the national consciousness,' as a Paraguayan tourism site puts it, and the 'folk medicine tradition of Paraguay is a well-respected area of expertise in the country'…'while modern medical facilities increase in quality and prescription, the use of medicinal plants and traditional healing methods are also on the rise' (VisitParaguay 2013; Le Temps 2013). The use of medicinal plants originating from the practices of Indigenous Guarani Peoples are recognised and refined by Paraguay's contemporary herbalists and growers in a process that VisitParaguay describes as part and 'product of lengthy experience and trial and error; something of a jungle scientific method in itself' (VisitParaguay 2013).

Figure 6.0 (a) A medicine woman prepares a treatment on a street corner in San Pedro Department, Paraguay (source: authors photo).

One of the agronomists described Paraguay as among the least charted territories of modern botanical study. Western science is only starting to scratch the surface to recognise what the medicine women have long known, such as the anti-cancer properties of Lapacho tree bark (Le Temps 2013). And yet the wild habitat and forests in which the diverse medicinal

flora thrives is expected to be completely eradicated over the next 20-30 years at the current rate of deforestation, threatening Paraguay's medicinal plants with extinction (Le Temps 2013).

Ka'a he'ê – a key herb on the carts of medicine women – is representative of the everyday culture and tradition of herbal medicine in Paraguay. Yet ka'a he'ê is also representative of the threat of extinction for multiple medicinal plant species at stake, made explicit in the State's 2006 decree when the plant was added to the list of critically endangered species in Paraguay (MAG 2006).

The claims made by respondents in the previous chapter that ka'a he'ê is an active treatment *for* diabetes, rather than solely a way for those suffering with diabetes to enjoy sweetness as it is sold and promoted in the West, rests on the properties of the molecules that are not being synthesised.

With many medicinal plants therapeutic properties' yet to be substantiated by scientific or medical regulatory authorities and threatened by extinction, what might be lost by expending the knowledge and generations of experience found in countries such as Paraguay? Which molecules get selected to be reproduced and which do not? Such questions highlight the neglected considerations and unfolding stakes playing out in the background of molecularisation.

Chapter Six.

The corporate 'cash molecule': breaking and (re)making the stevia promise.

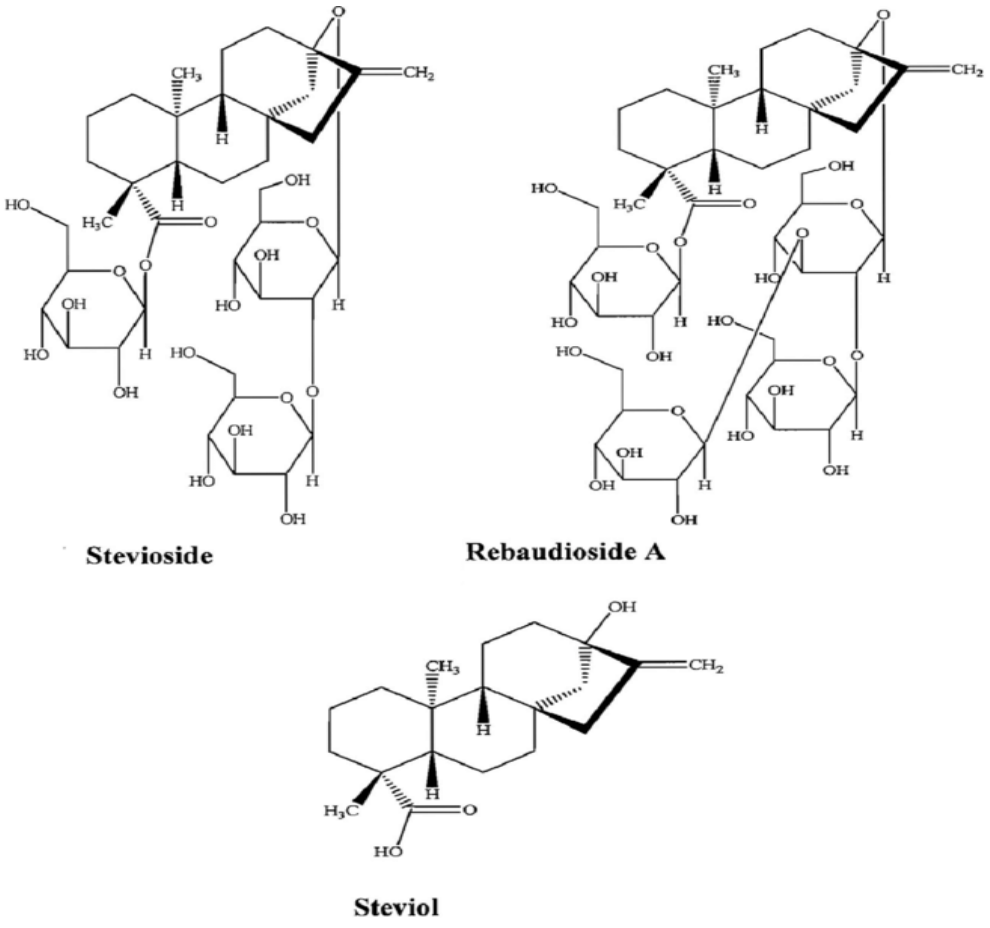


Figure 6.1 Chemical structure diagrams of three molecules found in Stevia rebaudiana (Source: Brusick 2008)

'I don't know if you are aware that this plant has in its leaf 40 different molecules' says a representative from **Pure Circle**, the world's largest stevia leaf company. I have arrived at the company's South America head office on one of Asunción's busiest and wealthiest boulevards. Another glass display cabinet! Another box of Cargill's Truvia! As well as green cans and bottles of *Coca-Cola Life, Pepsi True,* and *7up Green*, all sweetened with stevia, Nestle products and local stevia brands lined up proudly alongside crystal-marble trophies engraved with the words 'Ka'a he'ê Pure Circle' awarded for winning the best exporter prize by the Sudameris Bank three years running. Sat on swivel office chairs either side of a desk, my respondent chooses to begin with molecularisation;

> From the 40 molecules, there are 13 steviol glycosides that are described and accepted internationally and everybody knows them. Not everybody, but I mean scientists know. The ones that are known are really four or five of them. Everybody knows there are more. The stevia plant also contains antioxidants, painkillers, growth promoters, all kinds of things. […] We only focus on the sweetener part. From all those molecules, we basically focus on five molecules which are the ones that we consider the most interesting from a natural sweetener standpoint. The gold standard, let's say, of these molecules is Reb M. Reb M is 500 times sweeter than sugar and has zero aftertaste. In other words, it is the perfect sweetener. The problem with Reb M is that it is 0.01% of the leaf - you would need a thousand kilos of leaf.[114]

Incorporated in 2001, Pure Circle has been at the heart of breeding efforts to increase the sweetness of stevia as well as globally propagating stevia's promissory narrative of a sustainable cash crop for small farmers (epitomised by the 'This Leaf is Powerful' video transcribed at the beginning of Chapter Five). The company operate what they call a vertically integrated supply chain, which according to their website includes: Plant Breeding proprietary stevia varieties with high glycoside content**;** harvesting with third party farmers across four continents; extraction; purification; application and finished products (Pure Circle 2018). The company boasts 200 patents, and over 300 patents pending covering stevia-related products and processes (Pure Circle 2019). Pure Circles' incredible growth in less than 20 years dominates the history of stevia in the 21st century following the plant's export from Paraguay. Headquartered in the USA with a turnover exceeding US$130 million and listed on the London Stock Exchange, today Pure Circle have laboratories and offices in the UK, USA, Mexico, India, and Brazil (and more). They operate two large extraction and manufacturing facilities in China and Malaysia and hold almost 100,000 contracts with 'third party farmers' across China, Paraguay, and more recently Kenya, Zambia, India, and the USA, supplying the largest global food and drink multinationals including Coca-Cola. No other company embodies the dynamics between cash crop and cash molecule like Pure Circle across its global production networks.

This chapter follows the transformation of stevia the cash crop into stevia the cash molecule, and how the promissory narrative outlined in Chapter Five has been both globalised and reinforced by this process and, more recently, disrupted. While acknowledging that other stevia leaf businesses exist, this chapter focuses on Pure Circle as the largest stevia company in the world and the company dominating production in Paraguay. Like the previous chapters I tell this part of stevia's story through ethnographic encounters with Pure Circle employees and campesinos contracted as 'third party farmers' to cultivate stevia for the company. I also consider Pure Circle Stevia's global reach and engage with the corporate narratives and accounts of exporting the promise to China and smallholders in African countries.

I describe the molecularisation of stevia in two stages, the first stage structured production of stevia around reb A, a naturally abundant molecule in the leaf. The second stage of molecularisation is re-structuring stevia production around the rarer reb M molecule established in the 2018 co-emergence of Cargill's lab-grown stevia sweetener EverSweet™ and Pure Circle's new proprietary variety of stevia plant Starleaf™. Both these technological innovations to

[114] Personal communication (ref. 39). Pure Circle, Asuncion, Paraguay. 3/10/18

access stevia's rarer cash molecule, I discover, are eroding the smallholder stevia promise of rural poverty alleviation and sustainable livelihoods in Paraguay and beyond. The breaking of the 'cash molecule' promise stands in juxtaposition to the re-making of the promise for new groups of large-scale farmers in Paraguay, and corn and ex-tobacco farmers in the United States. New promissory narratives constructed around sustainable land use and resource efficiency highlight two of the four frictious dis/connects outlined in previous chapters on sustainability and authenticity, but my encounters 'on the ground' travelling through Paraguay reveal multiple contestations over ownership and (in)justice. Highlighting that no matter how far removed from the land the new versions of stevia are, they are inescapably tied to an agricultural legacy that is – as one participant put it – 'engrained to the collective unconscious of Paraguay'.

Refining the cash molecule: steviol glycosides, steviosides, rebaudiosides.

Stevia's molecularisation began a century ago with the isolation and categorization of multiple compounds[115] found in the plant's leaves by the Paraguayan chemist Ovidio Rebaudi, a colleague of Moises Bertoni (Rebaudi 1920). The most common, stevioside, is about 140 times sweeter than sugar, but of the other steviol glycoside molecules, rebaudiosides were found to be even sweeter. Rebaudioside A, commonly referred to as 'reb A' is the most abundant rebaudioside in the leaf and is 240 times sweeter than sugar. Today reb A is the most commercialised source of stevia globally. The intense sweetness and abundance of reb A in the leaf is one of the central reasons stevia became framed as such a sustainable cash crop for small farmers, due to the small land area required to get the equivalent sweetness compared to other natural sweeteners such as sugar. Since stevia was exported from Paraguay in the early 1970s a global stevia industry has developed around optimizing the sweet molecules that can be extracted from the leaf, predominantly by perfecting the refinement of reb A. This first wave of molecularisation, combined with import bans on whole stevia leaves in many countries, is why outside of Paraguay I argue that stevia has been predominantly understood as a molecule. One might find, for example, a can of cola or baked-beans 'sweetened with stevia', however in small print the ingredients almost always read 'steviol glycosides', and (up until very recently) those glycosides have been mostly reb A.

Many of products using steviol glycosides adopt the image of the leaf, unlike sugar or artificial sweeteners where the origins of the sweetness are often hidden. The idea of the molecule originating from a plant has been fundamental to the marketing narrative of authenticity and naturalness, and ultimately the success of stevia. However, in order to refine leaves into steviol glycosides resembling white sugar crystals, stevia must undergo a highly industrial chemical refinement and crystallisation process. These production processes have sparked controversy over the use of the term

[115] In a recent study, stevia leaves were found to contain 'more than 30 different steviol glycosides, such as rebaudioside and stevioside that display antitumor and antiviral activities, as well as antimicrobial, antihypertensive, antifungal, and hypoglycemic effects' (Ramos & Muriel 2019: 102).

'natural' applied to products sweetened with steviol glycosides, and some have criticised the industrial methods as not being environmentally friendly (Kienle 2014; Watson; 2012; Meienberg et al. 2015).

This molecularisation can also be observed physically in the way ka'a he'ê has been modified and bred since it was domesticated as La Criolla, Eirete, Morita (the first Japanese variety) and consequentially the many other varieties of *Stevia rebaudiana* that exist today, the vast majority of them bred specifically for higher steviol glycoside content. The modifications have changed the look, properties, fertility and durability of the plant, as well as who can access, grow and own it. These changes were highlighted across my encounters with respondents, from the leader of the Indigenous community who didn't recognise the modern breeds of ka'a he'ê from its wild relatives, to the various farmers who spoke to me of trade-offs between sweetness and fertility, sweetness and medicinal properties, as well as the pros and cons of farmer autonomy verses corporate contracts. Pure Circle owns patented varieties of stevia as part of an agricultural package supplied to the company's 'third party farmers', including seedlings and agro-chemicals to keep the plants healthy (Pure Circle 2018). Up until 2018, Pure Circle's main commercial variety was called PC1, a variety bred for a higher content of the cash molecule reb A.

In the last decade things have changed. In 2012, synthetic biologists were granted the first patent (EP2742142) on producing steviosides, steviol glycosides and rebaudioside A by recombinant organisms (EPO 2012). In 2014, Cargill and Evolva announced the synthesis of the elusive rebaudioside molecule, reb M, the rarest and highest-value stevia molecule, 500 times sweeter than sugar. Since then, the possibility of mass production of reb M, 'the gold standard sweetener' has loomed over the leaf industry and the race for the further molecularisation of stevia has intensified. Coinciding with Cargill's commercialisation of EverSweet™, Pure Circle's new proprietary variety of stevia, StarLeaf™, was launched - bred to contain 20 times more reb M molecules than its predecessor PC1. The 2018 co-emergence of Starleaf™ and EverSweet™ marked the beginning of restructuring stevia markets around reb M. From a consumer standpoint these changes appear subtle, but the significance of a letter swap from reb A to reb M can be understood by looking at the meanings, livelihoods and narratives surrounding 'third party farmers' cultivating the cash molecule prior to 2018.

Exporting the promise.

Central to Pure Circle's global operations in producing stevia the cash molecule has been its role in reproducing Paraguay's promise of stevia as a cash crop for low-income small farmers, and exporting the idea that 'Stevia is a force for good in the world' (Pure Circle 2019). The promotional video 'This Leaf is Powerful' transcribed in the opening of Chapter Five amplifies many of the promissory framings of stevia as a cash crop for small farmers in Paraguay, including 'protecting millions of wildlife habitats', 'educating thousands of children' and 'improving the lives of 25,000 farmers' as well as saving CO^2 from the atmosphere and preserving water (Pure Circle 2014). These narratives around social, economic and environmental benefits of stevia have bestowed on it a reputation as a green, natural, sustainable sweetener and an ethical commodity to buy into. But perhaps most significantly, the narrative has encouraged thousands of small farmers to sign up to contracts with the company in Paraguay and beyond.

Entitled *'Sweet in so many ways,'* two Pure Circle videos circulating online at time of writing target low-income farmers in Paraguay. Narrated by experts making the case for the benefits of stevia and by farmers themselves, one video asserts that 'with stevia the family can stay together, the family can stay at home and work on the farm and that is a big opportunity not just for now, that is an opportunity for the next 15 to 20 years' (Pure Circle 2015a). Another video features images of small agro-forested plots of stevia and the story of a family pictured in front of a dilapidated wooden farmhouse with earthen floors. The four siblings' clean white school uniforms juxtapose against their surroundings symbolise the family's rise out of poverty - thanks to stevia. The farmer squints at the camera squatting between rows of stevia plants:

> 'My name is Fermin Melgarejo, I am happy with my work. The crop I grow I supports my family and I am glad that they [Pure Circle] take my product seriously and pay a fair price giving us a livelihood that increases our quality of life. In three months we have already made profits that will be very beneficial for our family and neighbors because we can offer them work, a livelihood.' (Pure Circle 2015)

Starting around 2014, the stevia promise was exported and promoted to smallholders in Africa. In two more promotional videos (circulating on the company's YouTube site at time of writing), stevia is described as a crop that 'Enriches Lives For Kenyan Farmers'. To uplifting piano music, the videos depict Kenyan families narrating what they love about growing stevia:

> 'My name is Peter Munga. Stevia has really helped me and my family financially. I can pay for my kids' education and have now even built a house! We are much more empowered economically than we were before. The stevia plant is easy to maintain we harvest every three months and compared with other crops this is most suitable for farmers' (Pure Circle, YouTube 2016a).

The promissory cash crop narrative has proved so alluring that it has been adopted and disseminated by dominant corporations capable of significant global influence. During the UK launch of the new green *Coca-Cola Life* in 2016, Coca-Cola promoted Pure Circle stevia in Africa and as a sustainable cash crop 'growing farmers incomes' in the face of 'climate change' (Coca-Cola 2016a):

> 'Not only is stevia changing the way we make our drinks; it's also changing the world economy. Where farmers previously drew irregular income from their land, stevia now improves families' lives, as the story of *Mr. Stevia* in Kericho County, Kenya, reveals' (Coca-Cola 2016).

The story of Mr. Stevia tells a story of an entrepreneurial farmer 'thinking outside the box,' uprooting his tea plants for 'a crop that can withstand pest infestation, and some of the other adverse impacts in agriculture, including climate change' (Coca-Cola 2016).

These advertising narratives and representations of farmers exemplify the 'power of this leaf' as a tool for brands to align Corporate Social Responsibility (CSR) agendas with goals of poverty alleviation and sustainable development. These videos and indeed the wider corporate marketing of stevia both reproduce and re-make the promises stemming from the development of the cash crop in Paraguay. On one hand they reproduce the potential of the underlying roots of promise to succeed and benefit low-income farmers. On the other, the corporate re-making of the promise blurs the

distinction between stevia as a whole leaf cash crop and stevia as a highly processed molecule. As I followed stevia, and learned of its diverse meanings, varieties, and ecologies, it became increasingly clear that this nuanced distinction between cash crop and cash molecule significantly affects who can and who cannot benefit from stevia. It is, however in these videos' direct appeal to small-farmers to uproot their crops, plant stevia and earn a decent living under a corporate contract, that demonstrates the significance and stakes riding on this promise.

It's worth noting that, conversely, there are no videos romanticizing the cultivation of stevia in China, despite the country making up around 80% of global production (Godoy 2019). Stevia was exported to China in the 1970s to meet expanding Japanese demand, overtaking Paraguay as the world's largest stevia producer between 1982 -1987 (Kinghorn and Soejarto, 1991). Respondents I interviewed during 2018 estimated there were around 30,000 hectares of stevia[116] cultivated in China, grown largely on small family-run farms organised by the Chinese government into growing regions, sharing agricultural machinery, technicians and infrastructure (Bamber & Fernandez 2012).

Some respondents in Paraguay pointed to the poor human rights status of China's stevia labour force, and the US Customs and Border Protection (CBP) agency's 'import alert' against Pure Circle in 2016 stating a 'detention order on stevia produced in China with forced labor' (CBP 2017).[117] As of 2020 the detention order remains in place for 'Stevia and its Derivatives' no longer against Pure Circle, but against the companies Inner Mongolia Hengzheng Group and Baoanzhao Agricultural and Trade LLC. How these companies fit into the wider supply chain of stevia is unclear. In its 2018 annual report, Pure Circle claimed it exported 80% of China's total production, generating, they boast, 'employment opportunities for approximately 70,000 individuals' in China (Pure Circle 2018).

In the Pure Circle office in Asunción, I ask the respondent why his company continues to operate in Paraguay when 90% of its leaf was grown in China? He replied, he couldn't speak for China but 'Paraguay being the country of origin of stevia, it's a nice thing to market'.[118] During the past decade ambitions around producing stevia in Paraguay have been revived. Pure Circle appears to have benefited from at least three public-private partnerships to develop small-holder stevia farming in Paraguay (Halliday 2009; Food Ingredients First 2014; Coca Cola 2016a). In 2009, Pure Circle was reported to have 1500 hectares of stevia in Paraguay and had signed a USD $150,000 deal with the Paraguayan government and USAID with a long-term aim of '6000 hectares controlled by Pure Circle in Paraguay' and a plan to construct an extraction facility to manufacture the cash molecule (Halliday 2009). As I discovered in the previous chapter, these two aims never became reality. In a separate government funded project titled 'Mil Familias' (*a thousand families*) a Pure Circle director was quoted describing how his company was part of a 'five-year plan to fight poverty' in Paraguay (Food Ingredients First 2014). The Paraguayan government has invested significant resources and trust in the Pure Circle company to deliver rural socio-economic development, I now turn to my encounters in the

[116] It was difficult to find reliable statistics on Chinese stevia cultivation. A recent article stated that there are 18,133 hectares dedicated to stevia cultivation in China (Godoy 2019).
[117] It is significant to note that as of 2020, stevia remains one of only 13 detention orders the US Customs and Border Protection agency has issued halting importation of goods tainted by convict labor, forced labor, and forced child labor, others include the 'gold mined in Democratic Republic of Congo, tobacco harvested in Malawi, diamonds mined in Zimbabwe, and rubber gloves produced in Malaysia' (Business & Human Rights Resource Centre 2020).
[118] Personal communication (ref. 39). Pure Circle, Asuncion, Paraguay. 3/10/18

countryside meeting some recipients of such promissory 'corporate cash molecule' cultivation programmes, to see how their experiences stand up against the public/private 'long-term aims' and 'five-year plans'.

Cultivating the cash molecule.

The Pure Circle respondent in Asunción warned that I wouldn't learn anything new by meeting his company's 'third-party farmers', instead inviting me to visit the company's nursery, laboratory and warehouse where I could see the 'mother plant of PC1' and the new Starleaf™ varieties being tested and propagated. I drove past the vicinity on my way to meet two farming families who supplied stevia leaves to Pure Circle. Their experiences represent other meanings drawn from and built around the stevia promise in Paraguay, and the stakes riding on its success.

Ruta tres (route 3) cuts through San Pedro, the agricultural heartland of Paraguay. Mile upon mile of cattle ranches interspersed with vast green carpets of soybeans zoom past our hire-car window. It is not unusual to see horse and carts, and animals on the streets of towns alongside large lorries and trucks crammed with cattle and motorbikes carrying families. Yellow Lapacho, Paraguay's iconic national tree, is in full blossom. It is early spring, but already it is surpassing 40^{o}C. Feeling weary from the humidity, we bump along an unpaved off-road for a few kilometres until we reach the welcome tree-shaded lawn of a home owned by an ex-Pure Circle farmer and his extended family. The farmer's several small grandchildren shriek in excitement at the sight of my baby who is about to become their muñeca (dolly) while I listen to their grandfather's stories of stevia.

More customary te're'e and freshly baked chipa are shared. The ex-Pure Circle (PC) farmer explains why he devoted one hectare of his family farm to cultivate ka'a he'ê, and why, eventually, he quit.

> I started growing ka'a he'ê because I was looking for a viable cash crop because we were cultivating sesame, manioc and maize, compared with those, ka'a he'ê is more economically viable and less work because to harvest it you can harvest one quarter of a hectare in one day with four people you just need to know how to do it […] We started with zero knowledge and ended up being experts on ka'a he'ê.

He goes on;

> I signed an agreement with Pure Circle and they provided plantlets of the improved variety (PC1) and also chemical inputs needed to keep the plant healthy but these were not given for free because the costs for inputs would later be charged every time we sold the crop. [119]

Keen to demonstrate his expertise, he fires out statistics and numbers, exact measurements and quantities of minerals, organic materials, sunlight hours, climatic conditions, and various other inputs required for precision cultivation, care and harvest of ka'a he'ê. 'We had to construct and pay for the irrigation system, the pump and the ferti-irrigation system to mix it'. Things started off well: 'I got 3800 kilos in the first harvest in December, and then 3600 in February, and then less in June'. He explains, 'The fixed price was G$ 8,300 guaranís per kg of dried leaves, every harvest I got around G$23 million until the third year when the production started to decrease'. He complained, 'it is a plant that requires too many nutrients from the soil and that's why it needed chemical fertilisers which look like these very small

[119] Personal communication (ref. 36). Ex-Pure circle third party farmer, San Pedro, Paraguay 29/09/18

balls, you have to put three grams in each hole and you have 135,000 holes!' He exclaimed, 'so the good thing is that kids and young people can help but it is a lot of work!'[120]

Eleven families began cultivating stevia in this Colonia alone, the older farmer reminisced. There was cooperation among them, sharing tractors and labour. His family were fortunate to be one of the few recipients of the Mil Familias *(thousand families)* project which he and other farmers referred to as the 70:30 program (Pure Circle's public-private partnerships with the Ministry of Agriculture). He enthused, 'a 70% government donation and 30% loan to repay over seven years was a good incentive to start production, […] it is a pity these kind of programmes start and then they stop it'.[121]

His positivity waned, there was only one Pure Circle technician, he complained, who visited the farms less and less, and who 'didn't have sufficient knowledge to fight the plant's illness.' 'That's why I quit,' he said bluntly, the culmination of increasingly expensive inputs, accompanied by less technical support and reduced pay for harvests. Even worse, he protested, was the strict company monitoring. Before the harvest the Pure Circle technicians would take samples to monitor quantities and make sure the farmers were not breaching their contracts. He described how the company would 'use a machine to calculate the percentage of sand in the harvest, percentage of stalks and humidity, and it was ridiculous because it was too high so each harvest earnings were reduced.' He recounted how he had created a WhatsApp group with 35 Pure Circle-contracted families from San Pedro as well as Concepcion, Iguazu and Horqueta.

> I wanted to create a Producers Association, but the company didn't like it. I talked to the manager and said you *have* to listen to what the producers say, we are learning from you, it's a good experience, but you have to learn what we have to say as well, but they didn't like it. […] Pure Circle were worse than priests because we had to just obey what they said![122]

Talking about the broader context of campesino livelihoods in his region, the older farmer talks about debt as 'a serious problem'. A campesino family, he says, may 'start with getting some loans from the *Credito de Agricola*, and if they cannot repay, they have to refinance, which means to take it to a private bank that buys it, and then the interest gets higher and higher and higher.' He elaborates how he has seen this lead to loss of land and livelihoods, similar to accounts recalled by the Horqueta family.

The older farmer remembers the changes to the Paraguayan landscape since the 1980s and 90s, asserting that the government's approach has 'failed' campesino agriculture. As soybean plantations expanded, he describes what he experienced in his community:

> The problem is that in settlements such as this one, families are lacking this cash crop like cotton or sesame and when there was no alternative they end up selling their land and who buys it? Foreigners mainly Brazilians, and when a Brazilian gets this 10 hectares he is planting soya which is then affecting the neighbours' crops, and so he's expanding and expanding, and in the end people migrate to the cities, and it is very difficult to come back to the land, to access land again…

[120] Personal communication (ref. 36). Ex-Pure circle third party farmer, San Pedro, Paraguay 29/09/18
[121] *Ibid.*
[122] *Ibid.*

He goes on,

> This is also because there is no national plan to strengthen the campesino agriculture. There are uncoordinated activities, supporting the sesame here, or making a greenhouse there, maybe some irrigation over there, but there is no overall plan.[123]

Closing my encounter with the ex-Pure Circle farmer, I ask him how he feels about the future?

> What worries me enormously is this rate of deforestation, the contamination and expansion of soy, what kind of environments will they have in the future? It's uncertain because water, streams, lagoons are drying, rivers are drying.[124]

The older farmer stopped growing Pure Circles' stevia in 2016, but as a diabetic, the plant remains growing in his allotment as a daily part of his diet.

Later that day, the ex-Pure Circle farmer helps arrange a visit to another family farm who remain under a contract supplying leaves to Pure Circle. Several kilometres along another dirt track, I arrive at the family farm home to a couple with four daughters and one son. When the only son left agricultural college, his parents granted him one hectare of land. His parents who started with 15 hectares are one of the few campesino families I met who have managed to capitalise on processing a raw cash crop into a commodity, which enabled them to not just stay on their land but increase it. The family now own 120 hectares, 30 hectares grows sugarcane which they boil into a syrup in underground furnaces and sell to producers of top-quality rum. On the remaining land they raise cattle.

The only son is young, perhaps early twenties. Following an inspirational college fieldtrip to the Pure Circle nursery, he signed a contract to grow PC1 stevia for Pure Circle in 2015. The first couple of years – he explains, speaking in Guaraní – he was very happy with the contract and the harvest, earning approximately 15 million guaranís per year. He enjoys the security of having a contract with Pure Circle, 'the company guarantee to buy everything' he says, 'what I am investing, I will get back, that's why I like it because I'm investing a lot'. Bashfully, he tells me that in 2016 he was the winner of Pure Circle's Top Producer in Paraguay award. But this year, he goes on, 'the company is losing interest because they are focusing on the new variety StarLeaf.' Like the older farmer, he complains, in its third year his harvest is decreasing and the company are paying less, and he is purchasing fertilisers – the 'small white balls' – but these are expensive, and 'when there is no more organic material, the chemical is not doing anything, it's not enough'.[125]

The young farmer is clearly proud of being associated with Pure Circle. He picks a leaf for us to try, 'this is PC1,' he says. He tells me he is the only farmer remaining out of the 11 others who signed up to Pure Circle contracts, he is positive about his future with the company because he has been told he will be one of the select farmers that will be able to grow the new Starleaf™ variety. We stroll up and down the field of PC1 stevia, the young farmer says this one hectare

[123] Personal communication (ref. 36). Ex-Pure circle third party farmer, San Pedro, Paraguay 29/09/18
[124] *Ibid.*
[125] Personal communication (ref. 37). Pure circle third party farmer, San Pedro, Paraguay 29/09/18

alone provides between 2-6 jobs, depending on 3-4 harvest times per year he says, workers come from an Indigenous community whose settlement borders one side of his family's land, pointing to a large area of trees in the distance.[126]

I ask him about challenges small farmers face in Paraguay. 'Soy expansion' the young farmer asserts without hesitation, 'it's affecting campesino agriculture, it is not creating jobs because it is mechanised so they don't need people to work that land and that means that families really have to rely on only what they can do on their own land'. He goes on, because of this 'the main problem for this region and nationally is the lack of a good cash crop'. Enthusiastically, he asserts that 'a good cash crop would be exactly like ka'a he'ê because you can harvest it three times a year which means you can have money at least three times a year!' No other cash crop provides that, he explains. Other common smallholder cash crops like sesame can lead to debt, because with only one harvest per year farmers have to manage a lump sum to sustain a full year of family costs, 'this is not easy'.[127] The need for a viable campesino cash crop - central to the long-time promissory narrative of stevia and reiterated to me by every farmer I met in Paraguay – was reaching a point of saturation.

In the field of neat black plastic rows bursting with stevia, the sun was intense. We find shade alongside a hedgerow. I tell the farmer he is the youngest I have met, most of my respondents had been in their forties, fifties or sixties.

Thump.
A bird falls to the ground.
We notice but carry on.

I ask, 'In order for ka'a he'ê to benefit communities, what do farmers need?' He replies, 'we need a secure buyer, we need the right variety with a good yield of leaf, we need access to loans, small-scale farmers require special access to loans because…'

My translator stops our conversation and walks over to the bird.

The foot-long white, yellow and brown speckled bird lies on its back gasping for air. 'We call it Piririta', the young farmer says affectionately stroking the dying bird (also known as the Guira Guira cuckoo). Piririta are good for farmers, they eat pests, he explains, 'it's a bird that sings starting at midday when it gets hot.' 'This is related to soy', the farmer says unemotionally, as Marcos attempts to revive Piririta by dripping water into its orange beak, 'now they are spraying all the soy crops many insects are contaminated and then these birds are eating the insects and dying'. The bird that fell from the sky marks the end of my journey, I don't get to ask the young farmer the closing question I asked all the others I had met in Paraguay, 'how do you feel about the future?' Perhaps the bird answered the question for him. 'The environment is contaminated and so the insects are contaminated' he sighs as we walk to back to the farmhouse.[128]

[126] Personal communication (ref. 37). Pure circle third party farmer, San Pedro, Paraguay 29/09/18
[127] *Ibid.*
[128] *Ibid.*

The bitter-sweet aftertaste of the stevia leaf lingering in my mouth is offset against the sticky treacle smell of boiling sugar cane steaming from the subterranean furnaces surrounding the farmhouse. I shake hands with the young farmer's father, thanking him before we leave, and we joke at how father and son are both involved in a sweet business. 'You think ka'a he'ê can be a good cash crop for your son?' I ask him in Spanish. He looks at me seriously, 'the young people are all relying on marijuana, which is a problem' he says his 'esperanza' for ka'a he'ê is that it be a 'good alternative to working on the marijuana plantations.'[129]

The aspirations and hopes I encountered of those cultivating 'cash molecule' stevia under a contract model of farming did not differ greatly from my encounters documented in the previous chapter – of those cultivating public varieties of stevia (la Criolla or Eirete) through largely organic and independent models of farming. Similar assertions around the financial potential and family benefits of stevia, as well as the idea that it is, was, or could be the 'perfect cash crop' for campesinos were repeated. Both contract and independent farmers spoke of the fragility of the promise as part of the ongoing need to secure a cash crop like stevia for families to become more resilient to the ongoing challenges they face in their country. When describing the particular challenges they faced as small-scale farmers, both independent and contract stevia farmers were worried about the lack of opportunities for rural young men and the lure and danger of the prevalent marijuana industry. They all shared concerns over the lack of support for the 'campesino model' and small-scale farming in particular, including poor access to credit, rising debt, and the risks and consequences of land loss and land conversion. All farmers I encountered raised concerns with land conversion to transgenic or industrial soy in particular, and associated soy with some form of contaminated environment, whether in regard to negative health impacts, deforestation or reduction of biodiversity.

It was only when the farmers discussed trade-offs that the differences between the contract and independent models became clear. Two main divergences were the different agro-ecological conditions and inputs required to grow different types of stevia and the differing degrees of farmer autonomy over their land, labour and produce. The PC1 plants from seed to leaf are effectively never owned by the farmer. The company supplies everything except soil, water, sunlight and labour. On the one hand, this gave farmers security, having a contract with a reliable buyer and a relatively stable price. However, the contracted farmers complained about problems with plastic mulching allowing stronger weeds to grow which required arduous labour or Monsanto's Round-up™, a toxic herbicide, which the younger farmer said he applied between his rows of stevia. The plastic mulching they added made the plant more prone to disease, requiring the farmers to purchase fungicide from Pure Circle. Farmers complained that PC1 relied increasingly on expensive chemical inputs to survive as the years went on and accused Pure Circle of finding excuses to pay less and less for their harvests.

I have observed how experiences of farm realities, livelihoods, and meanings stemming from stevia differ, but remain connected through perceptions of the benefits it offers, the hopes for the future, and similar stakes pinned on its

[129] Personal communication (ref. 37). Pure circle third party farmer, San Pedro, Paraguay 29/09/18

potential. As families continue to carve out their futures in relation to the plant, stevia's promise-in-the-making, however – unbeknown to those I had spoken to – was beginning to undergo a 'big shift'.

Disrupting the promise.

Back in the Pure Circle office in Asunción one of the company managers explains: it's not as easy a cash crop as the promotional videos depict, 'you have to put in everything you have, you need a lot of money', he goes on, 'it will take you about two years to recoup your original investment but then from there on you're going to have a very nice income'.[130] A farmer with a good yield, he explains, 'is going to have an income that is higher than cultivating marijuana,' again acknowledging the hidden reality that cannabis is one of the few viable cash crops for small farmers in Paraguay (TNI 2016). The average Pure Circle farm size in Paraguay, he tells me, is between one-quarter of a hectare to two hectares, 'to put that into perspective, Pure Circle has 625 farmers across 500 hectares of land'. Last year (in 2017), he went on, 'we had contracts with 900 farmers'. I am surprised at the significant reduction, I was expecting to hear about the company's target of reaching 6000 hectares I had read about. He didn't say whose decision it had been to terminate the farmer contracts. Before I could ask, he excitedly began to talk about what he termed the 'big shift' or the 'transition period' for the company around the new Starleaf™ variety of stevia;

> The big shift here has been that we used to work with small farms and now we're trying to favour large scale farmers.[131]

I tried to hide my shock. I had just returned from travelling the country meeting small farmers, and everything I had read about stevia described it as a crop *for* small farmers, it was a non-mechanised crop. He went on, oblivious to my concern, 'yes the type of farmer that we are trying to develop now is completely different from the one we had in the past'. He elaborated,

> We're trying to focus now on better farmers because we want to make sure that the new variety are handled by people that are really good farmers of this crop because prices are more valuable. We need to put a lot of effort in selecting farmers properly.[132]

How are you selecting these 'better farmers'? I ask. He replies,

> We are trying to find and focus on what we call large-scale farmers that are not only able to grow crop, they're also able to do their own nursery, they're able to have a harvesting machine that can harvest the crop. They have a drying machine that can dry quickly, they have a cleaning plant, a planting plant and they do the bales and put them into a 25-ton [shipping] container.[133]

[130] Personal communication (ref. 39). Pure Circle, Asunción, Paraguay. 3/10/18
[131] *Ibid.*
[132] *Ibid.*
[133] *Ibid.*

He elaborates the ideal new kind of Pure Circle stevia farmer.

> They will be economically independent and sound to make the investments that need to be done. I mean, it's one thing for you to buy a pair of scissors and just wait for the sun to do the job. […] We're talking here about $700,000 USD for a dryer and harvester only, so I need to have a 100-hectare farm to dilute all these costs.[134]

He excitedly explains that a soybean farmer here has around 10,000 hectares, and 'if you go to The Chaco you're going to find people that have 50,000 hectares. So extension is not really a problem'. He leans back on his chair, 'we are now developing a number of farmers that have a potential of escalating to 100, 200, 500, even 1,000 hectares. 1,000 hectares is already a very large farm.' Because of this hunt for larger farms, he goes on, 'we are actively exploring other regions of the world. One of them is the US. We have now started with a number of North Carolina farmers' who once grew tobacco.[135]

'Are you still going to source leaves of the farmers that have small plots of land or just phase them out…?,' I ask with unease. 'Sure, we are sourcing leaf from them but we are not actively bringing new small farmers into the game,' he says. I ask about the public-private programmes to support small farmers, mentioning an article on Coca-Cola's website that stated through Pure Circle's program 'a first-year farmer can receive significantly greater income compared to other crops, resulting in substantial improvements in the standard of living for farmers and their families' (Coca-Cola 2016). He tells me that this '70:30 programme' was a collaboration between Pure Circle and the Paraguayan Ministry of Agriculture that 'provided financial assistance and critical equipment to support small-scale farmers'. He laughs, 'that was a very politically promoted plan,' noting that in reality, 'there was only about seven families on the programme'. He explained what he saw as the challenges, 'we help out the small farmers, but at the end of the day, they relied a lot on our technical support, on basically us having to babysit them through the process.'[136]

In just two years, between 2016 and 2018, the company narrative has completely changed. In 2016, Pure Circle's videos depicted small agro-diverse, agro-forested plots of stevia grown alongside subsistence crops, the promissory narrative focused on poverty reduction and sustainable livelihoods. In 2018, Starleaf™ was launched with a promotional video shot by drones above vast green fields, barely a hedgerow or a person in sight, stevia harvested by machinery. The differences in the videos visually represent what I was told in the Pure Circle office that day in Paraguay. In the latest Pure Circle video uploaded in 2019, an ex-tobacco farmer in the US stands in a large field of Starleaf™ and talks about his future,

> Five years from now we'll have infrastructure in place to successfully grow this crop, we'll have mechanisation from front-end to harvest all the way through so we can take some of the hands off the plant (Pure Circle 2019).

The 'big shift' from PC1 to Starleaf™ embodies the next stage in molecularisation of the plant, with leaves containing 20 times more of the elusive reb M molecule. However, this has implications, taking 'hands off the plant' in order to produce reb M in an economically competitive quantity. In 2018, the company announced aims to plant 16,000 tons of

[134] Personal communication (ref. 39). Pure Circle, Asunción, Paraguay. 3/10/18
[135] *Ibid.*
[136] *Ibid.*

Starleaf, 'a dramatic increase' of 200%, as a result of 'new farming partnerships in North Carolina' (Pure Circle 2018). This 'big shift' has coincided at a time when at least three companies employing synthetic biology techniques to biosynthesise reb M in large quantities are reaching commercialisation (Amyris 2019; NutraSweetNatural 2021). The global corporate stevia industry is undeniably being restructured around reb M (and to a lesser extent the also finite reb D molecules).

The Pure Circle director explained bluntly that it comes down to economics, in order to profit from leaf-sourced steviol glycosides in the face of new competition from what he called Cargill's 'non-natural' and 'GMO stevia', stevia leaf must be cost-competitive. With the shift to Starleaf™, he explained, Pure Circle could refine reb M at a price competitive with EverSweet™. 'If, let's say reb M costs $500 per kilo, and this other product costs $470, that is not a problem. Now, if the [biosynthetic] product cost $50, then we'll probably face some problems.'[137]

While the synthesis of the new cash molecule via synthetic biology requires no stevia farmers at all, the cultivation of the cash molecule crop, as I have discovered, implies a new type of stevia farmer altogether. In Paraguay, the new kind of stevia farmer eligible to cultivate the cash molecule is wealthy, can independently invest in expensive machinery and already owns huge tracts of land. Cultivating stevia in largescale monoculture ultimately deskills labour and replaces jobs with machines. With campesinos desperate for rural employment in an expanding people-less rural development model of mechanised monoculture in Paraguay, this shift is significant in many ways but especially to the small farmer promise. The inequities between farmers with capacities Pure Circle *now seeks* and small-scale campesinos it *previously sought* is an issue that perpetuates rural poverty in Paraguay (BASE-IS 2020). As already discussed, few viable cash crops remain for small farmers in Paraguay that provide sufficient returns to sustain campesino family livelihoods and reduce the risk of the last resort of which many farmers spoke, having to sell their land. While stevia has long been a promise-in-the-making in Paraguay, these latest developments shift the promise even further from reach, if not break the promise altogether.

The new promise being re-made about stevia is virtually the same for the Starleaf™ stevia variety as the biosynthetic cash molecule EverSweet™. Both new promises are based on 'sustainability' through comparative land-use calculations reducing cultivated land, CO^2 emissions and water use. While Starleaf™ claims its sustainable superiority in comparison to sweetness derived from sugarcane plantations, EverSweet™ claims superiority in comparison to sweetness derived from stevia plantations. I have critiqued the reductionist notion of sustainability Cargill ascribed to EverSweet™ in Chapter Three as it ignores the one of the three fundamental 'pillars of sustainability' globally recognised as 'integrated and indivisible' in the UN Sustainable Development Goal Agenda (UN SDGs 2021). The social pillar and its intersectionality between the socio-environmental and the socio-economic are intrinsic to any assessment of sustainability as I discussed concluding Chapter Five. Pure Circle's recent adoption of a Cargill-style reductionist sustainability is perhaps more stark as it stands in such contradiction to its original promissory narrative about what 'makes stevia sweet in so many ways' in its former narrative aimed at convincing small and subsistence farmers to invest in stevia.

[137] Personal communication (ref. 39). Pure Circle, Asunción, Paraguay. 3/10/18

Before I left the Pure Circle office in Asunción, we commented on the national obsession surrounding stevia encountered with anyone with any relation to the plant. The man smiled, 'it's something that is very ingrained in the collective unconscious of Paraguay. There is this dream of stevia! …it's a strong fantasy and it's funny, but with the fantasy alone not much is being done. I'm not blaming anyone with this. It's not easy.'[138]

Stevia goes synthetic.

By early 2019 Paraguayan newspaper articles were warning about impacts of 'Synthetic Stevia' (ABC 2019). The American Stevia Federation came out publicly condemning 'against steviol glycosides extracted by methods other than the leaf called Stevia' fearing consumers were being misled, while the Paraguayan Chamber of Stevia hurriedly completed its designation of origin scheme (ADN Paraguayo 2018). Another Paraguayan newspaper reported that plantings of stevia had reached an all-time low, confirming the government agronomist's worst predictions of just 300 hectares (ABC 2021). By the end of 2018, Paraguayan stevia exports had fallen 84% in just one year from 1042 tons in 2017 to just 160 tons, reducing the value from $2,580,786 USD in 2017 to $522,708 in 2018 according to the Investment and Export Network (Rediex) within Paraguay's Ministry of Industry and Commerce (La Nación 2019; Godoy 2019). The promise of Paraguayan ka'a he'ê in 2020 appears to have deteriorated even more since I was there in 2018; one newspaper printed data showing that the majority of sweetening products in Paraguayan shops now use imported Chinese stevia (ABC 2020). Meanwhile the US FDA's import ban on 'Stevia Leaves, Crude Extracts of Stevia Leaves and foods Containing Stevia Leaves and/or Stevia Extracts' was edited in 2019 to include a new paragraph:

Figure 6.2 The emblem of the Stevia ka'a he'ê ® designation of Origin certification Scheme. Launched in 2018. Source: ADN Paraguayo (2018)

> It should be noted that steviol glycoside(s) may also be produced by fermentation technology without a need to use stevia leaves in the manufacturing process. In such cases, the import alert does not apply (FDA 2020).

As Paraguayan production spiralled in 2018, Pure Circle reported that use of stevia worldwide had increased by more than 31% (Pure Circle 2019). Concern over the impact of synthetic reproduction of stevia sweeteners upon Paraguayan and small farmers globally have been reported since Evolva and Cargill applied for their first patent (ETC group 2012). For years now, many have questioned the ability for natural product markets to co-exist alongside synthetic replicas (ICSWGSB 2012; FOE 2014). However, synthetic stevia sweeteners only became commercially available in 2018, a move that coincided with Pure Circle's 'big shift' in cash molecule, stevia variety and business model. The consequences of these shifts were starting to reverberate in 2018 through the confusion and frustration reflected from Paraguayan state agronomists, small businesses and farmers. To close this chapter, I summarise the reactions I encountered with participants across Paraguay to the new ability to produce stevia via synthetic biology fermentation.

[138] Personal communication (ref. 39). Pure Circle, Asunción, Paraguay. 3/10/18

Ka'a he'ê in Paraguay is widely consumed and even small supermarkets have ka'a he'ê sections, where shelves are full of various green and white packaged teabags and sweeteners in liquids, powders and leaves. These products adopt the iconography of leaves and some even images of Guaraní Indians (see Figure 7). Many of these products however are misleading, while explicitly labelled 'Ka'a He'ê' and 'natural', the small print ingredients often include a higher proportion of artificial sweeteners such as saccharin, or aspartame or refined corn-sucrose, than steviol glycosides.

Figure 6.3 My own photos of stevia ka'a he'ê products in a small supermarket in Plaza Uruguay, downtown Asunción, October 2018.

A main concern from respondents regarding the impact of biosynthetic stevia revolved around the ability for large companies to deliberately mislead consumers through labelling, images, language and advertising, a problem clearly already playing out on Paraguayan supermarket shelves on products packaged as leaf-sourced stevia. Conflicts over food labelling regulations regarding the 'naturalness' of products made using synthetic biology fermentation, and whether they can be labelled as natural, 'nature identical' or even 'non-gmo' has been an ongoing epistemological battle-ground between companies, producers and consumer groups (Roseboro 2018; US Right to Know 2019). Socio-environmental NGOs contest biosynthetic 'natural' products as 'GMOs 2.0' and have released a 'Shoppers Guide' for how to identify synthetic biology in consumer goods, accusing companies of sneaking ingredients and techniques that are 'unpredictable, untested, unjust, and unsustainable' (SynBiowatch 2016). Despite pockets of backlash, as of 2021, with further biosynthetic products launched over the last 3 years, and now 3 versions of biosynthetic stevia commercialised heralding its purity and naturalness, the epistemological battle looks increasingly won by the SynBio industry. The molecularised interpretation of natural equivalence has significant consequences for the co-existence of the different modes of production (Roseboro 2018). In Paraguay the importance placed on how ka'a he'ê and how naturalness is interpreted, labelled and governed demonstrates the stakes of expanding one mode of production at the expense of another.

In 2011, steviol glycosides derived from farm-grown stevia leaf were entered on the International Numbering System (INS) of the UN's CODEX Alimentarius, the international body for food standards, safety and fair practices in the food

trade, under the ingredient code INS 960. Since then, companies using synthetic biology techniques have been pushing for steviol glycosides 'produced by fermentation of a genetically modified yeast' to be classified under the same ingredient code (FAO & WHO 2018). In the office of a small Paraguayan stevia business, one of my respondents who was a part of the Paraguayan Chamber of Stevia 'CAPASTE', described how controversial this has been.

> Paraguay said no you cannot do that! You are going to kill all the farmers in the world if you do that, stevia will die, worst we don't know what effects it could have, and it could kill stevia around the world and nobody would know that it is not natural, if it comes from the plant or if it comes from the synthetic production.[139]

The corporate lobbying to include biosynthetic stevia didn't quite achieve its aim to gain the exact same classification as the leaf but came considerably close. In 2018, the UN CODEX settled the directives for labelling steviol glycosides 'identical' to those produced by the plant. Henceforth, leaf-derived steviol glycosides would be categorised **INS 960a** while those derived from 'multiple gene donors expressed in yeast' would be categorised **INS 960b** (Codex Alimentarius 2019). This landmark decision in 2018 not only set a precedent for the future of stevia, but for the numerous other synthetic biology 'natural' ingredient substitutes that are undergoing R&D. The small stevia business-owner expressed his concerns,

> I think it is going to have a bad effect because with this 'a' and 'b' and other forms of extraction for producing stevia is going to be very complicated for people to understand, I think it is something that we can teach the consumers to say 'a' is natural and 'b' is not natural, but […] it is very difficult for the consumer to have an extract from the leaf and an extract from other sources but both of them are stevia. So I imagine that nobody will know. And normally it's only the biggest companies that have the money to educate. But the big companies will not want to educate the consumers about this.[140]

He explains that small-businesses and farmers in Paraguay 'can't compete with something that is made cheaper' elaborating the importance of the notion of naturalness as something connected to the earth. The businesswoman I met in Asunción had a similar reaction when I asked whether she thought biosynthetic stevia would affect her livelihood, responding angrily,

> Of course it will. If they do it in a lab the prototype is going to be expensive but once they can mass produce it the cost will go down and that will kill the plantations. I mean why plant it if you can have a product made in the lab, again it's going to be much cheaper than all the things we need. Stevia has a lot of cost especially with small producers, so if a company can do everything on their own with everything under their control and with cheap prices of course they will decide to go that way instead of the hard work that we are doing.[141]

Again, the notion of naturalness was deemed the crucial issue, as the businesswoman argued,

> **I**t's not natural because stevia is a plant, and if you go back to the origin it is a plant and the leaves are sweet, that's where you get the sweetness from, and of course it has to go through a process like sugar to get white

[139] Personal communication (ref. 42). Asunción, Paraguay. Paraguay 9/10/18
[140] *Ibid.*
[141] Personal communication (ref. 26). Asunción, Paraguay. 20/09/18

> crystals. The other is genetically modified organism, it is not natural at all and it is not stevia, they can call it what they want, but it is not stevia.[142]

I explained that Cargill refers to their product EverSweet™ as a 'stevia sweetener' and other companies are calling their synthetic product 'steviol glycosides' describing the leaf molecule, rather than the whole genus name stevia. The businesswoman replied, exasperated,

> No but the steviol glycosides *are* the sweetener, the natural sweetener made from the leaves, so they cannot call it that, they can call it whatever but not stevia *or* steviol glycosides. […] There are a lot of natural sweeteners, but nothing born in a lab can be called natural. It's going to kill all the plantations, and all the farmers, and the people that live off this industry![143]

Unlike the business owners, few small farmers I met were aware of synthetic biology or fermented steviol glycosides, but when I explained that scientists had discovered a way of producing the same molecules found in the stevia leaf by genetically engineering microbes in the laboratory to copy the natural process, they all had a similar reaction of dismay, that this should not be considered a natural process or product, one said 'I'm not a technician but I know that something produced in a lab will not be the same thing and would not have the same quality as something that is naturally produced.'[144]

Those who were aware, or those who said they were feeling the impacts of biosynthetic stevia production, were already trying to refine their focus toward the 'niche markets' for organic or medicinal Paraguayan stevia. Others were more sceptical, asserting that companies employing synthetic biology fermentation will continue to rely on and exploit the natural and green reputation of stevia as a leaf, so will support a minimal amount of leaf production for the imagery. The agronomists I interviewed shared this view,

> They want to make synthetic rebaudioside M, so they no longer need to cultivate, they are going to get the molecule synthetically, but they will keep growing the crops, I think, to justify what they will do in laboratory.[145]

Some in Paraguay believed the biggest companies in the industry had financial stakes in both leaf and synthetic production in the form of investments throughout the wider agro-industrial complex entwining agro-chemicals and commodity crops such as corn, soy and sugarcane. Aside from Cargill, it is difficult to corroborate such connections with other companies in the industry such as Pure Circle. The world of parent companies, corporate affiliates, subsidiaries and strategic partnerships are entangled and often deliberately murky (Whittel 2014). Through the lens of Cargill's EverSweet™ however, this complex process can be observed. The R&D of EverSweet™ involved multiple corporate deals and investments, from mergers and acquisitions in the early days of Evolva, to the Cargill takeover, and finally to the 2018 joint venture between Cargill and its main competitor DSM to commercialize EverSweet™ under a whole new company named Avansya, the same name as its previous competitor's brand. Multiple companies, brands, diverse investments and global commodities have entwined in bringing EverSweet™ to market. The industrial agricultural

[142] Personal communication (ref. 26). Asunción, Paraguay. 20/09/18
[143] *Ibid.*
[144] Personal communication (ref. 36). Ex-Pure Circle third party farmer, San Pedro, Paraguay 29/09/18
[145] Personal communications (ref. 44). Caacupe, Paraguay 11/09/18

complex from which synthetic stevia emerges has been conducive to its reproduction. However, EverSweet™'s success, indeed the success of any biosynthetic stevia sweetener, is clearly rooted in the reputation and associations stemming from the leaf and the plant itself. From the very DNA inserted into the organism to convert a feedstock into steviol glycosides, to the perceptions of naturalness, the connection between plant and synthesis cannot be disentangled.

Indeed, it is the impossibility to separate new forms of stevia with the 'natural' plant and the plant's legacy that has fueled a palpable sense of injustice in Paraguay. Heralded as the country of origin, Paraguay is widely considered the provider of stevia to the world and the diversity of participants I encountered in Paraguay all felt in differing ways that they deserved to benefit from the promise of stevia.

Concluding a sense of injustice.

On October 3rd 2017, one year before I arrived in Paraguay, a public forum was held in the capital Asunción under the title 'El ka'a he'ê amenazado por la biología sintética y las patentes' translating into English as *Ka'a he'ê threatened by synthetic biology and patents.* The event was organised by the civil society group - the Latin American Technology Evaluation Network known as 'Red TECLA' - and a Paraguayan social research group called 'BASE-IS'. Participants included representatives from the Pai Tavyterâ community, civil society, academics and campesino organisations, among others. During the event participants remarked how ka'a he'ê had already been 'privatized' through patents held by companies such as Pure Circle, and that this process had paved the way toward what they referred to as the current 'threats' and 'risks' of synthetic biology. One asserted in Spanish: 'today, large corporations in the food industry produce stevia's active ingredients in fermentation tanks; with this they are stealing the plant not only from the indigenous people but also from the peasants' (BASE-IS 2017). Another added that there are 'hundreds of small producers' in Paraguay who 'maintain the agro-ecological cultivation of the Creole variety of the plant, despite the lack of state support for family farming' (BASE-IS 2017). One Pai Tavyterâ leader presented his people's understanding of ka'a he'ê as a plant beyond its use as a sweetener, others described this as a 'collision of knowledge' with food agribusiness (BASE-IS 2017). Following the event the Paraguayan organisation summarised the sentiments on its website that the synthetic biology substitution of 'active ingredients such as stevia' implies a more profound cultural effect beyond market distortion and land concentration, they suggested that it could 'alter the general perception of the importance of diverse crops as agricultural legacies of specific civilizations' which would increasingly render them **'substitutable or expendable, along with the farmers who have raised them for centuries**' (BASE-IS 2017).[146]

The accusation highlighted at this event of stevia 'being stolen' from Indigenous Peoples, the peasants that bred the first varieties, or indeed the Paraguayan nation, was recurrently raised in my own encounters through the notion of ownership. 'Ka'a he'ê is our plant' was claimed by the Pai Tavyterâ, but also by campesinos who conceptualised ownership through the prism of the stevia promise *belonging* to them, in contrast to the promise of soy which *belonged* to the latifundios and big-business. The Paraguayan state amplified a form of ownership by heralding stevia as a sovereign genetic resource and a plant of national interest that one government respondent asserted should benefit

[146] Personal communication (ref. 40). BASE-IS HQ, Asunción, Paraguay 4/10/18

'our people, with our raw materials, with our soil, with our germplasm.' These diverse notions of ownership in Paraguay connect and contrast to the formalised ownership regimes of Intellectual property rights and the patents owned by Pure Circle and Cargill and other companies in the burgeoning stevia industry. Intellectual property regimes rely upon molecularisation to distinguish innovation from evolutionary or agricultural legacy. These processes of molecularisation involve plant breeding techniques and methods of molecule isolation, extraction and alteration that can be patented, in contrast to the cultivation of an unmodified plant and a naturally occurring molecule.

In this chapter I characterised stevia's molecularisation into two stages. The *first* stage, transforming stevia into a corporate cash molecule, was marked by increasing commercial focus on steviol glycosides, the sweetest molecules, primarily reb A, found in its leaves. The first stage globalised both the plant and the campesino cash crop promise that first emerged in Paraguay in the 1970s. Since the early 2000s, the promise of stevia has been re-invigorated as bringing socioeconomic and sustainable development to low-income farmers in rural Paraguay and beyond, extending the promise to proprietary varieties of stevia through 'third party' farmer contract models. The extent to which this model met the stevia promise in Paraguay remains uncertain, but it certainly fell far short of the goal of reaching 6000 hectares, let alone the 20,000 hectares many hoped would enable Paraguay to take over Chinese production (El País 2016; Godoy 2019). The 'third party' contract farming families spoke to me of great potential and great need for a small-farmer cash crop, though they also described a promise only ever marginally met, a response similar to the independent farmers I encountered cultivating organic native stevia in the previous chapter.

The latest second stage of stevia's molecularisation disrupts the promise altogether. The new cash molecule of economic interest is reb M for its ability to replace 100% of sugar ingredients. However, reb M is available in such minute quantities in the leaf that stevia has been modified into a new proprietary variety, Starleaf™, which in order to be cost competitive with new biosynthetic stevia, must be cultivated in large, mechanised farming systems. While the synthetic biology fermentation of biosynthetic stevia can do away with stevia farms and farmers altogether, the leaders in the leaf industry are undertaking a 'big shift,' abandoning the small farmer promise to favour large farms and wealthy farmers capable of investing in infrastructure and machinery. Combined these two developments work to expand both directly and indirectly mechanised industrial agriculture of stevia, corn and soy at the expense of small peasant farmers, in doing so breaking and re-making the stevia promise.

Ownership has emerged as another important zone of frictious dis/connect illuminating one avenue to interrogate what biosynthesis implies. Conceptualisations of ownership between the 'worlds' of those who understand stevia as a bioeconomy commodity, as a sacred family member, as a cash crop, as a cash molecule, and as will be seen – as cash DNA – stand in contrast and illuminate the stakes riding on stevia. A strong sense of injustice in Paraguay has developed in response to the molecular forms of stevia ownership which has increasingly transformed ka'a he'ê into a privatised resource. This sense of injustice – as another significant zone of dis/connect – is not solely about the rightful owners of stevia or the unfulfilled promise of stevia. It is also about who deserves to benefit from stevia, and the historical colonial and contemporary allegations of corruption and (mis)appropriation that have affected Paraguay's Indigenous peoples and campesino farmers. It is as equally about what is being gained or expanded through the 'changing nature' of stevia as it is about what is being lost or expended in the process, and how these changes reverberate and have indirect effects and affects.

As the participants at the event in Asunción highlighted, these 'shifts' not only 'threaten ka'a he'ê' as an endangered wild species and its closest relative (the creole variety) being maintained by peasants, they fear these shifts also imply that the meanings, livelihoods, uses and knowledge that has built up around the stevia plant, indeed its very authenticity or 'agricultural legacy' as they phrased it, is 'substitutable or expendable'. Across my interactions in Paraguay, many spoke of *what constitutes stevia* as something tied to both spatial-endemic origins and the plant's socio-ecological interactions over time and the sense that this history or legacy could somehow be eradicated through the synthetic reproduction of stevia.

Further cementing this sense of injustice was the dismay I encountered over the idea of the appropriation of authenticity and in particular the appropriation of the 'naturalness' of stevia. Naturalness was amplified as the signifier of 'real' or authentic stevia. While there is no universal definition of 'natural stevia', all participants in Paraguay from business to state to campesino actors, spoke of natural stevia as being connected or indeed rooted to the land, the seed, the soil, the climate, the farmer. The socio-ecological context was described as being the defining marker of a natural product, rather than a molecule that looks the same under the microscope. Yet by giving the biosynthetic product the same names as the molecules derived from the plant as Cargill and its competitors do referring to products as a 'stevia sweeteners' or steviol glycosides inescapably ties them to a specific agricultural legacy in Paraguay. The 'ancient use' as companies describe it, and the past 20 years of naturalness and agricultural imaginary constructed around stevia are ingrained globalised associations of the plant. The chapters throughout this thesis have highlighted multiple aspects of this agricultural legacy that have fed into a broader authenticity narrative to boost stevia's global popularity. This authenticity narrative amplifies naturalness and connections with particular people from stevia's socio-ecological bio-cultural past such as 'Guaraní Indians' giving products healthy, green, and ethical credentials alongside portrayals of 'hard-working' peasant farmers in Paraguay and Kenya (Coca-Cola 2016; Pure Circle 2016). My research has shown that while representations of these actors have been instrumental in diverse promissory narratives and corporate invocations of the 'natural' and 'ethical', the reality 'on the ground' is glaringly disconnected.

Following stevia through juxtaposed 'worlds' described over the last four chapters has not only highlighted multiple understandings of stevia beyond its use as a zero-calorie sweetener, but has underlined four discursive zones that connect differently conceived and perceived notions of ownership, authenticity, sustainability and justice within and between these worlds. The frictious way these notions play out through contradiction and contrast illuminates important considerations over what biosynthesis implies.

2018 turned out to be a pivotal year in comprehending what biosynthetic 'natural' stevia implies for the socio-spatial and agro-ecological relations in Paraguay**.** EverSweet™ and Starleaf™ co-emerged in juxtaposition to a drastic reduction in leaf exports and number of small stevia farms in Paraguay. The breaking of the 'cash molecule' promise of stevia for small farmers in Paraguay stands in juxtaposition to the re-making of the promise for a new group of large-scale farmers in Paraguay, and ex-tobacco and corn farmers in the United States.

Contrary to broad concerns about biosynthesis eradicating or replacing entire agricultural versions of plants, what appears to be happening is much more insidious and obscure. Agricultural leaf-derived 'stevia' will likely remain available alongside biosynthetic 'stevia'. However, the significance of subtle definition changes – from reb A to reb M,

and from INS960a to INS960b – I have discovered imply not only a different molecule, source, or production process, they imply transformative changes to livelihoods, meanings, rural development strategies, as well as changes affecting land-use, rural migration, biodiversity conservation, and ultimately who can and who can no longer benefit from stevia.

The biosynthesis industry seems in denial or incompetent of any serious consideration of the social and cultural knock-on effects of their industrial process either in terms of driving forward the mechanisation of stevia farming, and the effects that entails, or of driving down the price of stevia, or for the impact upon the predominant socio-cultural understandings of 'naturalness', or even the effects of what is quite blatantly an overt obscuration of significant differences between leaf-derived or fermentation derived 'natural' molecules.

The transformative and (in)direct changes brought about by biosynthesis of natural products are being grappled with as part of broader considerations over positive and adverse effects of synthetic biology through ongoing negotiations at the UN Convention on Biological Diversity (CBD), a multilateral governance arena charged with ensuring the conservation and sustainable use of biological diversity, and the fair and equitable sharing of benefits over genetic resources.

As stevia's story continues to unfold across the multiple sites traversed in this ethnography, I turn now to the CBD as the final site of investigation. The CBD weaves together the sites, actors and molecules already encountered as well as institutional interpretations of ownership, authenticity, sustainability and justice, and opens up a new conceptualisation of stevia as 'digital sequence information' I characterise as 'cash DNA'. (I use cash DNA to signify the change in the value of stevia moving from the production of its valuable molecules, to the value of stevia's genetic instructions 'unlocked' through the 'secrets' of its DNA). As multiple worlds collide at the CBD, established modes of molecularised governance struggle to keep pace.

Chapter Seven.

Stevia and Synthetic biology at the UN Convention on Biological Diversity.

> In the vast lobby of a sparkling conference arena, part of the Cancun Moon Palace Hotel complex in Mexico, a pirate-clad performer with a megaphone invites the thousands of passing delegates attending the United Nations Biodiversity Conference to witness 'The 2016 Captain Hook Award Ceremony for Biopiracy'. An audience quickly assembles, I join the others recording the event on a smartphone. The 'greediest biopirate award' the performers announce, goes to… 'Coca-Cola for massively profiting from Stevia in their beverages while traditional growers, the Guaraní groups living across Paraguay and Brazilian borders make very little; and developing SynBio stevia with Evolva threatening the livelihoods of those farmers even further' the crowd cheers ironically (Synbiowatch 2016). What starts out as a comedy NGO stunt with stick-on beards and eye-patches, quickly turns confrontational. A delegate from a country being issued the winner of the 'Worst Government Behaviour Award' for not tackling biopiracy takes the megaphone gesturing a group of synthetic biology students funded to attend by the *International Genetically Engineered Machine (IGEM) Foundation* to stand alongside her as she angrily responds to her pirate-clad accusers. A stand-off ensues between the pro-SynBio NGOs and students, and civil society groups and members of the youth biodiversity network critical of synthetic biology.

Stevia has repeatedly been mobilised during the meetings and conferences of the UN Convention on Biological Diversity (CBD) as an example of both a 'genetic resource' requiring a benefit-sharing agreement between corporate users and the Indigenous traditional knowledge holders and simultaneously as an example of a sustainable small farmer cash crop threatened by synthetic biology. The story of stevia has become embroiled in the story of synthetic biology and looked upon by many as a test-case for the future of commercial lab-grown ingredients. Since 2010, the CBD has been the highest global governance platform for knowledge-making and decision-making on synthetic biology.

This chapter interrogates the governance spaces in which the geopolitics of synthetic biology play out, and how the framings, imaginaries and mobilisations adopted by participants at the CBD intersect with the story of stevia and synthetic 'natural' product replacements more broadly. While other controversies played out at the CBD in relation to synthetic biology, particularly around the potential release of gene-drive organisms, biosynthesis was discussed as having more imminent impacts as lab-grown 'natural' products were entering the market or nearing commercialisation (for a broader analysis of synthetic biology politics at the CBD, see Scott 2015 or Eastwood 2019).

This chapter focuses on the terms, framings and imaginaries in which participants contested synthetic biology R&D. I start by situating synthetic biology within a short history of the CBD's biotechnology battles and legal protocols. I focus on three areas of negotiation that are of particular significance for governing biosynthetic innovation. Firstly, I look at the development of the language around 'Socio-economic, Cultural and Ethical (SECE) considerations,' a framing negotiators used to contextualise global concerns over impacts to rural livelihoods, socio-ecological sustainability, cultural beliefs, and questions over private versus public benefit, trade and commodity production. Those advocating for 'SECE considerations' mobilised stevia as an example of 'sustainable use' and attempted to situate and embed SynBio innovations within the socio-ecological contexts from which they emerged and affect as a result. The decisive outcome of the talks, however, failed to ensure SECE contexts be taken into account.

Second, I analyse the uncontested framing of synthetic biology into disaggregated organisms, components and products (OCPs). Paradoxically, disaggregation was mobilised in negotiations to argue for very different outcomes: more regulation and less regulation. Disaggregation reflects synthetic biology as a worldview, but also reflects the molecularised epistemology of the living world that restricts the terms through which policymakers were able to assess new technology. Such shortfalls were demonstrated in the fact that stevia was mobilised simultaneously as organism, component and product at the same time.

Thirdly, I turn to what continues to be the most contentious issue to emerge from synthetic biology negotiations - Digital Sequence Information (DSI), and how debates that played out over the so-called '(de)materialisation of genetic resources' opens up a political chasm between distinguishing the genetic code from the materiality of life. Stevia mobilised in this context reveals the latest reconfigurations of value around a new world of stevia as a privately held digital genomic sequence, or as I call it 'cash DNA'.

Finally, I look at these three contested processes in tandem: socio-ecological **decontextualization**; the **disaggregation** of the living world and emerging **dematerialised** perceptions of 'life itself', and unpack them in reference to my ethnographic observations following stevia in Paraguay and the United States. I argue that decontextualization, disaggregation and dematerialisation both in the technological sphere and the policy-making sphere co-produce and co-constitute an increasingly molecularised logic of governance. In a field where regulatory policy is recognised as struggling to keep pace with technological advance (Wynberg & Laird 2017), I conclude that while this molecularised logic of governance is ill-equipped to address the joined-up, multi-sited problems and issues at stake that stevia has been mobilised to represent, the very nature of multi-lateral, multi-sited platforms such as the CBD and its overarching goals remain significant and more imperative than ever to achieve.

Synthetic biology at the CBD.

One of the three Rio Conventions agreed at the 1992 Earth Summit, the Convention on Biological Diversity (CBD) entered into force in 1993 with three major objectives: the conservation of biological diversity; its sustainable use; and

'the fair and equitable sharing of the benefits arising out of the utilization of genetic resources', more commonly referred to as the ABS objective (Access and Benefit-Sharing). Almost every country is signatory to the CBD with the notable exception of the United States. A key underpinning of the CBD is its aim to address centuries of unequal exchange of biological resources and associated 'traditional' ecological knowledge between the so-called 'providers' of the biodiverse South and the 'users' of the colonial North (Wynberg & Laird 2009; Bond & Scott, 2020). During the 1990s, ecosystems increasingly became imagined as 'depositories of vast biological intellectual property' for 'bioprospectors' seeking new molecules and compounds for pharmaceuticals and consumer goods (Bond & Scott 2020:25). In 1995, the World Trade Organization's agreement on Trade-related Aspects of Intellectual Property Rights (TRIPS) established that genetic materials could be 'treated as standard commodities to be patented and traded without any reference to ABS' (Bond & Scott 2020: 26). The following decade saw Northern patent offices receive record numbers of applications seeking to patent biological materials (Oldham 2007). The term *biopiracy* was coined to contest ongoing commercial exploitation of Indigenous Peoples' and local communities' traditional knowledge and use of plants, crops or natural remedies without adherence to the CBD's objective on fair and equitable access and benefit-sharing (RAFI 1994; Shiva 1997; Oldham, 2007). After a decade of contentious debate at the CBD the 'Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization' was adopted in 2010. The Nagoya Protocol came into force in 2014 aiming to provide 'legal certainty and transparency for both providers and users of genetic resources and/or associated traditional knowledge (Nagoya Protocol 2011).

During the same period, another protocol was under formation at the CBD in response to the biotechnological breakthroughs of the 1990s enabling the transfer of genes between species and the application of genetically modified organisms (GMOs), particularly in agriculture. Broader concerns surrounding GMOs' potential risks to biodiversity, human health and socio-economic impacts, as well as the United States' push for global acceptance of GMO exports, were topics that sparked further contestation at the CBD (McAfee 2003). These concerns culminated in the Cartagena Protocol on Biosafety which came into force in 2003. The Cartagena Protocol aims 'to protect biological diversity from the potential risks posed by living modified organisms (LMOs) resulting from modern biotechnology' (Cartagena Protocol 2000). The protocol does not distinguish GMOs from LMOs, defining them 'as any living organism that possesses a novel combination of genetic material obtained through the use of modern biotechnology' (Cartagena Protocol 2000).

These two protocols and the so-called 'biotechnology battles' that preceded them (McAfee 2003) foregrounded the arrival of synthetic biology as a 'New and Emerging Issue' (NEI) at the CBD in 2010[147]. Synthetic biology officially entered negotiations in 2012 at COP 11, when parties identified that 'organisms, components and products resulting from synthetic biology techniques may have impacts on the conservation and sustainable use of biological diversity and associated social, economic and cultural considerations' setting in motion a process to gather 'relevant information' (CBD 2012). In 2014 at COP12, parties decided to extend the information gathering process, establish an Online Forum

[147] 'New and Emerging Issues' (NEI) is a governance mechanism introduced in 2006 by the CBD COP to permit issues of particular novelty and urgency to be considered at the meetings of the SBSTTA (Decision VIII/10 Annex A).

and an Ad Hoc Technical Expert Group (AHTEG) to address seven 'substantive issues' on synthetic biology[148] and deliver its conclusions to the CBD's main advisory body known as the 'SBSTTA' (Subsidiary Body for Scientific, Technical and Technological Advice) at its 20th meeting in April 2016. I began ethnographically following synthetic biology in 2015 and attended the week-long 2016 'SBSTTA 20' meeting in Montreal, Canada, as an observer.

When policymakers came to the negotiating table on synthetic biology at SBSTTA 2016, they did so with the first substantial, globally-collected, peer-reviewed body of knowledge on synthetic biology which addressed questions policymakers themselves had set (CBD 2015; CBD 2016b). After days of negotiation, an operational definition for synthetic biology was agreed: 'synthetic biology is a further development and new dimension of modern biotechnology that combines science, technology and engineering to facilitate and accelerate the understanding, design, redesign, manufacture and/or modification of genetic materials, living organisms and biological systems' (CBD 2016). Policymakers clashed over the findings of the Expert Group, listing the 'potential benefits and adverse effects' that synthetic biology could have upon the overarching goals of the convention, and the regulatory 'gaps' synthetic biology opened up. Gaps were identified within the framings of synthetic biology as organism, component or product (OCP), as well as gaps over potential impacts of synthetic biology to the diverse global 'socio-economic, cultural and ethical' contexts within which a SynBio 'organism, component or product' (OCP) would be deployed or have an effect.

It was in these debates from SBSTTA 20, to the following Conference of the Parties (COP 13) in Mexico and 2 years later at COP14 in Egypt 2018 that I subsequently attended, alongside other discussions at the UN International Labour Organization[149] and the UN Conference for Trade and Development (UNCTD 2018), that I observed how stevia was repeatedly mobilised as an example warning of the 'potential adverse effects of synthetic biology'. The CBD Expert Group (AHTEG) report identified synthetic biology as having direct and indirect, intended or unintended, as well as immediate or delayed effects upon the '**sustainable use of biological diversity',** including the assertion that 'Increased demand for biomass crops, as well as changes in patterns of extraction of biomass, minerals and other sources of energy, may lead to changes in land use' and 'Replacement of natural products may lead to changes in the agricultural practices of communities, which may adversely affect traditional crops, practices and livelihoods' (CBD 2016b – see also annex 10.3). In response, stevia was mobilised as an example of the 'sustainable use of biological diversity', with groups describing stevia as a low-impact cash crop sustaining agrobiodiverse farms and small farmer livelihoods.

Meanwhile stevia was also mobilised as an example of a 'genetic resource' in debates over synthetic biology's adverse effects upon the '**Equitable sharing of the benefits of biological diversity'** the CBD Expert Group identified as including:

[148] The substantive issues included: developing an operational definition of synthetic biology, SynBio's relationship to biological diversity, whether rules governing Living Modified Organisms (LMO's) under the Cartagena Protocol could apply to the organisms, components and products of synthetic biology, the adequacy of existing national and international arrangements, legislation and regulations to address the impacts of synthetic biology, and finally, the potential impacts of synthetic biology, in terms of both benefits and adverse effects.

[149] I was invited to attend a conference at the United Nations International Labour Organisation in Geneva titled 'Governing Biotech 2.0: How Synthetic Biology will Impact Rights, Livelihoods and Life. 9th December 2015. Hosted by the International Union of Foodworkers (IUF) & the ETC group funded by the EC programme: Synenergene (2017).

(k) Loss of market share and income by Indigenous and local communities due to the altered exploitation of genetic resources;

(l) A shift in the understanding of what constitutes a genetic resource and the implications thereof, such as the misappropriation of the original source of the DNA information and, consequently if benefits are derived from the use of such DNA information without prior informed consent and mutually agreed terms the fair and equitable sharing of the benefits would not be possible;

(m) Inappropriate access without benefit sharing due to the use of sequenced data without material transfer agreements under the Nagoya Protocol;

(n) Patent driven and open source approaches to synthetic biology may have different implications in the context of access and benefit sharing;

(o) Indigenous peoples and local communities will not necessarily support or benefit from the utilization of genetic resources in synthetic biology (CBD 2016b - *original copy in Annex 10.3*).

These imaginaries of synthetic biology's 'potential adverse effects' played out across the CBD meetings I attended. While other 'natural products' were mobilised during these conferences to illustrate related issues including saffron, vanilla, vetiver, artemisia, ginseng, rose oil, clary sage, squalene, agarwood and patchouli, stevia seemed to dominate as an example representative of two of the main political battles over fair and equitable futures for synthetic biology and the utilisation of genetic resources. I now summarise three areas of intense debate in the multilateral negotiations on synthetic biology that are also pertinent to the issues in this thesis around the biosynthesis of 'natural' products, and bring insights to the interconnections that emerged between sustainability, authenticity, ownership and justice.

(De)Contextualising the Socio-economic, Cultural and Ethical.

The Captain Hook Awards for Biopiracy was one of multiple side-events and stunts during SBSTTA20, COP13 and COP14 where NGOs mobilised stevia's various socio-ecological contexts to remind states of their legal obligations to the CBD, framing stevia as an example of a genetic resource being accessed and utilised in new ways by synthetic biology. However, imaginaries of synthetic biology's detrimental impacts were also voiced by states. Ethiopia, speaking on behalf of the Africa Group, opened the Plenary session on Synthetic Biology at the SBSTTA 20, describing toiling farmers whose livelihoods provide both income and environmental protection to contextualise the issues at stake for the continent.

> Some of the most important natural product commodities produced sustainably by African farmers are already being challenged by synthetic biology, by replacements biosynthesised in factories and laboratories. For example, millions of African women who produce Shea butter and cocoa butter, hundreds of thousands of farmers who tend vanilla plants in the forest, hundreds who grow rose petals for rose oil and tend saffron cultivate to protect soil from erosion, the tens of thousands of Africans who grow Artemisia. Chair, it is in this context that Africa would like to emphasise the need to consider socio-economic impacts when dealing with the organisms, components and products resulting from synthetic biology (Ethiopia, SBSTTA 20).

The African position was supported in 18 statements at SBSTTA 20 that referenced socio-economic, as well as cultural and ethical impacts and considerations as 'crucial', 'necessary', 'highly relevant', 'requiring action' as well as how

Norway phrased it; 'socioeconomic, cultural and ethical impacts should be assessed as we are on the brink of whole new era of molecular biology and engineering possibly with far reaching and deep societal implications' (Norway, SBSTTA 20).

At COP13 in Cancun eight months later, 'socio-economic, cultural and ethical concerns over the adverse impacts of synthetic biology' were voiced by even more countries. In the opening Agenda item session on synthetic biology, St Kitts & Nevis[150] asserted - speaking on behalf of the Caribbean Community - 'we are concerned with implications of Synthetic Biology for Caribbean livelihoods that are grounded in commodity production'. South Africa added, 'we would like to urge parties and other governments to apply socioeconomic considerations based on the respective national circumstances and priorities including cultural practices, religious beliefs, and farming practices, in particular those related to the value of biological diversity of Indigenous Peoples and Local Communities'. A total of 23 parties argued that the socio-economic, cultural and ethical (SECE) considerations 'be taken into account' in decisions on synthetic biology, stressing the 'importance of SECE in achieving the three objectives of the CBD'; that 'SECE is important in the overall assessment of synthetic biology'; that 'each country needs to take decisions on the basis on SECE', and that this requires 'an ongoing process to address SECE and prioritise Socio-economic assessments'. Two party statements went further in their opposition to synthetic biology, advocating a moratorium until risks were fully understood. Bolivia asserted, 'synthetic biology is a new dimension of modern biotechnology, and it contravenes the fundamental pillars of the CBD as set out in objectives, so we see it as a challenge and a threat to biodiversity conservation.' Venezuela added 'we believe that any benefits arising [from genetic resources] should benefit humanity and not be solely for patents and profits. We support the proposal by Bolivia that there should be a moratorium on this technology until there is clarity'.[151]

In the side lines of SBSTTA 20, COP 13 and COP14, flyers and reports were handed around by civil society organisations (CSOs) imagining socioeconomic impacts to farmers in developing countries. One booklet by the ETC Group presented case studies describing 13 high-value cash crops for small farmers (including stevia) 'potentially displaced' by biosynthesis and arguing that those affected should be able to 'participate in the political and economic negotiations involved in any technological change' (ETC Group, 2016). Another side-event advertised by a poster of a green stevia leaf beside the title: 'Synthetic biology and Natural Products: Social, Economic and Biodiversity impacts' drew delegates of diverse nationalities crammed into an unsuitably-sized seminar room to listen to speakers from Friends of the Earth 'outline the threat to natural products' and summon imaginaries of cash crops in sustainable agro-ecosystems. The speakers warned Southern governments to be ready to protect their natural commodity markets due to 'misleading natural labels' and 'gaps in governance frameworks'.

In contrast, pro-biotech NGOs and groups of SynBio iGEM students attending their first UN meeting-organised side-events to promote their own imaginaries of synthetic biology as promising answers to what one group called 'crops in crisis' and two other groups called 'common enemies: starvation, malnutrition, environmental degradation, diseases

[150] It is conventional at the CBD COP's and SBSTTA's for the Secretariat staff and the Chairs of the sessions to refer to delegates speaking on behalf of their country under their country name, so instead of the 'delegate from St. Kitts and Nevis', they are simply referred to as 'St Kitts & Nevis'.

[151] All the country statements in this paragraph were quoted from Working Group II (WGII), Agenda item 17. On 6th December 2016. The COP13 working groups were also recorded as webcasts available at: https://www.cbd.int/cop2016/media.

and pests' (See side event flyers in annex 10.5). These groups downplayed the novelty of SynBio and argued in the Working Group that not one 'product of SynBio' would 'pose a special challenge for risk assessment and risk management' as they were 'sufficiently covered by existing biosafety systems' (PRRI, WGII COP 13).

Despite rarely speaking up against SECE considerations on the plenary floor or during the side events, in the contact group negotiations (which cannot be recorded), many Parties were clear they did not want SECE considerations to enter the text of the COP decision, let alone take action on any such considerations. At SBSTTA 20, one party repeatedly asserted they were 'really not comfortable with language on socio-economic or cultural and ethical considerations', another argued 'cultural and ethical aspects are not part of this convention'. A concerted effort was made (particularly by importer/exporters of GMOs) to remove any single reference to SECE. Eventually one party conceded that if any consideration of SECE was going to be recommended 'it must be scientific'. Another negotiator refuted that 'some cultural and ethical issues cannot be quantified through strictly scientific means' and asserted the COP recommendation should encourage the participation of Indigenous Peoples and local communities. In defending broader approaches to gathering knowledge beyond the 'hegemonic status of Science as a neutral vessel of universal truth', the delegate nodded to long-standing debates within the CBD over the scope, role, and limitations of capital 'S' Science, in the context of cultural and socio-ecological diversity (Rivers 2019: 117; Harding 2008; Gupta 2013). While it was clear why some delegates *did* want SECE included, the reasons why some delegates *did not* want SECE included were obscure. I witnessed delegates refer to the idea of socio-economic assessments as 'unmeasurable', 'subjective' and 'ethereal' in the COP13 concurrent negotiations under the Cartagena Protocol on socio-economic risk assessment of living modified organisms (LMOs). [152] Equally notable was that the polarisation between those who saw the socio-ecological context in which the technology would be deployed as more or less important reflected the divide between countries with more or less financial stakes on biotechnology.[153]

Summoning a starkly different approach in the synthetic biology negotiations was the Bolivian delegation who confounded many parties at COP13 by repeatedly calling for a conceptual shift from Life Science to 'sciences *for* life, including the knowledge, experience and perspectives of indigenous peoples and local communities, in order to compare and better understand the potential benefits and adverse effects of synthetic biology' (suggested text of the Bolivian delegation, COP13). Their calls were largely ignored by the other parties. However, their intervention highlighted that the narrowly defined 'science-based-decision-making' logic of environmental governance was not simply an unquestioned universal and opened up a space for alternative epistemological approaches to governing the living world. One interviewee who had experience working for both Bolivian government and civil society complained that while decisions regarding SynBio have repeatedly 'encouraged' IPLC participation, the structures are not designed to accommodate these perspectives, 'I don't think that IPLCs must adapt to this space, this structure' because of this he complained 'IPLC participation means too little'[154]. In the CBD 'open-ended online forum on synthetic biology' (an

[152] Unlike the UN Climate Change Convention, the CBD allows observers to be present during Contact Group negotiations, but recordings and media are banned. The statements from SBSTTA and COP contact groups are derived from my notes, and I do not ascribe any statements to a specific delegation to preserve these important observation rights.
[153] Personal communication (ref. 16) COP13, Cancun, Mexico. 10/12/2016
[154] Personal communication (ref. 10). COP13, Cancun, Mexico. 16/12/2016

interim information-gathering process between COPs), one spokesperson on behalf of 'Indigenous Peoples' participation also described the difficulties of this divide:

> There is a huge gap between Western scientists and Indigenous Peoples and Local Communities, on one hand there are labs, technical staff, trained professionals, budget, commerce, profits, on the other hand there is our traditional knowledge and our advocacy (men, women, youth and elders) to defend our life and survival and to having a healthy environment. We do not have budget and or personnel to work in this field, however we are already aware of the socio-economic impacts of these on the preservation and care of Mother Earth and all her ecosystems (CBD 2018).

After many days of polarised debate in side-events, conference corridors and contact group negotiations on SECE consequences of synthetic biology, compromise was reached during COP13 in the softening of the language enabling interpretive flexibility for parties who were not comfortable with SECE. I highlight below in ***bold italics*** the language that was a product of this compromise. The final COP13 Synthetic Biology decision: ***'invites'*** rather than 'urges' 'parties ***in accordance with their applicable domestic legislation or national circumstances,*** to take into account, ***as appropriate,*** socio-economic, cultural and ethical considerations when ***identifying*** the potential benefits and potential adverse effects of organisms, components and products resulting from synthetic biology techniques in the context of the three objectives of the Convention' (CBD 2016c). The subsequent decision 9. '***encourages'*** socio-economic, cultural and ethical considerations to be taken into account ***'if appropriate and in accordance with domestic legislation or national circumstances***', listing 4 areas of activity (relevant for SECE consideration): a) conducting further research into benefits and adverse effects of the Organisms, Components and Products of synthetic biology; b) in promoting and enabling public and multi-stakeholder dialogues and awareness-raising activities on the Organisms, Components and Products of synthetic biology, and c) in the development of guidance and capacity-building activities on potential benefits and potential adverse effects of the Organisms, Components and Products of synthetic biology (CBD 2016c).

The final decision included the words 'socioeconomic, cultural and ethical' but clearly lacked any substantial imperative for action or future co-ordination for further assessment. Perhaps this is down to the conventional norms and molecularised logic of environmental governance, that restricts policymakers' ability to grasp or address issues perceived as 'non-Scientific' (Jasanoff & Martello 2004). Or perhaps it is down to the lack of meaningful participation of IPLCs in decision-making processes, despite the CBD being one of the few global treaties that makes space for IPLCs to engage. While the question of whether the socio-economic, cultural and ethical should be considered in the governing of synthetic biology was highly contested, virtually all parties and participants were united upon (or at least did not contest) the repeated referral to synthetic biology in terms of disaggregated organisms, components or products.

(Dis)Aggregating Organisms, Components & Products.

The disaggregated framing of synthetic biology in terms of organisms, components or products (OCPs) was rationalised to fit the CBD system that distinguishes between living modified organisms and non-living components or products (AHTEG report in CBD 2016). The Expert group and later COP13 decided that organisms from synthetic biology are 'similar' to 'Living modified organisms' as defined by the Cartagena Protocol on Biosafety. While non-living

'components would refer to parts used in a SynBio process (for example, a DNA molecule), the term 'products' would refer to the resulting output of a SynBio process (for example, a chemical substance)' such as steviol glycoside (CBD 2016). While this disaggregation has implications for how the science is understood and governed, it was almost universally accepted by participants. However, in the negotiations themselves parties put more emphasis on either organisms or components and products in pushing for different regulatory outcomes. While some parties emphasised the novelty of components and products of SynBio in order to highlight gaps or loopholes in regulation, and therefore that *more* oversight and action was needed, other parties emphasised the non-novelty of SynBio organisms, and that components and products were *already* regulated domestically, to argue that *no further* oversight or action was needed. As Canada, supported by 'like-minded' pro-biotech countries, stated:

> The Cartagena Protocol on Biosafety provides an agreed-upon framework that will be useful for assessing all of the Living Modified Organisms (LMOs) that result from Synthetic Biology, and Components and Products [of SynBio] are covered by existing sector and commodity specific legislation (Canada, SBSTTA 20).

Canada attempted to shift and reframe debate on socio-economic, cultural and ethical (SECE) considerations toward the measurement of risk, particularly environmental risk, as defined by the Cartagena Protocol on Biosafety, and away from 'risk assessment' toward, as they stated, 'risk management approaches once environmental risks have been identified' (Canada, SBSTTA 20). Like-minded parties hoped that if SynBio could be considered solely an issue of biosafety, narrowing the regulatory focus to the living organism, it would shut down more complex-to-resolve issues around SECE considerations, broader questions over 'sustainable use' and the direct and indirect implications of products and components. The scope of the Cartagena Protocol is limited to 'transboundary movement, transit, handling and use of all living modified organisms that may have adverse effects on the conservation and sustainable use of biological diversity' and is dominated by interests facilitating environmentally safe trade of LMOs (Cartagena Protocol 2000). While Article 26 of the Cartagena Protocol includes a clause on 'socioeconomic considerations', the four-page 'voluntary Guidance on the Assessment of Socio-Economic Considerations' published in 2017 only concerns organisms (e.g. a GMO seed, GM fish or a yeast cell) and does not mention synthetic biology, nor components or products (CBD 2017). Significantly, as this group of likeminded pro-biotech countries tried to push SynBio solely into the remit of the Cartagena Protocol, the same parties simultaneously joined forces in concurrent negotiations under the Cartagena Protocol to halt knowledge production of one of the Protocol's key expert working groups, the 'AHTEG on risk assessment and risk management of LMOs' including synthetic biology, as well as blocking the 70-page 'Technical Series' publication 'Guidance on Risk Assessment of Living Modified Organisms and Monitoring in the Context of Risk Assessment' which was controversially published and distributed by the CBD secretariat during COP13 and then recalled several days later (Corporate Europe Observatory 2018).

While disaggregating the organisms from the components and the products seemed to work in the favour of those advocating *less* regulation at the negotiations, like-minded parties on the other side of the debate - wanting *more* regulatory oversight - also invoked disaggregation. Norway was one of those advocating to extend the regulation beyond organisms, emphasising the novelty of components and products, and arguing that while some countries may have domestic legislation to deal with impacts, many did not, particularly those countries likely to be negatively

affected by synthetic biology, and that therefore the CBD should address this gap.[155] This line of debate argued that regulatory gaps on components and products demonstrated the need for a new legal mechanism to implement the second goal of the CBD, 'the sustainable use of biological diversity'. In interviews during COP13 and COP14 delegates reasoned that the first and third goals of the CBD had related Protocols to ensure they were met, yet the second goal was repeatedly overlooked, loosely conceived and wrongly interpreted.[156] In other interviews delegates explained to me they had hoped that by outlining gaps on the broader, direct and indirect impacts of synthetic biology, with a focus on disaggregated components (e.g. DNA sequences) and products (e.g. synthesised compounds), they could push the treaty in the direction of forming a horizon-scanning and technology appraisal mechanism.[157]

As an observer, I was particularly ambivalent over this uncontested living/non-living duality in the framing of SynBio as disaggregated Organism, Component and Product. To speak to this disaggregated language, policymakers and NGO participants mobilised stevia simultaneously as all three. It was clear that different political actors saw utility in encoding synthetic biology in disaggregated terms to identify if and how synthetic biology OCPs were relevant to the treaty and its protocols, and debate gaps in governance. However, it seemed to obscure the intersectional and joined up nature that one SynBio innovation could operate as Organism, Component and Product at the same time, seen for example in biosynthesis R&D. Attempting to regulate them separately did not seem to fit the picture I had observed on the ground across the worlds of stevia, where stevia at various times operated or was understood as 'more than' organism, component and product entangled socio-ecologically in various (socio-economic, cultural and ethical) contexts. Moreover, this disaggregated approach more closely mirrored the worldview of SynBio, as a science built on the dis- and re-aggregation of the living world in terms of 'interchangeable and standardised parts, devices and building blocks' where digitalised components exist in online depositories and biobanks subject to anthropocentric (re)design (Lewins 2013; BioBricks 2021). How stevia was mobilised according to these terms during the CBD conferences reveals the paradox and opaqueness of the OCP framing:

> **As an 'organism'** (a living biological entity) stevia was mobilised in diverse framings; it was spoken about as a plant traditionally known to Indigenous Peoples for 'time-immemorial'; a sovereign organism; a valuable genetic resource, a patented variety, it was also mobilised as an 'organism' in terms of a plant or seed used in agro-ecological farming systems. As a SynBio organism, in contrast, stevia was mobilised as a yeast 'micro-organism' or 'living cell factory' engineered with stevia components (DNA).
>
> **As a 'component'** stevia was mobilised as both a material and immaterial element, a strand of DNA, or a digital genetic sequence, or as a written set of instructions to 'edit' and instruct a micro-organism to metabolise steviol glycosides or 'imitate' a stevia leaf. In this way stevia was amplified as cash DNA - a commodity genetic resource.

[155] Personal communication. (ref. 11) COP14, Sharm-el-Sheikh, Egypt. 21/11/2018
[156] Personal communication. (ref. 11) COP14, Sharm-el-Sheikh, Egypt. 21/11/2018 & Personal communication. (ref. 13) COP14, Sharm-el-Sheikh, Egypt. 22/11/2018 & Personal communication (ref. 10). COP13, Cancun, Mexico. 16/12/2016
[157] Personal communication. (ref. 14) COP13, Cancun, Mexico. 18/12/2016 & Personal communication. (ref. 12) COP14, Sharm-el-Sheikh, Egypt. 22/11/2018

> **As a 'product'** stevia was most commonly referred to interpreted as a 'cash molecule' as a specific rebaudioside molecule solely for sweetening, which on the one hand was framed as a non-descript material product, a 'chemical substance' or 'organic compound' in reference to crystalised steviol glycosides produced by refined leaves or by synthetic biology fermentation. On the other hand, stevia was mobilised through associations to corporate branded or patented products; *Coca-Cola Life*™ for example, or sweeteners such as *Truvia*™, or *EverSweet*™. Throughout my fieldwork I encountered many of these interpretations of stevia or ka'a he'ê as well as some that were 'more than' organism, component or product.

These diverse manifestations of the utilisation of 'stevia' and implications of synthetic biology as organism, or component, or product with direct and/or indirect consequences were imagined in discussions, side-events, and iconography across a range of literary and campaign materials circulating during the CBD meetings. They demonstrate diverse understandings of stevia that stretch between the plant's material and immaterial properties and form interpretations beyond molecularised interpretations of a genetic resource. In this way, stevia was mobilised as a key area of contestation over synthetic biology that transcended framings of organism, component or product. The paradox of the OCP framing was illuminated further by the conflict that emerged around digital sequence information, where genetic information could be both commodified as a product to be traded in and of itself, could enter into an organism or could be derived from an organism. The disruption of the very notion of what constituents a 'genetic resource' described by some as the 'dematerialization' of 'genetic material' (Ruiz Muller & Vogal 2015; Bagley 2018), emerged as the most polarising issue breaking out of the synthetic biology negotiations, and at time of writing remains unresolved. I now turn to my observations on how the issue was problematised, and its relevance to the story of stevia.

(De)Materialising genetic resources.

> It's possible to forget that genes grow on trees. Chinese wormwood, for instance, holds genes for enzymes needed to assemble the malaria-killing compound artemisinin. But increasingly, the world's genes also exist as information—free-floating sequences in public databases, no harvest required (Servick 2016).

This quote from an article published in *Science* in the run up to COP13 foresaw the high stakes and controversy about to ensue over access and benefit-sharing sparked by developments in synthetic biology and gene editing.

In the COP13 opening Plenary working group on synthetic biology, countries from around the world made public their concerns over the impact of digital sequencing and synthesis of genes and genomes. The Namibian delegation asserted that 'the use of genetic sequence data is an example of a new and emerging issue that cuts right across the CBD and both protocols in a very fundamental way' (Namibia, WGII COP13). Many self-identified genetic resource 'provider-country' statements echoed the Democratic Republic of Congo in reiterating the joint position of the Africa Group, 'that [genetic] resources are precious due to information that they contain' (D.R.C. WGII COP13). In this framing, countries referenced the need to protect the sovereignty of their resources, 'our genetic and chemical information of plants, animals and microorganisms' (Indonesia, WGII COP13). In contrast, 'user-countries' argued to dismiss any reference to Digital Sequence Information (DSI) asserting it should be 'deleted in its entirety' because as Canada put it 'the Nagoya Protocol is about the ABS of genetic material only' (Canada, WGII COP13).

At the root of these contestations was the central question of whether the utilisation of genetic resources was equivalent to the utilisation of digital genetic sequence information. Or in simpler terms, was there a difference between a physical material sample of a 'genetic resource', and the immaterial digital information decoded or derived from that same 'genetic resource'? The 1992 CBD treaty defines genetic resources as the 'actual or potential value of genetic material' (CBD 1992). The key word being 'material'. Genetic material is defined as 'any material of plant, animal, microbial or other origin containing functional units of heredity' (*Ibid*). Hence the concept of materiality took on increased significance. If genetic resources could be 'dematerialised' – i.e. accessed without physical material access – then the CBD treaty and the Nagoya Protocol might have to come up with new ways to ensure benefit-sharing over digital sequence information. Negotiators mobilised imaginaries of (im)materiality and (in)tangibility of the living world to ascribe modes of utilisation of 'genetic resources' and most crucially where the value lies. The negotiators were well-aware that such imaginaries held different implications for future access arrangements, allocations of benefits, and the very viability of certain bioeconomic sectors (including lab-grown natural products).

'Hard copy *is* equivalent to soft copy' is how one negotiator repeatedly framed the problem over equivalence between DSI and materiality of genetic resources 'it doesn't need profound discussion or analysis that a book you take off your shelf or a book you are reading on your iPad are the same thing'. Another delegate agreed it was 'disingenuous' to say that information was different from the material; followed by one who described digital sequences as a 'mirror of reality.' Others rejected the hard/soft copy analogy, interpreting the definition of genetic resources inscribed in the CBD treaty as only referring to physical, tangible material. One delegate contended 'I prefer the image of a bushel of yellow thumb drives and of corn, they're not the same'. While both corn and thumb drive contain genetic information, the negotiator asserted 'you can't eat the thumb drives'. Another agreed 'How can information have genes that can be replicated?' looking strategically perplexed 'I just don't understand how it can be the same'. Forging a middle ground, one negotiator identified what had become apparent, that the issue was not a simple case of 'black and white...soft copy may not be the equivalent of a hard copy' (statements in this paragraph are also published in Bond & Scott 2020, page 27, which I co-authored).

Analogising digital - material equivalence eventually led to debates on issues of justice over the implications of equivalence. One negotiator was concerned about the 'supersonic speed of industry' another contended 'the CBD overtaken by technology was not imagined when CBD was formulated. We live in a different world now.' A different delegate recalled 'when the Nagoya Protocol was being discussed, synthetic biology was not alive in our minds.' Other negotiators described issues of injustice regarding the low adaptive capacity of developing countries and small farmers to respond to technological changes. A microbiologist who was attending COP13 as a delegate and speaking on behalf of the Africa Group, explained the injustice 'once they find, for example a good cotton variety that a community have developed over generations they can change one gene and patent it, this is unfair. It starts in the name of science, local people want to share what they know, they don't see it as something they own'.[158] Another negotiator pictured 'all those sequencers running day and night, all those biotech companies putting third world farmers out of business by the sequences they are stealing.' Multiple participants at COP13 noted that DSI opens 'a way to completely bypass the

[158] Personal communication. (ref. 16) COP13, Cancun, Mexico. 10/12/2016

agreement' that would 'completely destroy the Nagoya Protocol.' Meanwhile, various delegations raised the interconnection between all three CBD objectives – conservation, sustainable use, and fair and equitable benefit-sharing – to argue that if everything was digitized and freely accessible, 'the incentive to preserve and protect is lost' (statements in this paragraph are also published in Bond & Scott 2020, page 28, which I co-authored).

The issue of DSI thrust the distinction between the genetic code and the materiality of life to the forefront of political decision-making. By bringing digital sequencing practices into the remit of the CBD and Nagoya Protocol some parties hoped that they could re-establish sovereignty over 'sovereign genetic resources' that would be made available through emerging global mass gene sequencing projects (such as the BioGenome Project or Earth Bank of Codes[159]). In doing so these negotiators amplified a digital understanding over materiality of the living world. While their aim might have been justice in user/provider relations, their amplification of equivalence had the dual effect of moulding the issue of DSI towards a fit with established contours of ABS regulations, concentrating on 'due process', time schedules, conventions and norms. In contrast, those wanting to keep the material distinct from the digital, framed DSI as benefitting the 'whole of humanity' citing the liberation of information in the digital era, celebrating open-access, open-source biobanks as 'a hugely positive thing we do', and describing open access as being 'for everyone'. Such noble claims were countered by civil society groups as amounting to 'digital colonialism' or biopiracy in a long line of misappropriation of sovereign natural resources (Third World Network 2017 and La Via Campesina 2018).

Legal professor of biotechnology Margot Bagley (2017) describes why synthetic biology, as she puts it 'is raising 'digital biopiracy' concerns among NGOs and developing country officials':

> Researchers can take genetic code that has been uploaded to the internet, and, using a DNA synthesizer, recreate and modify that code to produce new substances, tests, and perhaps even new organisms, with no meaningful way (absent a viable watermarking technique) to track the origin of the genetic information that formed the basis for the discovery. As a result, [an] increasing amount of DNA species information [is] being made freely available in online databases combined with the dramatic reduction in cost and difficulty of DNA sequencing from commercial labs.

The implications of this newfound ability to commercialise a 'product' made of or by genes of multiple genetic origins, as opposed to a product resulting from a single genetic resource, were debated in reference to stevia during both SBSTTA20 and COP13.

I take a seat between the Jamaican and Brazilian delegation at a COP13 side-event taking place opposite the contact group negotiating room scheduled to begin straight after. A speaker from Swiss NGO Public Eye – responsible for publishing the 2015 report on the Guaraní People's claim over ka'a he'ê – outlines the case to delegates (Meienberg et al. 2015). With great positivity, the speaker frames stevia as a 'landmark' Access and Benefit-Sharing (ABS) case. Not only could it set a precedent as the first cross-border benefit-sharing agreement for a community whose territories

[159] The Earth BioGenome Project (EBP 2021) 'aims to sequence, catalogue and characterize the genomes of all of Earth's eukaryotic biodiversity over a period of ten years'. The Earth Bank of Codes (EBC 2021) 'aims to make nature's biological and biomimetic assets visible and accessible to scientists and innovators around the world'.

stretch between the Paraguay-Brazil border, but stevia could mark the first case of benefit-sharing involving a synthetic biology company.

The speaker announces that the access of the plant, the use of Guaraní Peoples associated 'traditional ecological knowledge', and its technological 'utilization' (represented by increased patent activity) of steviol glycoside molecules since the year 2000 leading to countless commercialised stevia products, means that stevia is clearly in scope of ABS legislation, and demonstrates the liability of several large companies to share benefits with the Guaraní Peoples. The speaker chooses to elaborate on the synthetic biology production of steviol glycosides to delegates as an example of stevia's 'utilization':

> Some of the gene sequences are coming from stevia plant, they are put together with other gene sequences, and then this new gene gets put in the yeast and then the yeast is producing this steviol glycoside in the laboratory, you don't use a plant anymore. The question is, how does this relate to benefit-sharing?[160]

He answers his own question, reminding the government delegates in the room of their obligations to the CBD;

> You all know that each party should take measures in order that benefits arising from the utilisation of traditional knowledge associated with genetic resources are shared in fair and equitable way…

He then acknowledges that the Nagoya Protocol on Access and Benefit-Sharing which came into force in 2014, has not been signed by all parties, explaining:

> The countries of origin; Paraguay has ratified the CBD but has no ABS law in place and has not signed Nagoya. Totally different in Brazil, they ratified CBD, signed Nagoya and have ABS legislation in place.

He explains that under Brazilian law Guaraní Peoples are recognised as a group irrespective of the border, 'Indigenous Peoples on their territories have rights that have been violated' which means 'the companies may be liable to share benefits with this People, whether they are in Paraguay or Brazil'. He gestures to three members of the Brazilian delegation sitting beside me in the audience 'I think it could be a learning case for everybody, including the Brazilian government?' one Brazilian delegate replies 'Yes for sure' mirroring the speaker's positivity.

The speaker concedes that the legal divergences between countries mean that ultimately there is little in the way of 'hard law' to enforce companies to comply with ABS on stevia, but there is what he called 'soft law' and what many referred to in negotiations as the 'spirit of ABS.' The Nagoya Protocol was supposed to set clear global regulations on access to genetic resources and the fair and equitable benefit-sharing from their utilization. However, since the inception of the Protocol, it has been marred by contestation between countries, with many arguing that the legal text is riddled with strategic ambiguities[161] opening up loopholes and rendering the regulations weak (Bond & Scott 2020). As of 2020, only two-thirds of countries are signatories to the Protocol, and within those signatories, various interpretations of the legal text have resulted in a diverse legal landscape. The speaker clearly hoped his NGO,

[160] Statements cited from a public Side Event 'The Two Worlds of Nagoya' organised by Natural Justice and Public Eye at COP 13, cited from a transcript recording, Cancun, Mexico. 09/12/2016

[161] As Scott and I recognised in our 2020 publication 'At numerous points in the text, negotiating Parties had side-stepped controversy by using non-specific language. These so-called 'strategic ambiguities' had made an agreed legal text possible despite a lack of consensus (Bavikatte & Robinson 2011), but they left in place open questions, such as the geographic and temporal scope of the Protocol and whether the definition of genetic resources encompassed only its physical form or also its information' (Bond & Scott 2020: 26).

alongside lawyers and anthropologists from the NGOs Natural Justice and the Paraguayan Grupo Sunu, would be able to facilitate a benefit-sharing agreement between the Guaraní groups and the corporate users of stevia, despite blurred obligations and weak compliance mechanisms.

The speaker tells delegates 'we have been in touch with a lot of companies' explaining that the following June (2017), corporate stevia users will convene in Paris to discuss 'the possibility to be engaged in benefit-sharing'.[162] Responses have been different – he impersonates – 'SynBio companies are ready, '*lets talk about it!'* Nestle agrees with the principle, '*but give us a bit of time'*. While others like the International Stevia [industry] Association partnered with companies such as Coca-Cola, and Cargill '*-we'll come to the table*'.[163]

In the side-event stevia was framed as representing a classic case of misappropriation or 'biopiracy' as well as a potential case of 'digital biopiracy' opened up through accessibility of its genetic code. One developing country negotiator in the audience commented, 'I have sympathy for biopiracy in Paraguay not really that different from huge Chinese plantations of stevia right? Still biopiracy, just different in a way, sexier because it involves high tech, but from an ABS perspective not all that different.'

In an interview after the event, I ask why the NGO speaker had used synthetic biology production as an example. He explains how the SynBio company Evolva have been the most forthcoming in terms of ABS. He laughs at how ironic it could be that a SynBio company could take a *moral high ground* over the established industry, exclaiming 'it would be like SynBio proving that *this is* biotech that cares about social justice'[164].

The stevia side-event touched on the root of the contestation over DSI when the NGO speaker explained that synthetic biology production utilized gene sequences (information encoded in DNA) originating from a stevia plant and combines them with other gene sequences (from various possible living sources) to produce rebaudiosides, in a process where scientists no longer *necessarily* require physical access to a stevia plant to reproduce the value it offers. Thinking through the controversies raised by DSI through the story of stevia highlights profound questions over shifting perceptions of the location or source of value in the living world in the onset of an era marked by advanced biotechnology, genetic molecularisation and lab-grown 'natural' products. Does the source of value lie in a plant's materiality, physically connected to the living world, rooted in socio-ecological contexts of ecosystems, geographies, borders, societies, farmers, production systems, and traditions, as I encountered across the worlds of both cultivated and wild stevia in Paraguay? Or is the source of value the information encoded in stevia's DNA, that once sequenced, transcends its physicality as a 'genetic resource' in its own right, existing in online biobanks as seen in the latest incarnation of stevia in Nebraska, and labs around the world?

In 2017, a Pure Circle variety of stevia became the first of its kind to have its entire genome sequenced, enabling its properties and processes to be accessed and re-produced anywhere in the world (Pure Circle 2017). In a project half-

[162] This occurs under Chatham House Rules at the Union for Ethical Biotrade (UEBT) Conference in Paris 2017. I obtain an invitation and observe companies and NGO participants discuss responsibilities and possibilities for stevia users to share benefits with Pai Tavyterâ and Kaiowá.
[163] Statements cited from a public Side Event 'The Two Worlds of Nagoya' organised by Natural Justice and Public Eye at COP 13, cited from a transcript recording, Cancun, Mexico. 09/12/2016
[164] Personal communication (ref.15) COP13, Cancun, Mexico. 09/12/2016

funded by Coca-Cola, the stevia genome was uploaded to CropPedia. Owned by a company called KeyGene, CropPedia is an online gene database and bio-informatics platform combining public and privately held varieties, which unlike Wikipedia is not open-access, but a for-profit enterprise funded through an annual licence fee (CropPedia 2021).

In this thesis, I have described the worlds constructed around stevia as it was transformed into a cash crop, then modified into a cash molecule. The latest transformations, I contend, mark perhaps the starkest juncture in its story, rendering stevia 'valuable digital information' or 'cash DNA' epitomised by the corporate sequencing of its entire genome. Though many participants I encountered in Paraguay didn't thoroughly understand the technicalities and specificities of this so-called 'bioturn' from cash crops to cash DNA, they were certainly feeling it. The disjunctures between these worlds demonstrate the continued relevance and importance of the CBD and Nagoya Protocol on ABS to ensure 'sustainable use' and fairness and equity in the benefits derived from genetic resources, be they digital or material.

Stevia rebaudiana CPR8 (SEQ ID NO: 174; CPR cloned from *S. rebaudiana* cDNA)
ATGCAATCTAACTCCGTGAAGATTTCGCCGCTTGATCTGGTAACTGCGCTGTTTAGCGGCAAGGTTTTGGACACATCGAACGCATCGGA
ATCGGGAGAATCTGCTATGCTGCCGACTATAGCGATGATTATGGAGAATCGTGAGCTGTTGATGATACTCACAACGTCGGTTGCTGTAT
TGATCGGATGCGTTGTCGTTTTGGTGTGGCGGAGATCGTCTACGAAGAAGTCGGCGTTGGAGCCACCGGTGATTGTGGTTCCGAAGAGA
GTGCAAGAGGAGGAAGTTGATGATGGTAAGAAGAAAGTTACGGTTTTCTTCGGCACCCAAACTGGAACAGCTGAAGGCTTCGCTAAGGC
ACTTGTTGAGGAAGCTAAAGCTCGATATGAAAAGGCTGTCTTTAAAGTAATTGATTTGGATGATTATGCTGCTGATGACGATGAGTATG
AGGAGAAACTAAAGAAAGAATCTTTGGCCTTTTTCTTTTTGGCTACGTATGGAGATGGTGAGCCAACAGATAATGCTGCCAGATTTTAT
AAATGGTTTACTGAGGGAGATGCGAAAGGAGAATGGCTTAATAAGCTTCAATATGGAGTATTTGGTTTGGGTAACAGACAATATGAACA
TTTTAACAAGATCGCAAAAGTGGTTGATGATGGTCTTGTAGAACAGGGTGCAAAGCGTCTTGTTCCTGTTGGACTTGGAGATGATGATC
AATGTATTGAAGATGACTTCACCGCATGGAAAGAGTTAGTATGGCCGGAGTTGGATCAATTACTTCGTGATGAGGATGACACAACTGTT
GCTACTCCATACACAGCTGCTGTTGCAGAATATCGCGTTGTTTTTCATGAAAAACCAGACGCGCTTTCTGAAGATTATAGTTATACAAA
TGGCCATGCTGTTCATGATGCTCAACATCCATGCAGATCCAACGTGGCTGTCAAAAAGGAACTTCATAGTCCTGAATCTGACCGGTCTT
GCACTCATCTTGAATTTGACATCTCGAACACCGGACTATCATATGAAACTGGGGACCATGTTGGAGTTTACTGTGAAAACTTGAGTGAA
GTTGTGAATGATGCTGAAAGATTAGTAGGATTACCACCAGACACTTACTCCTCCATCCACACTGATAGTGAAGACGGGTCGCCACTTGG
CGGAGCCTCATTGCCGCCTCCTTTCCCGCCATGCACTTTAAGGAAAGCATTGACGTGTTATGCTGATGTTTTGAGTTCTCCCAAGAAGT
CGGCTTTGCTTGCACTAGCTGCTCATGCCACCGATCCCAGTGAAGCTGATAGATTGAAATTTCTTGCATCCCCCGCCGGAAAGGATGAA
TATTCTCAATGGATAGTTGCAAGCCAAAGAAGTCTCCTTGAAGTCATGGAAGCATTCCCGTCAGCTAAGCCTTCACTTGGTGTTTTCTT
TGCATCTGTTGCCCCGCGCTTACAACCAAGATACTACTCTATTTCTTCCTCACCCAAGATGGCACCGGATAGGATTCATGTTACATGTG
CATTAGTCTATGAGAAAACACCTGCAGGCCGCATCCACAAAGGAGTTTGTTCAACTTGGATGAAGAACGCAGTGCCTATGACCGAGAGT
CAAGATTGCAGTTGGGCCCCAATATACGTCCGAACATCCAATTTCAGACTACCATCTGACCCTAAGGTCCCGGTTATCATGATTGGACC
TGGCACTGGTTTGGCTCCTTTTAGAGGTTTCCTTCAAGAGCGGTTAGCTTTAAAGGAAGCCGGAACTGACCTCGGTTTATCCATTTTAT
TCTTCGGATGTAGGAATCGCAAAGTGGATTTCATATATGAAAACGAGCTTAACAACTTTGTGGAGACTGGTGCTCTTTCTGAGCTTATT
GTTGCTTTCTCCCGTGAAGGCCCGACTAAGGAATATGTGCAACACAAGATGAGTGAGAAGGCTTCGGATATCTGGAACTTGCTTTCTGA
AGGAGCATATTTATACGTATGTGGTGATGCCAAAGGCATGGCCAAAGATGTACATCGAACCCTCCACACAATTGTGCAAGAACAGGGAT
CTCTTGACTCGTCAAAGGCAGAACTCTACGTGAAGAATCTACAAATGTCAGGAAGATACCTCCGTGACGTTTGGTAA

Figure 7.1 Image of a stevia gene sequence in the patent EP2742142 awarded to Evolva for 'biosynthesis genes whose expression results in production of steviol glycosides' Source: European Patent Office (2012).

Concluding, (De)Contextualising, (dis)aggregating and (de)materialising (stevia).

In an interview with one of only two Paraguayan delegates during COP13, I ask why Paraguay were not participating in the synthetic biology negotiations. The delegate explained his country have no 'official line or position' in relation to SynBio, 'we have no capacity in it, no knowledge capabilities'. When I meet him again in his own country in October 2018, I ask him again, he explains 'our country is based on exports, we want to support improvements in biotechnology as so much of Paraguay is transgenic [soy]'. When I asked about stevia, the participant gives a personal perspective:

> Synthetic biology is going to be a little negative because we produce something very natural, ours is more... say, environmentally friendly and human-friendly, naturally. The other is... [he pauses] we wouldn't like it because it's going to remove space, but we don't know what consequences can cause... as I say, we talk again about a natural value, not something synthetic.[165]

Not being able to speak or understand English, the Paraguayan delegate was unable to participate in, let alone follow the synthetic biology contact group negotiations. A problem explained to me by other 'developing country' delegates who spoke languages other than English.

In a separate side-event held during COP13 a former Paraguayan UN negotiator outlined what he referred to as the 'social and economic dangers of synthetic biology for Paraguay':

> Evolva told me '*we taught a strain of yeast to produce a sweetener similar to stevia but it is not the same because the plant has reb A and we have reb M*'. But in some varieties we can find reb M, they didn't invent anything! The whole teaching process is actually based on traditional knowledge of people well and alive defending rights. They didn't seek consultation. This is a case of what can happen to many traditional resources. Thousands of plants are potential development tools for countries losing them to greed and misunderstood process. Synthetic biology stevia has the potential to wipe-out a promising agricultural industry. Nagoya Protocol is about including people in markets not cutting them out. Companies just focused on increasing capital are going to take control from people who for thousands of years identified, nurtured and selected best lines.

The Paraguayan participant at this event described more closely what I had observed in Paraguay around the entangled nature of stevia as simultaneously a native herb, a cash crop, a potential development tool, a promise, an agricultural industry, and the sense of injustice over an agricultural legacy being lost or (mis)appropriated. In framing stevia as a warning case to 'many traditional resources' and 'thousands of plants as development tools', he highlighted the diversity of stakes raised by synthetic biology within SECE contexts in Paraguay but also within many countries globally. Both current and former Paraguayan civil servants attending the CBD meetings mirrored the sense of injustice I encountered in Paraguay concerning stevia.

The very issues at stake debated in the synthetic biology negotiations could also be observed unfolding across the stories of stevia I observed in Paraguay and the United States. The biosynthesis of stevia in the USA through the production of surplus corn decontextualize the socio-ecological modes of production where stevia is grown under specific sets of social and ecological conditions as a plant physically rooted to specific places in Paraguay and further afield. Decontextualization in 'natural' product replacements occurs not only in the literal sense of moving production 'from the land to the lab,' so to speak, but by both breaking and re-making ties of established agri-cultural relations between the social- and eco-systems that surround stevia. Biosynthetic stevia both relies upon this Socio-economic, Cultural and Ethical (SECE) context to mobilise imaginaries of naturalness and authenticity, while at the same time as having direct and indirect potential to eliminate these contexts or socio-ecological relations and in turn determine who benefits from producing stevia or steviol glycosides.

[165] Personal communication (ref. 41). SEAM, Asunción, Paraguay. 8/10/2018

The inability of negotiators with concerns over SECE impacts to ensure such considerations be taken into account can be seen as an effect of the intersecting forces of a molecularisation and molecularised governance logic embedded in the dominant structures regulating genetic resources, crops and commodities (stretching from Intellectual Property regimes to trade agreements to dominant scientific approaches to environmental management). As I argued in the previous chapter, molecularisation has increasingly enabled ownership over the living world by rendering plants and ecosystems technical. Isolating molecules or natural processes from non-human 'natural' contexts rendering them ownable has also made them governable, co-constituting a rational molecularisation logic supporting dominant global political economic and legal regimes. Yet, such a disaggregated focus on the molecule isolated and decontextualised from the socio-ecological embeddedness from which it emerges or is situated, is ill-equipped to factor in SECE considerations. As molecules with socio-economic, cultural and ethical 'baggage' become synthesisable, SECE considerations become increasingly important, yet are rendered invisible through a molecularised lens of governance. This is seen for example in the transformations rippling out from what on the surface appears a slight adjustment in a molecular interpretation of stevia from reb A to reb M, or INS961a to INS961b, that can already be seen to have ramifications for established socio-ecological relations around stevia and for who benefits from stevia.

Contentions and paradoxes of this molecularised governance approach played out in the different understandings and problematisations of how to regulate synthetic biology under unquestioned framings of SynBio in terms of organisms, components or products. The fact that one SynBio innovation could be all three at the same time (e.g. synthetic yeast *organism*, stevia DNA sequence *component* and biosynthetic stevia *product*) may have been one of the reasons that this disaggregation seemed to be ineffective in arguing for either more or less regulation over synthetic biology. 'Disaggregate in order to (de)regulate SynBio' mirrors the molecularised epistemology of the living world that underpins synthetic biology as a practice and demonstrates the allure and power of molecularised logic in describing problems or prescribing solutions by both advocates and critics of synthetic biology in their opposing agendas. The ineffectiveness to achieve meaningful consideration of SECE issues, though, highlights disaggregated OCPs as a restrictive framing. Certainly, in the debates concerning the materiality of DNA, any reference to organism, component or product was replaced with the more the contested concept of 'genetic resources'.

Imaginaries on all sides of these debates seemed to be characterised by a sense of inevitability over the onset of increasingly available Digital Sequence Information (DSI) on genetic resources as a new set of globally-circulating genetic commodities. Many parties used this imaginary to argue it was 'extremely urgent' to bring DSI within the remit of the CBD and Nagoya protocol regulations. Stevia was summoned to exemplify the possibilities of emerging practices of digital misappropriation raised by synthetic biology, despite the genes used to (re)produce stevia rebaudiosides in biorefinery fermentation tanks and new varieties not initially obtained from DSI – but through historical ethnobotanical expeditions appropriating traditional knowledge and samples from Guaraní communities over time. Stevia was nonetheless mobilised to highlight the value of DSI of genetic resources for multinational food and agriculture corporations, and to raise questions over who should own digital sequence information of actual or potential value. The re-imagining of stevia as valuable genetic information or what I term 'cash DNA' at side-events and discussions at the

CBD conjure up new perceptions of value beyond the socio-ecological contexts from which resources such as stevia emerge, and ascribe new values upon stevia's genetic information as a commodity in and of itself.

The problematic areas of contestation I observed and documented in this chapter concerning socio-ecological decontextualization, disaggregation of the living world and dematerialisation of genetic resources mirror the dynamics at play across the stories of stevia I observed unfolding in Paraguay and the USA. Although space is opened up to discuss potential impacts at the CBD, the continued adherence to a molecularised logic of governance restricts policy-makers' ability to affect any actual protections to those 'adversely affected,' let alone comprehend intersectional, multi-sited, joined up, indirect and unfurling effects of the technological shift that confronts it.

I am far from the first to point out that biotechnological innovation and development is outpacing policymakers' ability to regulate it (Trace 2016; Jasanoff 2016; WEF 2017; Bagley 2017; Laird et al. 2020), but as the next stage of molecularisation approaches it brings far greater reach in its amalgamation of gene-editing, artificial intelligence and mass genetic sequencing. The stakes over what is expended and what is expanded by these technologies, and ultimately who benefits from biological diversity are more pertinent than ever.

Conclusions.

What is stevia / ka'a he'ê? Is it a leaf, a 'powerful leaf'? Perhaps an 'ancient' leaf? Is it la criolla, Eirete, Morita, PC1 or Starleaf™? Is it a chemical structure represented in diagrams? Is it a crystallised rebaudioside molecule? Is it Truvia™, EverSweet™, NutraSweet™ or PureCane™? Is it a plant member of a spiritual family that must be respected, protected and nurtured? Is it a sovereign genetic resource? Or a tool to rectify injustice? Is it a means of schooling children and paying medical fees, a route out of poverty? Is it a more profitable use of corn than producing beef and ethanol? Is it a sweetener or a medicine, or both as a solution to the 'obesity pandemic'? Is it the next sugar? Or, is it a genomic sequence stored as information on a database that can be downloaded and reproduced anywhere?

Ethnographically following stevia / ka'a he'ê I have discovered it is all these things and more, but to different people, in different worlds, with different livelihoods and different stakes riding on them, and different capacities to affect change. As a plant at the commercial forefront of bioeconomic innovation into synthetic biology fermentation, 'cell factories' and biosynthetic 'natural' products, following stevia provides a lens that illuminates and helps grasp some of the important shifts taking place, shaping the future way humans produce food and 'natural' compounds, as well as the type of agricultural systems underpinning them and the impact they have upon human-ecological survival.[166]

Despite the divergences in meaning of stevia/ka'a he'ê, the many worlds surrounding the plant and its future are entangled through interconnected knowledges, histories, conflicts, imaginaries, discourses and promissory narratives. Following these this research unearthed five distinct interpretations of stevia that marked transitional moments in the way the plant became understood and treated. The chapters in this thesis are structured around these five distinct ways of knowing stevia/ka'a he'ê: as a sacred herb, as a cash crop, as a cash molecule, as a bioeconomy commodity, and finally emerging interpretations of stevia as cash DNA.

Worlds of stevia.

I started following stevia through corn – Cargill's corn – the highly industrialised and genetically engineered commodity crop used as a feedstock underpinning the biosynthesis of natural compounds in fermentation tanks. I followed the commercialisation of 'EverSweet® stevia sweetener' produced by genetically engineering stevia DNA into a yeast organism in a corn-fed industrial biorefinery in Nebraska, USA. The story of corn is a part of and demonstrative of a broader story about industrial agriculture and future production systems that needs to be understood in order to make

[166] Food production and land-use are central in the degree to which we can reduce CO^2 emissions and halt biodiversity loss (IAASTD+10 2020; UN SDG 2021).

sense of both the continuities and changes brought about by biosynthesis. Stevia in this world was known as a patent-protected innovation and commodity associated with promissory narratives of bioeconomy, sustainability and authenticity. The world of biosynthetic stevia stood in stark juxtaposition to the world of ka'a he'ê, the spiritual family member.

In the world of 'Aunt ka'a he'ê', the sacred herb, I heard stories of struggle and resistance in what the Guaraní Pai Tavyterâ and Kaiowá denounce as the '(t)he usurpation of our knowledge and biodiversity by multinational companies, who use, sell and profit from ka´a he´ê' (quoted and translated in Gaberell et al. 2016). The Guaraní Peoples – mobilised by their own assertions of cultural ownership of ka'a he'ê and by the promises of rights and justice through international legal regimes on ABS – challenge the present-day utilisation of stevia by both biosynthetic and leaf-derived businesses. In doing so, they situate stevia as part of previous and ongoing struggles against misappropriation, genocide and oppression. Their ontology and epistemology of the living world stands in stark contrast to the molecular biological or capitalist bioeconomic perceptions of nature and value, and genes as 'resources', yet they engage with these ontological divergences in their attempts to reclaim territory, ownership and justice.

The world of ka'a he'ê as a cash crop was first seeded not far from Indigenous territories, in the campesino colonias of Concepcion and San Pedro. As the 'designated land of origin', Paraguay has become a country of many worlds of stevia. In campesino communities, I heard stories of ka'a he'ê mirroring Moises Bertoni's early 20th century prophesies of stevia as a plant capable of bringing great wealth to Paraguay. Groups of campesinos and small businesses have dedicated themselves to breeding and sustaining ka'a he'ê, committed to the promise of a high-value, low volume crop suited to the small agro-diverse systems of peasant farmers, as part of efforts to improve rural socio-economic wellbeing. I discovered many NGO and state agency development projects that bolstered the promissory narrative of stevia as a 'campesino cash crop for sustainable development'. However, I also heard stories of state corruption and state failures in protecting the country's national and ecological advantages to ensure ka'a he'ê benefited Paraguay's people and endemic environments. In a highly unequal country devastated by the sprawl of industrial agriculture and mounting land concentration in favour of wealthy landowners, the unfulfilled promise of stevia looms large.

The world of cash molecule stevia magnified the sense of injustice I encountered with those committed to stevia's promise in Paraguay. Stevia interpreted primarily for its use as 'cash molecule' export commodity encompasses the meanings, livelihoods, stakes and agricultural systems that surround stevia for its sole purpose in producing its sweetest molecules: steviol glycosides or rebaudiosides found in the leaves of the plant. This world is about modifying and optimising the plant and the production systems to make it a 'gold-standard' sweetener' to rival the ubiquity and profits from sugar and other sweeteners. Through corporate breeding programmes and global value chains, stevia increasingly became a privatised resource through intellectual property rights and patents on varieties, techniques, and ultimately, biosynthesis. Until 2018, the 'cash molecule' promissory narrative was the same as the one first developed in Paraguay, a sustainable low impact cash crop suited to agro-ecosystems of small, subsistence farmers, touted by multinationals as a crop enabling children to study and rural development to flourish (Pure Circle 2015 and Coca-Cola 2016). In rural Paraguay I heard stories from 'third party farmers' contracted to grow cash molecule stevia who – like

the independent campesinos of ka'a he'ê – were committed to this promise, despite the differences in production models. However, in Paraguay in 2018, stevia's promise-in-the-making was in turmoil. The race to commercially mass-produce the sweetest but rarest stevia molecule - reb M - had been reached by Cargill with EverSweet®. In response, Pure Circle, the world's largest stevia leaf company, had developed a new stevia variety - StarLeaf™ - that contained twenty times more reb M than conventional stevia. But in order for Starleaf™ to be economically competitive with biosynthetic stevia, Pure Circle was in the process of undertaking what it called a 'big shift' throughout its production model in Paraguay. The company was terminating its contracts with small farmers and turning its back on unmechanised farming systems towards 'a new kind of farmer' capable of operating large-scale mechanised monocultures of Starleaf™, such as former soy plantation owners in Paraguay or tobacco plantation owners in the US. The effects of these shifts were already starting to ripple out in my encounters with farmers and agronomists in their confusion and exasperation. These events unfolded in juxtaposition to data showing stevia planting and leaf exports had reached an all-time low in Paraguay, despite an all-time high in global steviol glycoside consumption, and an all-time high in soybean production making Paraguay the world's 3rd largest exporter (Bronstein & Desantis 2018; La Nacion 2019; Godoy 2019).

2018 was clearly a pivotal year for the unfolding story of stevia. Serendipitously, it was the year I was on the trail of stevia in the US and in Paraguay. Sugar tax legislation was introduced in the UK and in Ireland and I observed supermarket shelves increasingly stocked with 'low-sugar' alternatives containing steviol glycosides. I studied the ingredient labels on mainstream brands (from San Pellegrini (Nestle) to Heinz) and found no indication which rebaudioside molecules products contained or how they had been produced, a signifier of the broader question mark over biosynthetic 'natural' ingredients in labelling. Of all the changes in 2018, the final decision of the CODEX Alimentarius (Joint FAO/WHO committee) on labelling regulations was perhaps the most significant, stipulating steviol glycosides produced using synthetic biology fermentation may be added to the international numbering system for food ingredients under the same number as those derived by the agriculturally-derived leaf. The difference between steviol glycosides biosynthesised by Cargill in Nebraska or those derived from Paraguayan campesino plots would henceforth be determined only by a single letter, either a or b. My encounters in this research showed labelling and description was a central area of friction that many asserted determined their ability or not to demarcate differences between different modes of production. The significance of the subtle letter swap from INS960a to INS960b, or indeed from reb A to reb M, obscures opposing production models and farming systems that underpin them and clearly, as a result, the (re)distribution of 'winners and losers'. This obscurity and its outcomes, I argue, constitutes a significant fault line in the molecularised logic of labelling based on chemical equivalence.

In response to these unfolding transformations and new modes of production, a new target molecule, new farmers, new lands and ultimately the re-making of stevia's promise, the sense of injustice across the diverse 'worlds of stevia' in Paraguay was palpable. Various respondents described opposition to 'the breaking of the smallholder promise', made accusations of biopiracy and corruption, and contested what they saw as the 'appropriation' of the plant's 'naturalness' and its 'agricultural legacy' inextricably rooted in past and ongoing cultural and socio-ecological relations. Some actors talked about the idea of ka'a he'ê being stolen and of their roles in stevia's story as being 'expendable or substitutable'.

Nowhere did the multiple worlds of stevia/ ka'a he'ê collide more forcefully than during the meetings of the UN Convention on Biological Diversity (CBD).

In the world of the CBD negotiations on synthetic biology, stevia is mobilised simultaneously to represent contestations over biopiracy bought about by (digital) access to 'genetic resources' without benefit-sharing as well as an example of a sustainable small farmer cash crop 'threatened by synthetic biology'. NGO contestation around stevia and other natural high-value, low-volume plants and crops cultivated or used by IPLCs, is reflected in the polarisation between states over the socio-economic impacts and cultural and ethical considerations related to the emergence of synthetic biology. Divergences in positions largely reflected the line between importers/exporters of GMOs and economies based on industrial agriculture on one side and on the other, economies with stakes in smallholder agriculture and natural products markets. Despite the stark political and scientific contestation between 'potential positive and adverse effects of synthetic biology', the terms through which the issues were debated – through digital-material binaries, through disaggregated and decontextualised framings of SynBio innovations as organisms, components and products (OCPs) – did not reflect the interconnected issues, multiple understandings, and unfolding impacts and implications I observed following stevia 'on the ground'. During CBD meetings, stevia was framed simultaneously as yeast or plant *organism*, a DNA *component* as well as a *product* such as EverSweet®. While some understand stevia for its intrinsic materiality rooted in socio-ecological systems, others treat it as a series of letters in a genetic code of instructions. While actors have opposing purposes for (dis)aggregated, (de)materialised and (de)contextualised framings in pushing for more or less governmental oversight, the decisive outcomes of the negotiations ultimately support the molecularised logic institutionalised in the global political economic system based on rewarding property rights for isolating and disaggregating molecules from the living world, and treating the social and environmental as 'externalities'. This logic also reflects the synthetic biology epistemology of seeing the living world as a 'computerised' system subject to anthropocentric (and profit-oriented) design, engineering and optimisation. While countries are 'invited' rather than 'urged' to consider the socio-economic, cultural and ethical, the final legal text treats them as decidedly avoidable considerations. Ultimately, the terms through which issues were discussed at the CBD constitutes a molecular approach that is incapable of addressing the joined up, multi-sited, and (in)direct reconfigurations and impacts that are and will continue to play out as companies increasingly pursue lab-grown 'natural' ingredients.

Unpacking dis/connects.

In tracing stevia, four specific discursive zones repeatedly arose in the responses and practices of participants and emerged from the research as central areas of friction causing dis/connect between the 'worlds' I encountered. I characterised them as *dis/*connects to emphasise their explicit or implicit dynamics of both connectivity and disconnectivity and their influence upon meanings and practices, where one world could *cause effect* to another and vis vera. These four dis/connects played out through the discursive zones of ownership, authenticity, sustainability and justice.

In the worlds surrounding biosynthetic stevia, notions of sustainability and authenticity were explicitly emphasised by companies targeting consumers or investors. In contrast, the Pai Tavyterâ and campesino communities performed a notion of sustainability and authenticity more implicitly through their low impact socio-ecological approaches, cultural practices and relations to stevia/ka'a he'ê. These communities emphasised notions of **justice** and rightful **ownership** in the way they related to the plant. While mention of **justice and ownership** were muted in the biosynthetic cash molecule worlds, their dynamics manifested implicitly through patents issued and registered, and the product's entanglement with a legacy derived from 'other ways of knowing' and owning stevia.

Unpacking the four dis/connects and the frictious way they played out through contradiction and contrast not only reveals the stakes between the worlds, but allows exploration of what biosynthesis implies, what it strengthens and expands across these worlds, as well as what it weakens, reconfigures, disrupts or expends. **Unpacking authenticity** dis/connects reveals stakes riding on how 'we' (as society at large) come to understand what characterises 'naturalness' in terms of plants and food. Does a 'natural' product imply something that has some degree of separation of human control, something that is characterised by a degree of variability depending on soil, climate, geography, multi-species ecology which influences the 'thing', for example when a crop is grown in the earth? Or is the authenticity or 'naturalness' of a thing a question of equivalence (as Cargill advocates)? For example, if a chemical structure looks and performs the same as a plant-derived chemical structure then it can be said to be the same or equivalent? If biosynthetic products are considered as authentic as the real thing, do we devalue the diverse contributions of peoples and ecologies to the point that those originally connected to the 'natural equivalent' no longer have the means to persist? Dis/connects around authenticity throughout this research have highlighted the centrality of legacy in how a thing gets interpreted as valuable or useful. Stakes riding on the importance 'we' place on not just *what* something is, but *how* something is produced through accumulations of skill and knowledge, histories of discovery, innovation, (re)production and consumption, and perceptions of that 'legacy' as an integral identifier of that thing. Legacies however are not equal, and colonial, gender and racial imbalances have also influenced discourses of 'discoverers' and knowledge producers through transitionary processes, epitomised by the disregard of the Guaraní word ka'a he'ê in the plant's Latin classification *Stevia rebaudiana Bertoni.* The plant's ethnobotanic legacy continues to be mobilised as a marker of pride, authenticity and ownership over stevia as well as a 'story' used to sell it.

Why do Cargill and competitors play up imaginaries of an ancient herb of South American or Indigenous origin, while playing down the technological wonder of conjuring multiple species DNA? These companies clearly perceive consumers preference toward the former imaginary. Yet perhaps if companies were more transparent about the novelty of genetic engineering as a fundamental part of the biosynthesis process, and embraced its use rather than attempting to normalise or obscure it through narratives of naturalness and 'age-old fermentation', it would avert the potential confusion of consumers seeking products that are plant-derived rather than lab-derived, and might hold less adverse effects upon small farmers, allowing people to decide how they interpret naturalness as more molecularly equivalent or more ecologically-embedded.

Unpacking sustainability dis/connects reveals stakes on what is determined as socio-ecologically desirable production techniques. If we think of biosynthetic 'natural' products as more sustainable, what models of agriculture are expanded? And equally important, what is lost in sustainability comparisons between isolated molecules and complex socio-agro-ecological systems? Mainstream sustainability appraisals are based on actions and developments that 'balance the three dimensions of sustainable development: the economic, social and environmental' as 'integrated and indivisible' (UN SDGs 2012). However, in the different worlds of stevia, I found different interpretations of sustainability. In the first promissory narrative of stevia as a sustainable cash crop the social benefits were framed as central, in terms of reduced rural-urban migration, reduced poverty, and benefits of agroecological farming (Oxfam 2017). Sustainability with a more social emphasis stood in contrast to the most recent corporate promise of stevia as a 'low-impact' bioeconomy commodity, which put emphasis on environmental and economic efficiency using less water and producing less CO^2 emissions compared to leaf-stevia, with zero reference to social outcomes or impacts (Cargill 2021e). Additionally, I discovered crucial subtleties hidden behind sustainability comparisons, depending upon whether stevia is defined and understood as a particular rebaudioside molecule or as an integral leaf. Cargill's claim of the environmental superiority of EverSweet® over leaf-stevia relates only to reb M production. This sustainability claim collapses in comparison to the production of all rebaudiosides or steviol glycosides found in the leaf (many of which are dually considered medicinally beneficial). This demonstrates the significance and the stakes riding on the obscuration of stevia through molecularisation, and the implications and meanings of different molecules beyond their level of sweetness. Meanwhile sustainability comparisons of leaf-derived stevia invoke the same criteria as Cargill and competitors - both organic stevia promoters and Pure Circle stevia assert that deriving sweetness from stevia rather than sugarcane uses far less water and far emits far less CO^2 (Fundacion Granular 2016; Pure Circle 2018). These differences in 'sustainabilities' are also highly variable in terms of agrochemical vis-a-vis agroecological inputs in farmers' fields. Most crucially, if sustainability comparisons were to encompass the (in)direct implications of expanding one type of agriculture at the expense of another, where one form of production is small-scale, labour intensive and community-based and one is mechanised and based in corporate contracts and ownership regimes, outcomes would diverge greatly. A more holistic sustainability appraisal of biosynthesis must entail considering the (in)direct impacts upon rural communities and land use, such as its potential to eradicate small-scale farming, generate social upheaval, and increase land conversion in the case of Paraguay, for example, to soybean monoculture. Such (in)direct impacts particularly upon land-use change and rural communities highlight vital but overlooked variables in reductionist sustainability calculations and comparisons focused solely on environmental and economic efficiency. The central role of small farms in maintaining agrobiodiversity and rural development demonstrate the importance of explicitly *holistic* sustainability appraisals that can consider complex social interconnectivity in technology choices. In an era of sustainable development goals, claims to sustainability are central in mobilising state, public and private support and investment towards future technological pathways, making interpretation of sustainability an important marker in understanding what biosynthesis implies.

Unpacking ownership dis/connects largely crossed over with **dis/connects surrounding concepts of justice** between the worlds of stevia. Focusing on these dimensions in tandem illuminates the stakes over the 'owners' of stevia in terms of who is able to benefit, or who will or who should benefit from the 'utilisation' of stevia. Across stevia's worlds I

encountered various notions of justice in relation to 'rightful' ownership over stevia / ka'a he'ê. Ownership was manifested through the assertion of legal rights to traditional knowledge as well as in terms of intellectual property rights, trademarks and brand names. I heard assertions of ownership through spiritual ontologies of more-than-human relationality, through years of dedication and commitment, through the production and sharing of agro-ecological knowledge, as well as being amplified through the idea of stevia's promise 'belonging' to campesinos, who asserted that – in contrast to the promise of soy for big farmers – stevia was a cash crop 'meant for them'.

Dis/connects at the interface of ownership and justice relating to stevia played out most dramatically through the concept of 'genetic resources' at the CBD meetings between actors and world regions who had divergent views on new forms of access and ownership expanded through synthetic biology tools and techniques. During the CBD conferences, stevia was summoned to debate questions of (mis)appropriation in relation to conventional methods of access and utilisation through accusations of biopiracy by the Indigenous Guaraní communities, as well as to contest the so-called 'de-materialisation' of genetic resources through new methods of digital access and utilisation representing concerns over digital biopiracy. This was despite the fact that stevia was accessed and utilised long before its entire genome was digitally sequenced and uploaded to CropPedia, a private genomic database in 2017 co-funded by Coca-cola and Pure Circle, and available to plant breeders only through an annual licence fee. NGOs framed the commercialisation of biosynthetic stevia brands (such as EverSweet®) as epitomising the dynamics of what digital sequence information (DSI) *could* be used for, through the profound ability of scientists to deploy artificial intelligence to scour databases in order to discover specific genetic information to edit or engineer microbes or plants to perform functions such as synthesising valuable 'natural' molecules (e.g. steviol glycosides) 'dematerialised' from and with no reliable way of tracing them back to the conditions from which they originate. In opposition to the concerns being raised on DSI, other groups argued for genetic commons, dismissing the idea of genetic sovereignty, believing that DNA information should be for everybody. The digitalisation of the stevia genome however into 'cash DNA' or a financialised genomic commodity demonstrates the reality of such well-meaning intentions of an open-source genetic commons. As only those with the financial and technological means to exploit DSI will be able to do so.

As of 2021, the issue of how to ensure fair and equitable benefit-sharing in the context of digital access to genetic sequence information remains an issue unresolved and on the agenda of multilateral negotiations at the upcoming CBD COP15 in China later this year. The Nagoya Protocol – underpinned by a legal objective to 'fairly and equitably' balance claims of ownership over the utilisation of the living world – remains in limbo, with some arguing it may be time to rethink the whole ABS paradigm as regulations no longer match up to today's technological reality (Laird et al 2020).

In following stevia, I have discovered that 'genetic resources' do not exist in isolation, whether they are a species of yeast, a seed, a specific plant molecule or a digital genomic sequence, they are often co-evolved from and embedded within diverse socio-ecological practices. The stories of stevia in this research have shown that when a genetic resource is 'accessed', agricultural legacies, livelihoods, economies, promises, development strategies, and hopes may be accessed too. The current governance system is not set out for ensuring 'fair and equitable access and benefit-sharing' over agricultural livelihoods or cash crop economies, but as automisation, industrialisation of agriculture and biosynthesis expand at the expense of the social and rural communities, it is a direction of development that deserves

to be questioned and scrutinised. At present there is no legal obligation on companies to share benefits from any profits derived from the utilisation of stevia, no matter how badly impacts affect the livelihoods of the original knowers, growers and utilisers.

Expansion and expendability

The privatisation of stevia's genome marks the plant's transition to being interpreted as 'cash DNA'. To close my analyses of biosynthetic futures through the lens of stevia, I now consider how molecularisation and the dis/connects across stevia's worlds reveal processes of industrial and corporate expansion, at the expense of biocultural diversity and socio-ecological resilience, and draw conclusions on some lessons stevia's stories may hold for other biosynthetic 'natural' products.

Expanding synthetic biology stevia 'cell factories' and industrialisation of agriculture

Since 2019, Cargill's biorefinery in Nebraska is no longer the only industrial biorefinery synthesising steviol glycosides and rebaudioside molecules in fermentation tanks. At least three commercial projects are underway, with notable crossovers in corporate partnerships. When Cargill partnered with rival company Royal DSM to consolidate their intellectual and infrastructural resources to advance stevia sweetener synthesis, they were not alone. Royal DSM also partnered with a separate US synthetic biology company – Amyris – to support construction of a second biorefinery in Brazil (Amyris 2017). Amyris constructed a 'speciality plant' for the biosynthesis of reb M in São Martinho in 2017. Like Cargill, Amyris obscures the novelty of using genetically engineered yeast also referring to it as 'age-old fermentation' in sustainable 'cell factories' (Amyris 2021). However, unlike Cargill, Amyris feeds its yeast on Brazilian sugarcane through a 'long-term strategic supply agreement with Raizen, the world's largest sugar producer' (Amyris 2019b). In August 2019, the Amyris CEO celebrated the launch of biosynthetic reb M under the product name PureCane™ by publicly announcing 'our goal is to win 30% of the current stevia market by 2022' (Joel Cherry quoted in Watson 2019). As the name PureCane suggests, unlike Cargill, Amyris amplifies the feedstock (cane sugar) as co-constituting its 'natural' consumer appeal, explicitly claiming its product is non-gmo , obscuring the genetic modification of yeast. As it states in the products website FAQs:

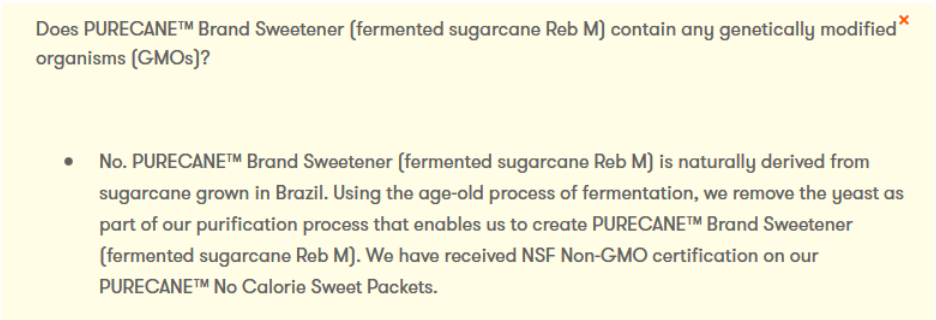


Figure 8.1 Pure Cane™ FAQ webpage (Pure Cane 2021)

April 2021 marked another poignant twist in the tale of stevia, another US-based synthetic biology company Manus Bio Inc. announced the commercialisation of a third biosynthetic stevia product to reach the market under the brand name NutraSweetNatural™. Manus Bio Inc. acquired and retrofitted Monsanto's 44-acre former aspartame (artificial sweetener) factory. Monsanto, the once main producer of NutraSweet aspartame sweetener, was the company that

the old Horqueta campesino accused of stalling Paraguay's first promise of exporting stevia to the US during the 1990s. It is ironic that the latest sweetener to be made in this US factory may once again contribute to the disruption of the promise of Paraguayan stevia, but this time the disruption is derived from the very genetic material and knowledge originating from the Paraguayan plant itself. Like EverSweet®, ManusBio's NutraSweetNatural™ stevia will be produced using the surplus US corn in the MidWest. The NutraSweetNatural branding and advertising narrative is striking, as seen in figure 8.1, the packaging uses images of stevia leaves, the ingredients even list 'stevia ***leaf*** sweetener', and the packaging is covered in straplines such as 'keeping nature natural' and 'To Mother Earth, with love', there is no indication to the consumer how the product is made except one paragraph on the packaging (figure 8.2) that hints that the production method is more sustainable than conventional methods where it says:

> Mindfulness matters when it comes to Mother Nature. We recognize that nature is not infinite which is behind our inspiration to develop NutraSweet Natural™. Our processes utilize sustainable practices, which preserve the planet's resources while meeting your desire to lead a healthier lifestyle. Change starts with all of us.
> *Keeping nature natural.*

Figure 8.2 Biosynthetic stevia product NutraSweetNatural by ManusBio Inc. Source: NutraSweetNatrual 2021.

The brands website similarly calls on authenticity narratives of the 'ancient' and 'traditional' - 'The Stevia leaf has been used as a traditional sweetener for centuries; NutraSweet Natural™ redefines stevia by capturing the best-tasting part of the traditional plant' (NutraSweetNatural 2021)

These latest developments demonstrate that the biosynthesis industry can no longer be considered 'new and emerging'. It has become an industry that has achieved scale up, and is expanding on 'natural' markets, bolstered by the opaqueness of labelling regulations on 'nature equivalence'. These synthetic biology companies all mirror the

narrative of Cargill amplifying notions of sustainability, efficiency and authenticity, while playing down novelty, genetic engineering and recently abandoning the label 'synthetic biology' for biodesign, bioconversion or hi-tech fermentation. Manus Bio Inc. describes itself as 'using proprietary fermentation technology' to 'recreate advanced natural processes for next-generation biomanufacturing and provide sustainable and cost-effective sources of ingredients' (ManusBio 2021). Amyris describes itself as 'Amyris applies its exclusive, advanced technology, including state-of-the-art machine learning, robotics and artificial intelligence to engineer yeast, that when combined with sugarcane syrup through fermentation, is converted to highly pure molecules for specialty ingredients' (Amyris 2020). The companies high tech messaging is no where to be found on the products they produce. Underscoring yet another dis/connect on how obscurity and transparency play out in authenticity narratives.

The recent expansion of biosynthetic stevia consequentially expands interpretations of 'stevia' as the reb M molecule. Molecularisation of stevia toward 'reb M' at the expense of other molecules bends back on itself, reconfiguring the agronomic, physiological, genetic composition of stevia, re-shaping the socio-spatial and agro-ecological interactions that produced it. The rarity of reb M expands industrial agriculture on several scales, firstly in terms of the transformations underway in cultivated leaf-derived stevia towards the high reb M variety Starleaf™ which can only be grown in large-scale mechanised systems, secondly in terms of expanding industrial monocultures of corn or sugarcane as fermentation feedstocks. Thirdly – based on the cumulative testimonies of small farmers' cash crop options – the likely expanse of soybean plantations in Paraguay as an (in)direct result of the biosynthetic reconfigurations and mechanisation of stevia.

Multiple layers of transformation are underway in which stevia, sugarcane, corn, and soy futures are interlinked. Cargill, an agri-business giant with markets in all four crops and now also in biosynthesis rides high on multidimensional processes of expansion and compression. While I described Cargill's dominance in the US, it's worth noting that in Paraguay, Cargill also dominates export agriculture, accounting for approximately 40% of soybean production (Shurtleff & Aoyagi 2017)[167]. But unlike US corn, the vast majority of wealth generated from soy does not stay in Paraguay. Paradoxically, the largest exporters in Paraguay such as Cargill pay the least taxes at around 1%. Paraguayan social researchers argue that Cargill's operations reveal the 'regressive nature of taxes on the one hand, and on the other, the concentrating and non-distributive feature of the wealth generated that characterizes the agribusiness model' (BASE-IS 2020). Expansion of agribusiness and production of low-value bulk export commodities at the expense of high-value smallholder crops in Paraguay is clearly not beneficial for the distribution of wealth derived from the land and stands to perpetuate Paraguay's problems with rural poverty and inequality, as well as deforestation and biocultural diversity loss.

[167]In Paraguay, Cargill has its own network of 40 country grain elevators, three private ports, an industrial plant with a daily processing capacity of 1,300 tons, 1.4 million tons of soy annually, and a fleet of enormous barges which export soy and other commodities to Uruguay, Argentina or Brazil for 'trans-shipping in ocean vessels' consolidating Cargill's position as Paraguay's biggest crop exporter and largest industrial actor (Jorden et al. 2020; Macdonald 2014; Shurtleff & Aoyagi 2017).

Stevia sweeteners biosynthesised over Paraguay's border in Brazil by Amyris raise more paradoxes when considering the worlds entwined around stevia. The dire situation of (Pai Tavyterâ) Kaiowá People in Brazil is compounded by their landlessness through land appropriation and mass deforestation through the expanse of sugarcane plantations over the past three decades (Ioris 2018). Human rights NGOs have highlighted slave-like conditions for workers on sugarcane plantations (Mendonça *et al.* 2013). Due to its very recent construction, I was unable to explore the worlds of stevia connected to Amyris' Brazilian biorefinery, but divergences in company press releases and secondary reports from NGOs working in Brazil highlight another terrain of conflict and dis/connect in stevia's unfolding story.

These recent developments support the argument I made in Chapter Three; biosynthesis is conducive to the reproduction of the industrial complex from which it emerges. Contrary to the synthetic biology narratives promising 'disruptive innovation' to the status quo, stevia has shown that biosynthesis does not disrupt industrial agriculture, it follows the grooves laid out by it. And synthetic biology is positioned to intensify (rather than overturn) the social inequities put in place within this model. This can also be observed through the way multinational agribusinesses such as Cargill are acquiring or partnering with small SynBio start-ups. While smaller companies such as Evolva or Amyris or ManusBio may appear to characterise the future of clean 'cellular agriculture', they are often underpinned by funds and benchmarks set by the incumbent industry with stakes firmly rooted in the status quo. Many of these smaller SynBio companies are supported by the financial (and moral) might of philanthropic organisations. The Bill & Melinda Gates Foundation – with resources dwarfing many low-income countries' economies – are well-known backers of synthetic biology and GMO agriculture, (in)famous for their techno-utopian vision of sustainable development, and as I witnessed during COP 14 in Egypt, controversial influence in government's political and scientific decision-making at the highest levels[168].

Biosynthesis fits the already existing infrastructure and global commodity flows that support the expanse of corporate consolidation over agricultural inputs, infrastructure, processes and products, in a continuum of a trajectory that has seen large-scale proprietary monocropping regimes expand at the *expense* of diverse and independent small producers, epitomised by the development and strategic use of US corn throughout the 20th century, contributing to the USA's wealth and dominance in agribusiness. In the 21st century global context, however, the companies at the front line of industrial agriculture are not based nationally. They are dominated by an increasingly consolidated group of multinationals headquartered in the global North who have what many consider a 'monopolised' control over seeds, infrastructure, inputs and trade, and considerable influence in UN decision-making (ETC group 2019).

[168] During COP14 the Africa group position on Gene Drives had completely changed from COP13, 2 years prior. SynBioWatch published the Gene Drive Files, which through freedom of information requests, and investigations following the money, revealed that the Gates Foundation had paid the lobby company 'Emerging Ag' $1.6 million dollars to mobilise 65 pro-SynBio voices in the 2017 online CBD consultation in order to counter calls for a gene drive moratorium that had been on the table during COP13 (SynBioWatch 2018; Corporate Europe Observatory 2018). I personally heard accusations of 'the Gates Foundation buying out Africa' in off-the-record conversations I had with members of African delegations on the shuttle busses transporting us between conference and hotel. There was a palpable sense of shock and dismay from the NGO and civil society meetings each morning of COP 14, and many articles on 'conflict of interest' appeared in the CBD Alliance daily Conference newsletter The ECO (CBDA 2018). This all culminated in an official debate at COP14 decision on 'conflicts of interest' in CBD processes (see CBD 2018b)

Rather than a clean green image of biosynthesis as a kind of 'post-industrial' agriculture moving production from the land to the lab and reducing resource consumption, stevia has shown resource efficiency at the expense of socio-ecological diversity, knowledges, relations and livelihoods, has ramifications that are far from sustainable in the terms recognised by global development institutions, where sustainability is achieved through balancing economic, environmental and social factors (UNCTD 2019; Trace 2016; UNSDGs 2021).

Synthetic biology 'natural' products represent continuity and change. Although each natural product assemblage is unique, biosynthesis can be situated as part of an *ongoing processes* of agricultural industrialisation and molecularisation, the historical trajectory of transferring production of valuable resources from South to North, and the increasing reliance upon corporate provision of food, agriculture and 'natural' molecules. Yet biosynthesis also marks a juncture and a break with the trajectory of the past, not just in the physical relations of production 'from the land to the lab', so to speak, but in terms of what is lost, expended or to use Foucauldian phrasing, 'let die' (Li 2009). Humans are just beginning to scratch the surface of what has been lost through the destruction of diversity biologically and culturally, and the wisdom held in socioecological relations (Pant & Ramish 2010; Maffi 2001; Corey & Coleman 2016; Muller 2015). These areas of emergent and often overlooked research I turn to in closing, as I unearth what is expended in the expansion of biosynthesis.

Expending bio-cultural diversity and socio-ecological resilience.

In 2017, in a feminist act of defiance against the (com)modification of stevia, 25,000 seedlings of ka'a he'ê were planted by the women of the Oñondive Producers Committee. They described their actions as an attempt 'to rescue what is related to the culture and traditional medicine of our people, beyond expectations of the domestic economy' (Conamuri 2017). The women's stated aim is to multiply production so that 'results of these practices will be seen over time not only in solidarity markets and in the mini-industry, but also in native seed exchange fairs' – demonstrates that 'reclaiming ka'a he'ê' in Paraguay has come to symbolise much more than simply an ABS claim (Conamuri 2017). When diverse communities came together in Paraguay to contest what they called the 'threat to ka'a he'ê by synthetic biology and patents' their aim was not just to cling on to ka'a he'ê as cash crop, but to 'reclaim ka'a he'ê' as a matter of culture, identity and legacy rooted in common conceptualisations of 'nature' connected to the land. In this way, ka'a he'ê is being amplified as a symbol of a broader struggle over land, culture, and livelihoods in Paraguay. Far from passive actors, the campesinas, campesinos and rural working class in Paraguay have become increasingly defiant in opposition to the industrialisation of agriculture, influence of agribusiness and corruption in their country, through land occupations and (at times) militarised struggles. The actions of the Oñondive Producers and the other campesino and indigenous organisations I encountered in Paraguay underscores how the cultivation of culturally and economically valued plants, such as ka'a he'ê, are important not solely to rural sustainable development programmes but to biocultural identity, diversity and as part of agroecological 'survival strategies'.

Stevia worlds and the dis/connects between them unearth more complex shifts beyond the quiet abandonment of the rural development and small farmer promise of stevia, though this itself is a significant finding. The dis/connected worlds illuminate crossroads where directions were taken at the direct and indirect *expense of* others. These can be glimpsed through the reverberations of particular technological, legal and regulatory choices. The lens of expendability

illuminates how ‘undesirable’ properties of stevia disregarded as having a bitter aftertaste represent molecules many respondents had staked livelihoods on as having diverse medicinal uses. Diverse uses of stevia as medicine or sweetener are related to diverse varieties both wild and bred. Yet if those I met convinced of stevia’s superiority as a medicine rather than a sweeter are eventually proven correct and steviosides are deemed effective by the medical scientific establishment, it is possible that these molecules will become synthesised too. It may be too late for those farmers to benefit from medicinal stevia, as incentive to sustain wild and bred varieties may have already been lost. What incentive is left to preserve and protect a plant’s endemic origins in socio-ecological re-production, once its entire genome is sequenced and specimen stored in a vault, with its use-value reproduced independently from it? Such considerations raise possibilities that biosynthesis may have (in)direct implications upon capacities to sustain agro-biodiversity, hence implicating a loss of agro-biodiversity. Complex rural social and cultural customs are based in socio-ecological peasant farming systems and communities. What is lost can go beyond the loss of horticultural and ecological knowledges and slowly transform regions and communities, disincentivising the passing down of wisdom and diminishing the social value of ecological knowledge. As the Horqueta family – who themselves embody 50 years of socio-ecological knowledge of ka’a he’ê – asserted, once a family loses their connection to the land, ‘it is very difficult for them to return’. How do we account for not just what is expended in the present but the future losses and the reduction of agrarian livelihood options, whether in the worlds of stevia or other cash crops? How does this affect the chances of reviving endemic species and agro-ecological farming systems in the future? Biocultural diversity loss is difficult to quantify in the moment, it is insidious, slow, multidimensional, but once it is gone, it is difficult to rebuild and regain (Maffi 2001). As society stands at a juncture where valuable molecules produced by plants can be produced independently from them, based on detatched, un-earthed , attention to what is lost, expended, un(der)valued and ultimately, ‘let die’, is imperative.

Recent global assessments alert that biocultural diversity is declining at an unprecedented speed (Hanspach et al, 2020) and this decline is a key indicator of how ‘biospheric integrity’ is being pushed beyond the planetary boundaries considered a ‘safe operating space for humanity’ (European Environment Agency 2020). The concept of biocultural diversity – with roots in the 1992 UN Convention on biological diversity – views nature-culture as inseparable, defined as the ‘diversity of life in all its manifestations—biological, cultural and linguistic—which are inter-related within ~~a~~ complex socio-ecological adaptive system(s)’ (Maffi, 2005: 602). The exert below from Pant and Ramish (2010) makes the point that while molecularisation can enable unprecedented technological feats, it does not account for nor reflect the complex socio-ecological, cultural, and living worlds in which the technology – or indeed the very biosynthetic molecules themselves – emerge.

> While conventional agricultural science has been interested in the raw genetic material held and managed by farmers all over the world, it has been much less appreciative or understanding of how local knowledge and cultural practices have created or sustained this landrace diversity (Nazarea 1995). Indeed, positivist science strives to identify and isolate universal scientific principles from cultural practices and spiritual traditions, downplaying relationships between culture and agriculture in general, and culture and agricultural biodiversity in particular. While this paradigm has certainly furthered human understanding and manipulation of simple systems, the generalizations of positivist science are much less useful for generating practical prescriptions for sustainably managing complex natural systems.
>
> Pant and Ramish (2010: 74)

Mainstream approaches in science and governance based on positivist science have historically separated nature from culture and socio-ecological systems, in 'unidirectional utilitarian conceptualization(s) of nature'. The ultimate manifestation of this molecularised perception can be observed through the latest world of stevia interpreted as digital cash DNA, or genetic sequence information and the novel abilities in its (re)production. Understood as a molecule stevia can be quite literally be 'un-earthed' to the point where the physical socio-ecological relations and biocultural diversity from which it originated are no longer necessary to access the specific values it holds.

Does expanding molecular understanding of 'natural' products and plants, come at the increasing expense of biocultural diversity? Such a question highlights neglected considerations and unfolding stakes playing out in the background of molecularisation. Diverse mosaics of knowers and growers of multiple 'natural' products may be replaced by a few industrial sites of biorefinery fermentation. Science and technology studies scholars warn against 'path dependency', where technological options are reduced to the point that society becomes dependent upon a single 'path' or means of producing a thing or providing a service, which can lead to what is termed technological 'lock in' (Stirling 2009). Stirling argues technology lock-in and path dependency contributes to societal vulnerability to economic or environmental shocks as society is more dependent on less diversity. Resilience – in a world of increasing environmental, health, climate uncertainty – can only be achieved by 'keeping open' as many diverse 'pathways to sustainability' as possible (Stirling et al. 2010)

This study has provided a rich picture called for by those working towards the 'responsible innovation' of synthetic biology by following the disjunctures and connections between the sites and spaces surrounding an increasingly (com)modified plant. Through the accounts, stories, contestations and interpretations of stevia /ka'a he'ê, as well as the regulations, definitions and technological transformations surrounding it, I have unearthed what synthetic biology 'natural' products imply to the socio-ecological worlds entangled within and beyond them. These implications became observable through dis/connects between conceptualisations, narratives and practices of authenticity, sustainability, ownership and justice which emerged as central dynamics involved in molecularising processes of expansion and expendability of agrarian and biocultural futures.

The trajectory of synthetic biology's 'natural' products is emerging through corporate and molecular amplification of authenticity in imaginaries of 'naturalness' and socio-ecological 'equivalence', as well as through reductionist notions of sustainability which ignore the vital dynamic of the social. It is a trajectory that is co-produced and intertwined with the increasing technological and legal ability to own, patent and benefit from the living world, natural processes and modified organisms, components and products. The dis/connects over ownership, sustainability and authenticity are seen in global conflicts and contestation amplifying injustice over the distribution of burdens and benefits. The molecularised logic of biotechnology is reflected in global governance institutions and is unable to fully comprehend, let alone address, the joined up, multi-sited and diverse issues that stevia is being mobilised to represent. It is vital that biocultural diversity and fairness and equity over any 'access' and 'utilisation' of the living world must come first in directing the fates and futures of global bio-economies and ecologies. The obscuration and lack of transparency over

what is a widely-considered a substantial change in the way 'natural molecules' are 'harvested' reveals the financial stakes and stark tactics that incumbent industries are adopting to try to convince consumers that nothing has *really* changed, while diverse food systems are increasingly corporate controlled and consolidated. At the most basic level of action, society deserves greater regulations on the labelling of synthetic biology 'natural' products which avert the greenwashing tendency of those profiting from the status quo. Accompanied by strict holistic sustainability appraisals to all promissory technological solutions to socio-ecological crises.

Another world *is* possible. I close this thesis with an ethnographic epilogue that tells the story of one campesino organisation I got to know in Paraguay during 2018. Their story couldn't be placed in previous chapters, yet they left a profound impact on me as the most open, defiant, inspirational, cohesive and pragmatic community I encountered. Ending with their story I aim not to emphasise that I believe all the challenges with ka'a he'ê can be overcome, far from it, but I aim to signify that the spirit, will and skill to create viable alternatives exist in the face of striking adversity.

Epilogue.

Another world *is* possible: ka'a he'ê as survival strategy.

Waiting on the side of the road not far from Yby Ya'u, a pickup truck pulls over with two men inside who nod and beckon us. My Paraguayan friend Marcos and I follow them to the concrete bloc headquarters of a campesino organisation. We are instructed to take a seat on plastic chairs next to several other organisation members.

The following two hours we are subjected to a crash course in the campesino organisation's past, present and future and their commitment to agroecology as both political philosophy and 'survival strategy' for what they see as an ongoing fight to secure their way of life, and how ka'a he'ê fits into this.

In a mix of Spanish and Guaraní the leader explains their group formed in 1995 when 1300 landless peasants 'sin tierra' occupied a 60,000-hectare private property, eventually winning title to the land in 1998. The organisation achieved two further land occupations. Successes however came at the cost of violence and three leaders from the community have been assassinated (Hill 2016). The leader claims Brazilians nicknamed 'Brasilaguayos hire private guards and vigilantes, like a paramilitary force', he eyeballs me 'so it's all very nice that we have this ka'a he'ê project, but if you analyse the context, the everyday realities that we face are complex'. This campesino organisation is testament to reports that access to land in Paraguay is quite literally, a matter of life and death.[169]

I sit like a child in a classroom as they teach me about ka'a he'ê. Scribbling numbers, statistics and diagrams on a white board the leader asserts 'we want to show you what we are doing now'. I try to keep up.

> What we do around stevia is just one more part of our dream because we are actually trying to strengthen our families' livelihoods and our organisation. While we are trying to find a cash crop, it's important for you to know it is just one aspect. […] To start to produce ka'a he'ê it involves political effort because there were so many failed programs, private and public programmes, more or less every new government introduces policies to support for the production of ka'a he'ê among campesinos, but it always fails.[170]

While the campesino organisation are cognisant of the history of broken promises, the persistent lack of fair access to credit and funding and the challenges of climate change and crop failure, their faith in the ka'a he'ê promise is unshaken. They describe it as part of a diversified strategy for sustainability, sovereignty and ultimately resilience. Part of this faith is rooted in what they tell me about the 'increasing interest from different kinds of companies, and more people are eating consciously', but also the domestic market, the medicinal market, the value of the entire plant for animal feed and agri-inputs. Their faith in ka'a he'ê is as a multifaceted herb, not simply a sweetener.

'Since 2015 we have 10 groups of five families each organised to produce as a collective production'. The leader explains, proudly handing me a glossy flyer (see annex 10.6) printed by Oxfam, which helped fund initial set-up costs.

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[169] Personal communications (ref. 32). Campesino Organisation HQ, Concepción, Paraguay. 27/09/18
[170] *Ibid.*

Today ‘we manage all the process to cultivate ourselves’ drawing on the whiteboard the networks formed between organisations and communities regionally and nationally. ‘Just last week we distributed 60,000 (stevia) plantlets among our members and we will distribute 80,000 more next week, we also have 50 new irrigation system to distribute’, pausing for breath, ‘we won't quit!’[171]

After lunch we visited a Guaraní-speaking family who are part of the campesino organisation, they have four young children and live on a farm won through land occupation. The family are subsistence farmers reliant on selling organic ka’a he’ê and tomatoes. Impressed, Marcos exclaims, ‘this is how campesinos live! A strategic self-sustaining combination of many things!’ Though their home is very basic, their land is a beautiful set up, loud with insect and bird song, closest to the farmhouse are fruit trees and animals, one milk cow, one pig and chickens, the next hectare is the family’s vegetable allotment, followed by one hectare set aside for cash crops. The final hectare is reserved for forest firewood and building materials. The farmer, quiet but confident, explains how ka’a he’ê ‘makes sense inside this diversified strategy not only because you are able to sell the leaves, but also because you can use the rest of the plant to feed the animals and use the extract as an antibiotic’. He stressed the importance of a reliable cash crop, while a family can subsist from the land, cash is needed for equipment, tools, schooling, and to help adolescents establish their own lives. Young people, the farmer explains, either must earn enough money to buy land which is increasingly expensive, migrate to cities, work the marijuana plantations, or risk their lives in land occupations.[172]

The farmer explains before they were introduced to agroecology during workshops and meeting technicians, ‘we used chemicals and non-organic techniques, but we were getting ill and the soil was infertile, now we are using different kinds of insects’ elaborating on pesticides, herbicides and fungicides they make: ‘organic doesn't mean just to leave it, it *is* a science’. He goes on, ‘I like this working principle, because the technician’s role is not vertical, it is horizontal, allowing farmers to be technicians for our own farms.’[173]

We later meet the community technician behind a bright pink farmhouse, with a sign reading ‘Vivero de ka’a he’ê orgánico: Proyecto incorporación de la familiar agricultura al mercado de la stevia en Paraguay’, translating as: ‘Organic Stevia nursery: incorporating family farming into the Paraguayan stevia market’. The stevia technician qualified in agroecology in Venezuela shows us the blossoming white aisles of ka’a he’ê, and we taste leaves, and talk about varieties, roots, diseases, seeds, plantlets, soil, sun, shade, climate change and the importance of irrigation.

The technician gives us a tour of the community ‘lab’. Bottles, barrels, kegs and caskets are precariously piled on rickety shelves labelled by hand. The technician lists the ingredients, microbiological reactions and purposes of the concoctions. He lifts the lid of one giant barrel mixing it with a large wooden club, it smells strong, ‘caca de vaca fresca!’ he says with a smile, fresh cow poo! It is mixed with numerous other ingredients, including some native species of beans before it is fermented to produce five essential minerals for plants. ‘This is the revolution!’ he goes on. Pointing to the dozens of jars containing different colour liquids, he explains, too fast to keep up, they contain different classes of bacteria and natural acids. He lists the range of ingredients used for insecticides, fungicides and

[171] Personal communications (ref. 32). Campesino Organisation HQ, Concepción, Paraguay. 27/09/18
[172] Personal communication (ref. 34). Family agroecological farm, Concepción, Paraguay. 27/09/18
[173] *Ibid.*

other chemical elements to produce organically including, milk, yoghurt, cow urine, garlic, chile, alcohol, ashes. Finally, presenting the vast composting process and wormery, 'all of this we make ourselves, 100-percent natural, 100-percent organic!', he exclaims, 'we distribute internally amongst the producers of the [campesino organisation], it's a philosophy of production, we do not to sell them, that's what the big companies do'.[174]

I ask if they'd ever considered producing stevia for Pure Circle. The technician responded, 'we cannot abandon our principles of working with agroecology and organic farming,' describing their respect for 'tierra madre' (mother earth). 'Big companies just don't care about any of these issues or the environmental and social aspects of the production'. He recounted a story of a community nearby who signed an exclusivity contract to cultivate a proprietary stevia variety, but when the contract was terminated the company 'bought tractors and chemicals and destroyed the whole production because they are not allowed to keep producing'.[175]

As we sit down on the veranda of the pink farmhouse, the technician explains, 'we are investing a lot in ka'a he'ê more than other cash crops, and doing it very consciously because we're trying to show the compatibility of ka'a he'ê with small-scale family agriculture, we want to show it is an economic initiative that *is* possible'. He elaborates it is 'easier to produce organically, you don't need to spend lots of money on external inputs and all the resources are already on the farm'. He laments however, 'convincing all the families is difficult […] the campesinos observe how big farmers use lots of agrochemicals and they want to do the same on their small plots'. Intensive agriculture, he explains, 'has had a very strong cultural influence into the minds of Paraguayan campesinos', but 'we are optimists and managing to show that it doesn't make sense for small farmers - *estamos transitando*'. He concludes, 'we are in transition'.[176]

[174] Personal communication (ref. 33). Vivero communidad, Concepción, Paraguay. 27/09/18
[175] *Ibid.*
[176] *Ibid.*

Annex Documents.

Annex Document 10.1

Copy of Participant information and consent form used in Paraguay (Spanish).

Annex Document 10.2

Original version (in German) of the Stevia Speaks commercial interlude.

Sie stammt aus Paraguay und ist längst ein internationaler Star. Jetzt begrüßen wir Stevia mit Coke Life auch im Team von Coca-Cola Deutschland. Hier entblättert die Süße aus dem Dschungel ihr Geheimnis.

¡Hola, amigos!

Mein Name ist Stevia. Ich bin die süßeste Latina der Welt. Okay, vielleicht mal abgesehen von J-Lo und Shakira. Ich gebe zu, die beiden haben längere Beine, können besser tanzen als ich und haben schickere Kleider. Aber ich stehe ohnehin nicht so auf Bling-Bling. Auf den ersten Blick bin ich ein robustes Wesen und eher klein und stämmig. Das macht mir nichts aus. Ich bin keine Lilie und auch keine Orchidee. Ich bin die unkomplizierte Freundin für den Alltag. Aber in einem Punkt mache ich keine Kompromisse: Meine Blüten öffne ich erst, wenn es mindestens 16 Stunden am Tag hell ist.

Meine Heimat ist Paraguay. Dort wuchs ich auf, mitten im tropischen Regenwald, in der Nähe des Paranà-Flusses, umgeben von wilden Früchten, riesigen Schlangen, seltenen Papageien, Tapiren und Pumas. Rund 200 Verwandte von mir tragen ähnliche Namen, doch nur in meinen Blättern fließt der süße Saft, den die Guaraní-Indianer seit Jahrhunderten kennen und schätzen.

Stevia spricht!

Die Guaraní sind die Urbevölkerung im Grenzgebiet zwischen Paraguay und Brasilien. Sie fühlten sich eins mit ihrem Regenwald. Sie betrachteten Tiere und Pflanzen als ihre Geschwister; in ihrer Weltanschauung sind alle Lebewesen gleich viel wert. Mein Name in Guaraní heißt:

“Ka’a He’e”, das süße Kraut.

Hey, Ihr denkt vielleicht, wer spricht schon Indianisch? Denkt Ihr. In meiner Heimat ist Guaraní zweite Amtssprache und sogar der Name meines Landes, Paraguay, ist Guaraní und bedeutet: „Wasser, das zum Wasser geht“. Er kommt wohl daher, dass wir prächtige Flüsse haben, aber keine Küste.

Die Guaraní benutzen meine Blätter für ihren Mate-Tee und als Heilmittel, zum Beispiel gegen Magen- und Verdauungsbeschwerden, Hautprobleme und Zahnentzündungen, oder um den Blutdruck zu senken. Auch heute werde ich in Paraguay zum Süßen von Tees und zur Herstellung von Süßigkeiten verwendet. Denn wir Paraguayer mögen es sehr süß! Wir leben im Einklang mit der Natur und müssen uns nichts verkneifen. Vielleicht bezeichnen wir uns deshalb in Umfragen immer wieder als die glücklichsten Menschen der Welt.

In der Wildnis trifft man mich kaum noch. Genauso wie viele Stämme der Guaraní habe ich durch die Zerstörung des Regenwaldes meinen ursprünglichen Lebensraum verloren. Ich stehe unter Naturschutz und muss angebaut werden.

Meine Familie ist international.

Als Korbblütlerin habe ich Verwandte in aller Welt, zum Beispiel Eure Sonnenblume. Doch im Vergleich zu ihr wirken meine weißen, sternenförmigen Blüten geradezu grazil. Wollt Ihr meine Blätter ernten, müsst Ihr das aber tun, bevor ich blühe. Sonst geht meine ganze Dschungel-Power in die Blüten und die Samen, die der Wind später in die Erde sät.

In Europa wurde ich zum ersten Mal im 16. Jahrhundert erwähnt; als die spanischen Konquistadoren in ihrer Heimat darüber berichteten, dass die südamerikanischen Eingeborenen die Blätter einer Pflanze benutzen, um ihre Kräutertees zu süßen. Zucker wurde damals noch in Gold aufgewogen.

Foto aus der Heimat: hier wurde Stevia entdeckt

Allein im Urwald – nur mit mir!

Eine erste wissenschaftliche Untersuchung über mich wurde Ende des 19. Jahrhunderts veröffentlicht, von Moisés Santiago Bertoni, einem Botaniker und Naturforscher, der mit seiner Familie aus der Schweiz nach Paraguay auswanderte. Jahrelang lebte er mitten im Urwald, nur um mich zu erforschen! Einmalig, diese Leidenschaft! Ihm und seinem Freund, dem Chemiker Ovidio Rebaudi, verdanke ich meinen lateinischen Namen: „Stevia Rebaudiana Bertoni".

Obwohl sie Jahre mit der Erkundung meines Innenlebens verbrachten, gelang es ihnen nicht, meinen Süßstoff vollständig zu isolieren. Das erstaunt mich nicht, sage ich ganz unbescheiden, denn man nennt mich nicht umsonst Stevia Wonder. Auch wenn ich nicht tanzen kann: Meine Musik, das sind Samba und Cumbia! Das kann man nicht im Labor erklären. Man muss mich erleben!

Erst in den Siebzigerjahren entführten mich in Paraguay lebende Asiaten nach Japan. Ja, so ist es: ich war zuerst *big in Japan*. Dort bin ich seit vielen Jahren berühmt und sehr beliebt. Heute werden meine Schwestern außer in Paraguay und Japan auch in Südkorea, Malaysia, China, Mexico, Kanada und Kenia angebaut.

Mein süßes Geheimnis

Um aus meinen kraftvollen Blättern das Steviosid zu gewinnen, bedarf es eines möglichst schonenden Verfahrens. Wie ich schon sagte: Samba und Cumbia. Wenn man es richtig macht, schmecke ich vollmundig süß mit leichtem Lakritzgeschmack – aber niemals bitter. Nur, wer mich gut behandelt, dem schenke ich mein ganzes Geheimnis.

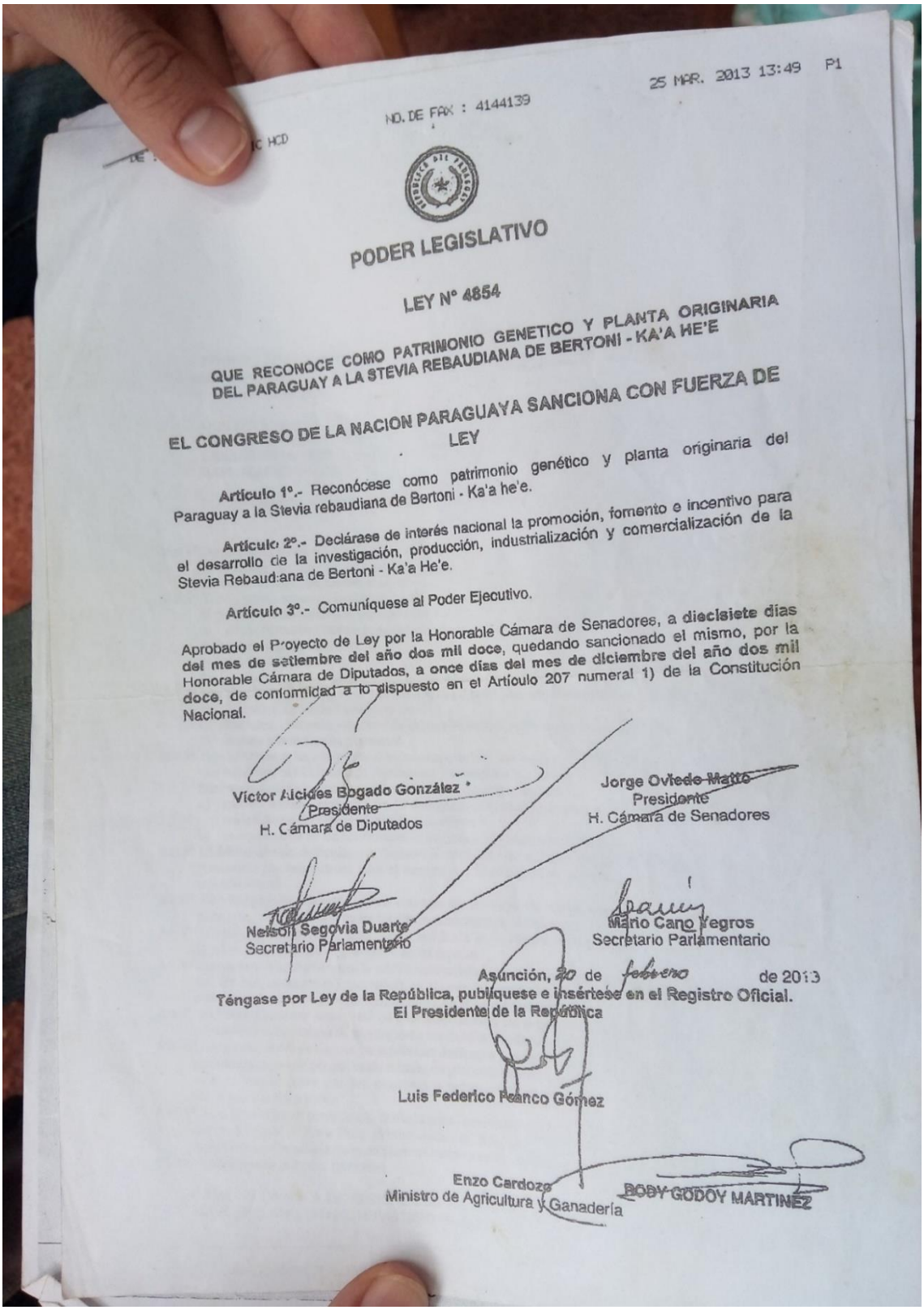
Und dieses Steviosid ist ein Naturprodukt. Es hat unverschämt viele Vorteile gegenüber Zucker und künstlichen Süßmitteln. Es ist nämlich sehr stabil und durchwandert Euren Körper nahezu unverändert. Ich habe praktisch keine Kalorien und beeinflusse auch den Blutzuckerspiegel nicht. Darüber hinaus rege ich weder Euren Heißhunger auf Süßes an, noch schädige ich Eure Zähne. Im Gegenteil! Meine Einnahme hemmt die Plaquebildung, weswegen mich auch die Zahnärzte lieben. Sogar zur Herstellung von Zahnpasta möchte man meine Zauberkräfte verwenden. Schließlich weiß ich, wie wichtig ein strahlendes Lächeln ist. Und außerdem verrate ich Euch noch einen kosmetischen Tipp der Guaraní: Nach einem Bad mit dem grünem Pulver aus meinen Blättern wird eure Haut samtig weich wie unsere paraguayanische Milchkaramellcreme.

Wenn Ihr nicht genug von mir bekommt, komme ich zu Euch nach Hause und wohne auf Eurer Fensterbank oder dem Balkon. Denkt daran: ich brauche viel Sonne und ausgewogene Feuchtigkeit. Kalte Füße sind mir ein Gräuel, im Winter solltet Ihr mich ins Gewächshaus stellen. Die Mühe lohnt sich. Denn ich bin die Sünde ohne Reue. Versprochen.

Source: https://de.coca-cola.ch/unternehmen/zuckerreduktion/ich-bin-stevia-die-suesse-aus-dem-dschungel

Annex document 10.3

Copy of the Paraguayan 1970 draft legislation that declares a national interest in the agricultural development of the cultivation of ka'a he'ê (Yerba dulce or *Stevia rebaudiana* Bertoni) and empowers the executive to dictate rules for its promotion, conservation, renewal and national exploitation.



25 MAR. 2013 13:49 P1

NO. DE FAX : 4144139

PODER LEGISLATIVO

LEY Nº 4854

QUE RECONOCE COMO PATRIMONIO GENETICO Y PLANTA ORIGINARIA DEL PARAGUAY A LA STEVIA REBAUDIANA DE BERTONI - KA'A HE'E

EL CONGRESO DE LA NACION PARAGUAYA SANCIONA CON FUERZA DE LEY

Artículo 1º.- Reconócese como patrimonio genético y planta originaria del Paraguay a la Stevia rebaudiana de Bertoni - Ka'a he'e.

Artículo 2º.- Declárase de interés nacional la promoción, fomento e incentivo para el desarrollo de la investigación, producción, industrialización y comercialización de la Stevia Rebaudiana de Bertoni - Ka'a He'e.

Artículo 3º.- Comuníquese al Poder Ejecutivo.

Aprobado el Proyecto de Ley por la Honorable Cámara de Senadores, a **diecisiete días del mes de setiembre del año dos mil doce**, quedando sancionado el mismo, por la Honorable Cámara de Diputados, a **once días del mes de diciembre del año dos mil doce**, de conformidad a lo dispuesto en el Artículo 207 numeral 1) de la Constitución Nacional.

Víctor Alcides Bogado González
Presidente
H. Cámara de Diputados

Jorge Oviedo Matto
Presidente
H. Cámara de Senadores

Nelson Segovia Duarte
Secretario Parlamentario

Mario Cano Yegros
Secretario Parlamentario

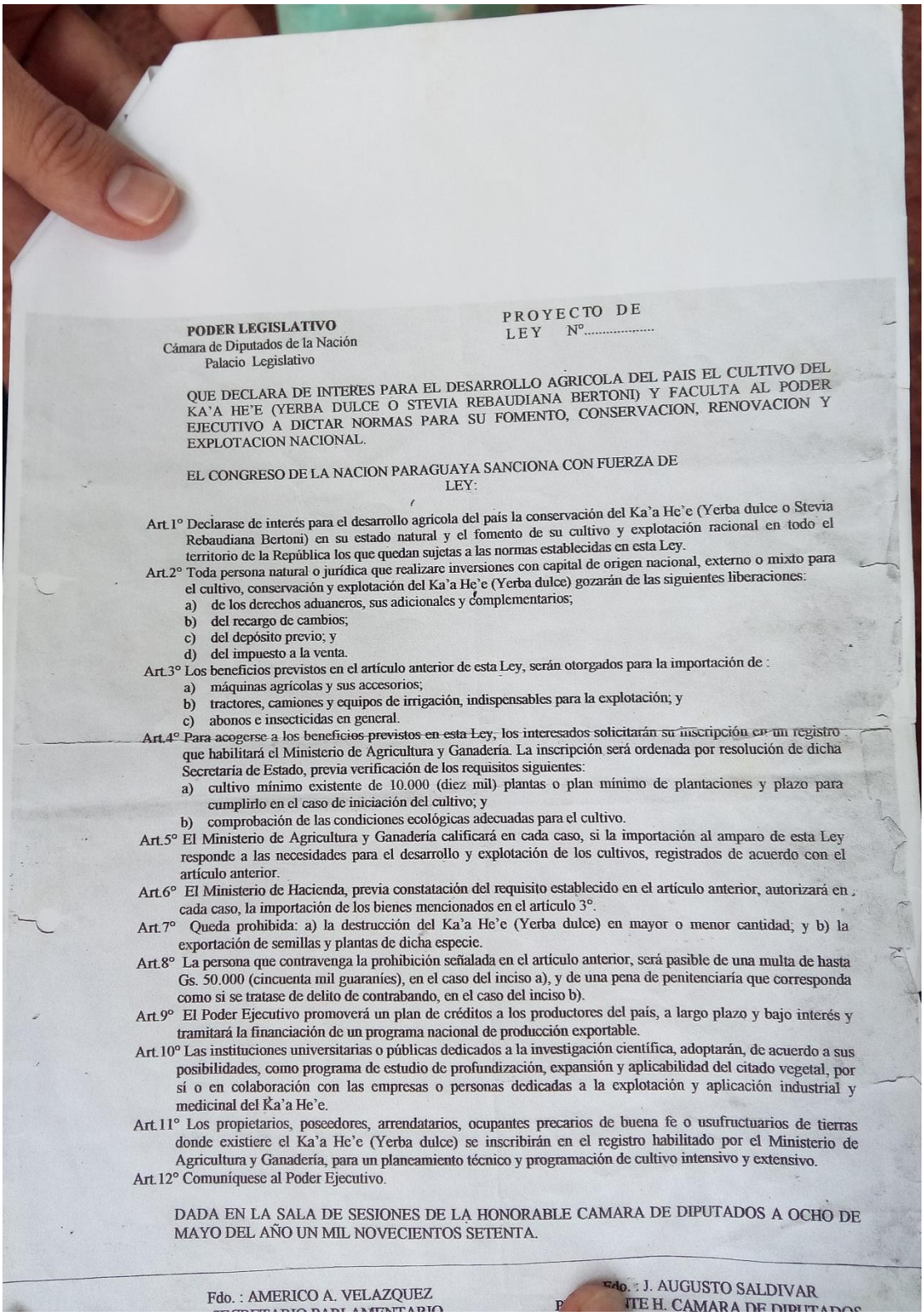
Asunción, 20 de febrero de 2013

Téngase por Ley de la República, publíquese e insértese en el Registro Oficial.
El Presidente de la República

Luis Federico Franco Gómez

Enzo Cardozo
Ministro de Agricultura y Ganadería

RODY GODOY MARTINEZ



PODER LEGISLATIVO
Cámara de Diputados de la Nación
Palacio Legislativo

PROYECTO DE LEY Nº.....

QUE DECLARA DE INTERES PARA EL DESARROLLO AGRICOLA DEL PAIS EL CULTIVO DEL KA'A HE'E (YERBA DULCE O STEVIA REBAUDIANA BERTONI) Y FACULTA AL PODER EJECUTIVO A DICTAR NORMAS PARA SU FOMENTO, CONSERVACION, RENOVACION Y EXPLOTACION NACIONAL.

EL CONGRESO DE LA NACION PARAGUAYA SANCIONA CON FUERZA DE LEY:

Art.1° Declarase de interés para el desarrollo agrícola del país la conservación del Ka'a He'e (Yerba dulce o Stevia Rebaudiana Bertoni) en su estado natural y el fomento de su cultivo y explotación racional en todo el territorio de la República los que quedan sujetas a las normas establecidas en esta Ley.

Art.2° Toda persona natural o jurídica que realizare inversiones con capital de origen nacional, externo o mixto para el cultivo, conservación y explotación del Ka'a He'e (Yerba dulce) gozarán de las siguientes liberaciones:
a) de los derechos aduaneros, sus adicionales y complementarios;
b) del recargo de cambios;
c) del depósito previo; y
d) del impuesto a la venta.

Art.3° Los beneficios previstos en el artículo anterior de esta Ley, serán otorgados para la importación de :
a) máquinas agrícolas y sus accesorios;
b) tractores, camiones y equipos de irrigación, indispensables para la explotación; y
c) abonos e insecticidas en general.

Art.4° Para acogerse a los beneficios previstos en esta Ley, los interesados solicitarán su inscripción en un registro que habilitará el Ministerio de Agricultura y Ganadería. La inscripción será ordenada por resolución de dicha Secretaría de Estado, previa verificación de los requisitos siguientes:
a) cultivo mínimo existente de 10.000 (diez mil) plantas o plan mínimo de plantaciones y plazo para cumplirlo en el caso de iniciación del cultivo; y
b) comprobación de las condiciones ecológicas adecuadas para el cultivo.

Art.5° El Ministerio de Agricultura y Ganadería calificará en cada caso, si la importación al amparo de esta Ley responde a las necesidades para el desarrollo y explotación de los cultivos, registrados de acuerdo con el artículo anterior.

Art.6° El Ministerio de Hacienda, previa constatación del requisito establecido en el artículo anterior, autorizará en cada caso, la importación de los bienes mencionados en el artículo 3°.

Art.7° Queda prohibida: a) la destrucción del Ka'a He'e (Yerba dulce) en mayor o menor cantidad; y b) la exportación de semillas y plantas de dicha especie.

Art.8° La persona que contravenga la prohibición señalada en el artículo anterior, será pasible de una multa de hasta Gs. 50.000 (cincuenta mil guaraníes), en el caso del inciso a), y de una pena de penitenciaría que corresponda como si se tratase de delito de contrabando, en el caso del inciso b).

Art.9° El Poder Ejecutivo promoverá un plan de créditos a los productores del país, a largo plazo y bajo interés y tramitará la financiación de un programa nacional de producción exportable.

Art.10° Las instituciones universitarias o públicas dedicados a la investigación científica, adoptarán, de acuerdo a sus posibilidades, como programa de estudio de profundización, expansión y aplicabilidad del citado vegetal, por sí o en colaboración con las empresas o personas dedicadas a la explotación y aplicación industrial y medicinal del Ka'a He'e.

Art.11° Los propietarios, poseedores, arrendatarios, ocupantes precarios de buena fe o usufructuarios de tierras donde existiere el Ka'a He'e (Yerba dulce) se inscribirán en el registro habilitado por el Ministerio de Agricultura y Ganadería, para un planeamiento técnico y programación de cultivo intensivo y extensivo.

Art.12° Comuníquese al Poder Ejecutivo.

DADA EN LA SALA DE SESIONES DE LA HONORABLE CAMARA DE DIPUTADOS A OCHO DE MAYO DEL AÑO UN MIL NOVECIENTOS SETENTA.

Fdo. : AMERICO A. VELAZQUEZ

Fdo. : J. AUGUSTO SALDIVAR

ITE H. CAMARA DE DIPUTADOS

Annex Document 10.4

Copy of AHTEG report to SBSTTA 20 of potential adverse effects of Synthetic biology, that stevia was mobilised to represent the effects to 'Sustainable use' and 'Equitable Sharing of Benefits of Biodiversity'.

Potential adverse effects

Potential adverse effects of synthetic biology with respect to conservation of biological diversity can result from direct and indirect, intended or unintended, as well as immediate or delayed effects. These effects may occur at the genetic, population, or ecosystem level. On this basis, the following examples of potential adverse effects were identified:

Objective 1: Conservation of biological diversity

(a) An engineered fitness advantage may lead to invasiveness;

(b) Enhanced gene flow that leads to loss of biodiversity;

(c) An increased pathogenic potential;

(d) Increased levels of toxic substances, which may lead to disruptive effects on soil, food-webs, and pollinators;

(e) Negative effects on non-target organisms, such as pollinators;

(f) Changes in organisms on the level of basic metabolic pathways, such as altered photosynthesis pathways, carbohydrate metabolism or nitrogen fixation, which, among other effects, may lead to changes in agricultural practice and land-use and may challenge risk assessment;

(g) Applications that are aimed at altering and replacing natural populations (for example, gene drive systems) may have adverse effects at the ecosystem level, and vis-à-vis the other two objectives of the Convention;

Objective 2: Sustainable use of biological diversity

(h) Increased demand for biomass crops, as well as changes in patterns of extraction of biomass, minerals and other sources of energy, may lead to changes in land use;

(i) Replacement of natural products may lead to changes in the agricultural practices of communities, which may adversely affect traditional crops, practices and livelihoods;

(j) Gene flow may lead to adverse effects on agrobiodiversity;

Objective 3: Equitable sharing of the benefits of biological diversity

(k) Loss of market share and income by indigenous and local communities due to the altered exploitation of genetic resources;

(l) A shift in the understanding of what constitutes a genetic resource and the implications thereof, such as the misappropriation of the original source of the DNA information and, consequently — if benefits are derived from the use of such DNA information without prior informed consent and mutually agreed terms — the fair and equitable sharing of the benefits would not be possible;

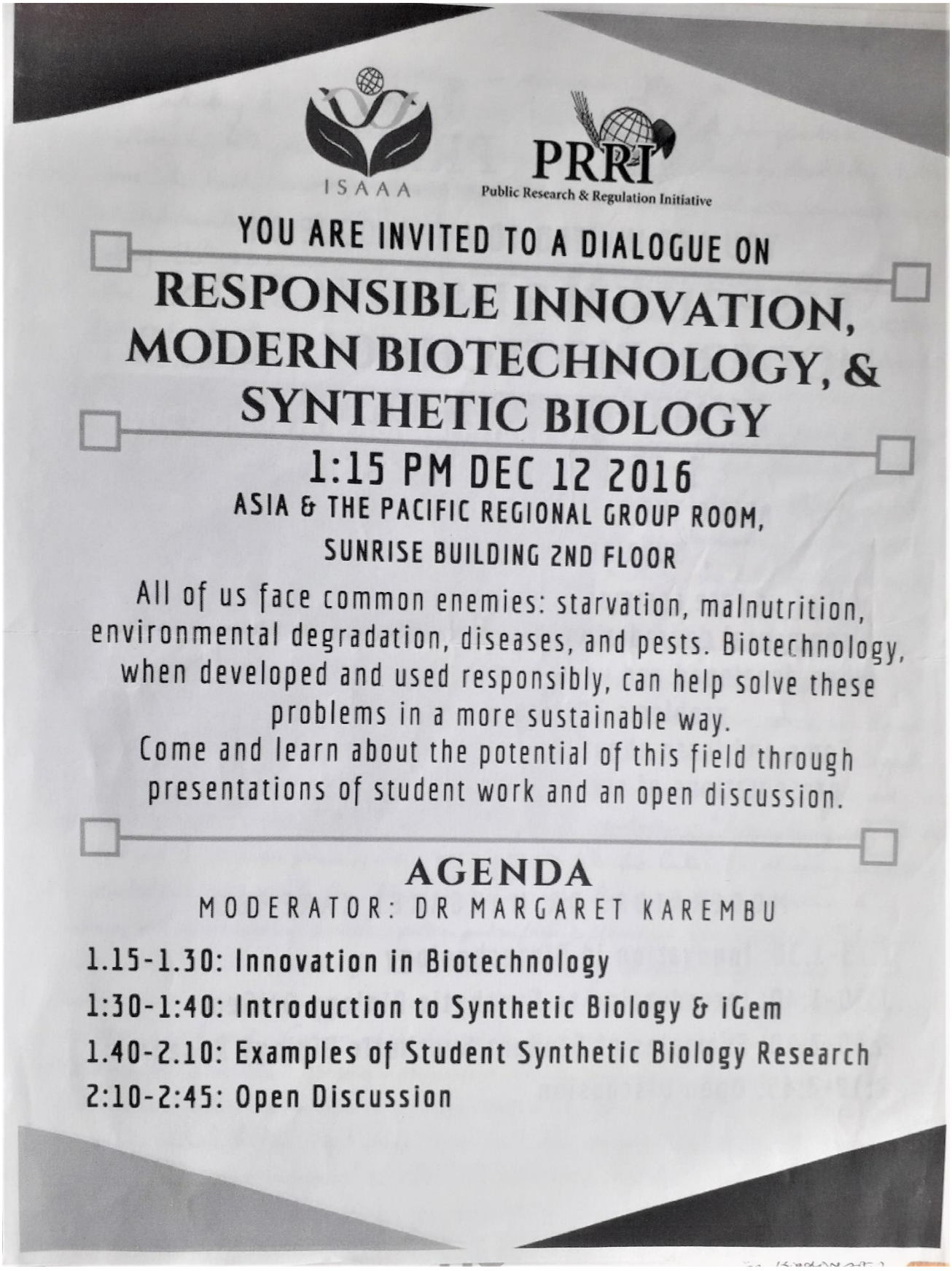
(m) Inappropriate access without benefit sharing due to the use of sequenced data without material transfer agreements under the Nagoya Protocol;

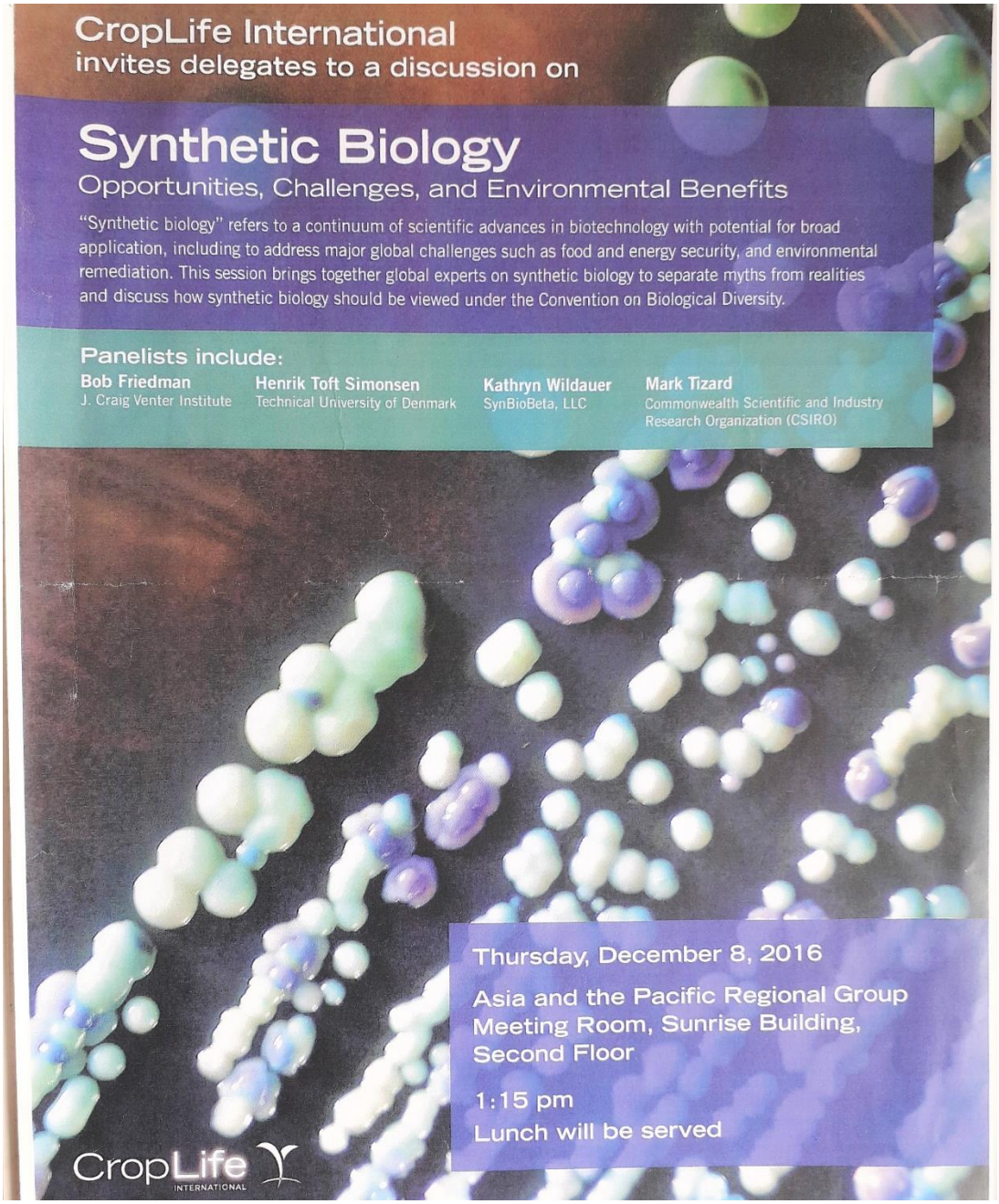
(n) Patent-driven and open-source approaches to synthetic biology may have different implications in the context of access and benefit sharing;

(o) Indigenous peoples and local communities will not necessarily support or benefit from the utilization of genetic resources in synthetic biology.

Annex Documents 10.5

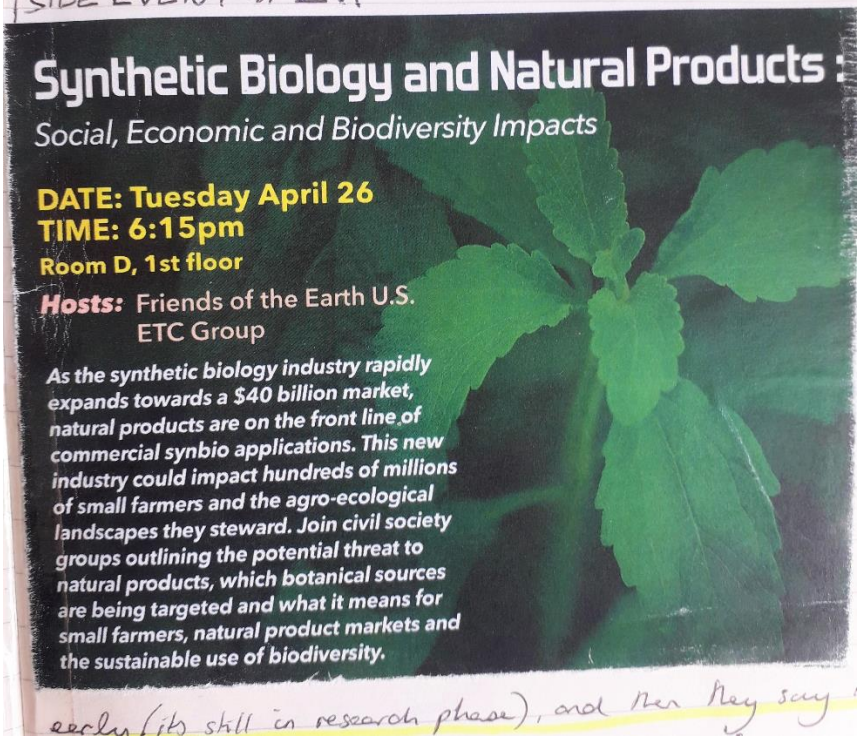
A selection of some CBD COP & SBSTTA side event flyers.




CropLife International
invites delegates to a discussion on
Synthetic Biology
Opportunities, Challenges, and Environmental Benefits
"Synthetic biology" refers to a continuum of scientific advances in biotechnology with potential for broad application, including to address major global challenges such as food and energy security, and environmental remediation. This session brings together global experts on synthetic biology to separate myths from realities and discuss how synthetic biology should be viewed under the Convention on Biological Diversity.
Panelists include:
Bob Friedman
J. Craig Venter Institute
Henrik Toft Simonsen
Technical University of Denmark
Kathryn Wildauer
SynBioBeta, LLC
Mark Tizard
Commonwealth Scientific and Industry Research Organization (CSIRO)
Thursday, December 8, 2016
Asia and the Pacific Regional Group Meeting Room, Sunrise Building, Second Floor
1:15 pm
Lunch will be served
CropLife INTERNATIONAL

In fact out of the ___ representatives from NGOs

SIDE EVENT #2:



easily (its still in research phase), and then they say

Annex Documents 10.6

Leaflet given to me by the campesino organisation described in the Epilogue. The leaflet was titled Cultivando el Futuro, and the main strapline translates as: Towards sustainable family farming. One of our most innovative bets is stevia produced organically.

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