PIÑATEX, THE DESIGN DEVELOPMENT OF
A NEW SUSTAINABLE MATERIAL

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Copyright Statement

Abstract

This is a research project by practice, which firstly develops a new material invention derived from natural fibres extracted from waste pineapple leaves; secondly it articulates the contemporary designer's role in facilitating sustainable solutions through:

Insights from my own material invention, Piñatex™, which integrates the materiality of design with the immateriality of concepts and values

Developing a visual model of mapping

I began with these questions:

'What are the challenges in seeking to make a new and sustainable material from the waste products of pineapple agriculture in the Philippines?'

and

'How can a design practice link elements of materiality (artifacts) with immaterial elements (value systems) in order to improve sustainable social and economic development?'

Significant influences have been the work of Papanek[1] (2003), Hawken[2] (1999) and Abouleish[3] (2008) and in particular the ethical business model initiated by McDonough and Braungart in Cradle to Cradle®[4] (2002). My own research project is inspired by the Cradle to Cradle® model. It proposes the development of a new material, Piñatex™ which is derived from natural fibres extracted from waste pineapple leaves and could be used in a wide variety of products that are currently fabricated in leather or petroleum-based materials.

The methods have comprised: Contextual reviews; case studies (SEKEM, Cradle to Cradle® and Gawad Kalinga); practical experiments in the field of natural fibres, chemistry, product development, manufacturing and prototyping, leading to an invention and a theoretical

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[1] V. Papanek, *The Green Imperative. Ecology and Ethics in Design and Architecture,* London: Thames & Hudson, 2003

[2] Hawken, P., Lovings Amory, B., Lovins Hunter L., *Natural Capitalism: The Next Industrial Revolution,* London: Earthscan, 1999

[3] I. Abouleish, *SEKEM: A Sustainable Community in the Egypt Desert,* Edinburgh: Floris Books, 2005

[4] W. McDonough and M. Braungart, *Cradle to Cradle: Remaking the Way we Make Things*, New York: North Point Press, 2002

model of mapping. In addition, collaboration has taken place across scientific, technological, social, ecological, academic and business fields.

The outcome is a new material based on the synchronicity between the pineapple fibres, polymers, resins and coatings specially formulated. The invention of the new material that I developed as a central part of this research by practice has a patent in the national phase (PCT/GB 2011/000802) and is in the first stages of manufacturing, commercial testing and further design input (Summer 2014).

The contribution to knowledge is firstly the material, Piñatex™, which exhibits certain key qualities, namely environmentally non-toxic, biodegradable, income-generating potential and marketability. This is alongside its intrinsic qualities as a textile product: aesthetic potential, durability and stability, which will make it suitable for the accessories, interiors and furnishing markets.

The theoretical mapping system *Upstream and Downstream* forms a secondary contribution.

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I have been fortunate to have Ananas Anam, my company and my team, here in London and in Barcelona, Spain, supporting me and allowing me (some!) time and space to work on this PhD thesis.

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The contacts, conversations and inspiration from Gawad Kalinga, the Ayala Foundation and the Philippine Board of Investment reassure me that the social and economic aspect of my research will find fertile ground for prospering in the Philippines.

This investigation was carried out in collaboration with Leitat Technological Centre in Barcelona, the Northampton Leather Technology Centre in the UK, Bangor University Bio Composite Centre in Wales and Bonditex S.L. in Spain.

Special thanks to Bonditex S.L in Spain for taking on my vision and developing the final samples first at laboratory level and then developing a system of production to make Piñatex a commercial proposition.

Special thanks to The Institute of Materials, Minerals and Mining (IoM3) in London for their willingness to help and link me with industry.

A grateful thank you to my family who have been supporting my endeavours unconditionally. Gracias a todos.

Finally, I would like to dedicate this work to my daughter Olaya, for she is the future, alongside her generation.

With love and appreciation to all

Author's Declaration

During the period of registered study in which this thesis was prepared the author has not been registered for any other academic award or qualification.

The material included in this thesis has not been submitted wholly or in part for any academic award or qualifications other than that for which it is now submitted.

C. Alvarez A. Hijosa

December 2014

CHAPTER ONE: – Introduction

> 'Prosperity consists in our ability to flourish as human beings – within the ecological limits of a finite planet. The challenge for our society is to create the conditions under which this is possible. It is the most urgent task of our times.'[5]
>
> Tim Jackson

There is a great sense of urgency amongst some of the most advanced thinkers and entrepreneurs in the world today – Paul Hawken, Michael Braungart, Ray Anderson, Ibrahim Abouleish – to do something about how to sustain and indeed to heal planet earth through our actions. As the 'Cradle to Cradle'®[6] approach puts it, this sense of urgency is 'an opportunity not to be missed'.[7]

In stark contrast and parallel to this positive attitude is the realization that we have to face problems that are vast and complex: we have reached a population of 6.94 billion people which is increasing incrementally. The process of fulfilling everybody's wants and needs is stripping the earth of its inherent capacity to produce life; a burst of consumption by a single species is overwhelming the skies, earth, waters, and all that depends on these. The cornucopia of resources that are being extracted, mined and harvested are so poorly distributed that 20 per cent of the earth's people are chronically hungry or starving, while the rest of the population, largely in the North, control and consume 80 per cent of the world's wealth.[8] Since business in its myriad forms is primarily responsible for this plunder, it is appropriate that a growing number of enterprises ask themselves: how can business be conducted in a sustainable manner in the latter days of industrialization and the beginning of

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[5] Tim Jackson, *Prosperity without Growth*, *Economics for a Finite Planet*, London; Washington: Earthscan 2011, p. 16

[6] W. McDonough & M. Braungart, 2002. Cradle to Cradle® is a trademark of McDonough Braungart Design Chemistry, LLC.

[7] Pierre Hupperts [et al.],*Cradle to Cradle pays off,* Amsterdam: Netherlands Ministry of Infrastructure and the Environment/Knoops, 2011, p 8

[8] Paul Hawken, Amory B. Lovins, Hunter L. Lovins, *Natural Capitalism: The Next Industrial Revolution,* London: Earthscan, 1999

an ecological age? The question is, can we create sustainable, profitable, expandable companies that do not destroy, directly or indirectly, the world around us?

Wahl and Baxter[9] have stated that 'Sustainability is rapidly becoming an issue of critical importance for designers and society as a whole. A complexity of dynamically interrelated ecological, social, cultural, economic, and psychological (awareness) problems interact and converge in the current crisis of our unsustainable civilization.'

How can our world survive a continued pattern of global degradation in living systems? How do we imagine our future when our commercial systems conflict with everything nature teaches us? What is the logic of extracting diminishing resources in order to create capital to finance more consumption and demand on those same diminishing resources?.

Paul Hawken, in his visionary book *The Ecology of Commerce: How Business Can Save the Planet ,* tells us that

> 'To create an enduring society, we will need a system of commerce and production where each and every act is inherently sustainable and restorative. Business will need to integrate economic, biologic and human systems to create sustainable methods of commerce'.[10]

A restorative economy will have as its hallmark a business community that co-evolves with the natural and human community it serves. According to Hawken, not only do business and industry form the principal instruments of global destruction, they are also the only institutions large enough, wealthy enough and pervasive and powerful enough to lead humankind out of the mess we are making.

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[9] Daniel C. Wahl and Seaton Baxter, 'The Designer's Role in Facilitating Sustainable Solutions', *Design Issues*, 24(2), Spring 2008, 72

[10] Paul Hawken, *The Ecology of Commerce: How Business can Save the Planet,* London: Orion House, 1993

In this fast-changing and uncertain environment, what is the role of designers, and how can we take on board our responsibilities and place sustainable practices at the core of our thinking, feeling and doing? We need to embrace change as a continuous flow of unknown factors that demand a broader consensus and interpretation of our surroundings, lifestyles, habits and design practices.

1.1 Etymology and meaning of sustainability and legislation

The etymological root of 'sustainability' comes from 'sustain', whose origin comes from the Middle English *sustenen,* from Old French *soustenir*, from Latin *sustinere*, from sub- 'from below' + tenere 'hold'.[11] From the *Collins English Dictionary* we have: 'to sustain what is already there – keeping where they belong communities, working together to realize the potential of their own resources, skills'. Sustain is being interpreted in this particular contextual association.[12] My thinking finds resonance in the meaning above, it being in tune with the aims of my project and Ananas Anam.[13] Throughout my work in the Philippines I have seen displaced and marginalized communities moving from the country to the cities, losing their homes, skills and pride; I am aware of the potential this PhD may contribute to the relief of this particular kind of hardship. Sustaining communities where they belong is one of the aims of this PhD.

Over the last quarter of a century the concept of sustainability has been incorporated in multinational and national legislation. The term sustainability or sustainable development has been acknowledged worldwide as the central concept for improving issues in politics, science and economics.[14] After the Earth Charter in Rio de Janeiro in 1992,[15] over 170 countries accepted the paradigm 'Sustainable Development' as a guiding principle. The document in which it is laid down is the *Agenda 21*[16], which contains important agreements for combatting poverty, population policy, waste, chemicals, climate, energy, and farming

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[11] Online Etymology Dictionary. http://www.etymonline.com/ (accessed: October 29, 2012)

[12] S. Anderson, *Collins English Dictionary - Complete & Unabridged*, 10th Edition, London: Collins, 2009.

[13] The company that I have established resulting from this PhD, www.ananas-anam.com

[14] U. Tischner, *Sustainable Design and Ecodesign*, Eindhoven: Design Academy Eindhoven, 2006.

[15] 'Earth Charter', Wikipedia,, http://en.wikipedia.org/wiki/Earth_Charter (accessed 18 Oct. 2014)

[16] Agenda 21 is a programme of action for the 21st century to bring the Earth to a sustainable future. It was adopted by the participating governments of the world at the United Nations Conference on Environment and Development (UNCED), otherwise known as the Earth Summit, in Rio de Janeiro, Brazil in June 1992.

policy, as well as financial and technical co-operation between industrialised and less industrialised countries. The Agenda clarifies that the poor and the rich parts of the world have to be regarded as one.

As a consequence of this, Nicanor Perlas from the Philippines co-wrote the *Philippine Agenda 21* (*PA21*),[17] which has been taken by the Philippines government into their constitution (1997). Nicanor Perlas was one of the official civil society delegates from the Philippines at the Earth Summit in Rio in 1992 and his *Philippine Agenda 21* was the creative response to the challenges of elite globalization based on the Earth Summit 1992.[18] The *PA21* is also the Philippines' commitment to the UNCED.[19] It lays down the mix of strategies that integrate the parameters in the country's overall development strategy, identifies the intervention areas (or Action Agenda) – from the national to the regional level – with the corresponding implementing platforms and plans.

This agenda and the meeting with Nicanor Perlas on one of my work visits to Philippines have been one of the formative influences on the vision towards my project's sustainable realizations in the Philippines.

1.2 Sustainable Development

In 1987, the United Nations released the *Report of the World Commission on Environment and Development*, which included what is now one of the most widely recognized definitions of sustainable development:

> Sustainable development (SD) is a pattern of resources used, that aims to meet human needs while preserving the environment so that these needs

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[17] *Philippine Agenda 21: a national agenda for sustainable development*, Manila: Philippine Council for Sustainable Development, 1997

[18] Nicanor Perlas, http://en.wikipedia.org/wiki/Nicanor_Perlas

[19] 'United Nations Conference on the Environment', *Encyclopedia Britannica*, www.britannica.com/.../United-Nations-Conference-on-Environment

> can be met not only in the present, but also for generations to come. The term was used by the Brundtland Commission, which coined what has become the most often-quoted definition of sustainable development as development that 'meets the needs of the present without compromising the ability of future generations to meet their own needs.[20]

Sustainable development ties together concern for the carrying capacity of nature with the social challenges facing humanity. As early as the 1970s, 'sustainability' was employed to describe an economy 'in equilibrium with basic ecological support systems' and Ger B. Asheim from the World Bank[21] tells us that 'development is sustainable if it involves a non-decreasing average quality of life.'

As a designer, Wahl's statement 'Sustainability is a process of co evolution and co-design that involves diverse communities in making flexible and adaptable design decisions on local, regional, and global scales'[22], brings sustainability to the realm of design evolution, which is the realm I wish to operate from.

As the global village becomes a reality in many forms of life, with modern travel, communications, business takeovers and amalgamations, it is becoming more and more important to respect and retain our diverse cultural identities, bringing traditions, skills and local knowledge that have come about over many generations and have been part of daily life from time untold, into the present economic reality.

How can we evolve as designers without destroying and distorting these traditions and skills, without taking away their integrity and connections with their very founders: the people that brought these traditions, values, and knowledge this far into the twenty-first century?

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[20] *Report of the World Commission on Environment and Development*, United Nations, 1987

[21] Asheim, G. B., *Sustainability*: *Ethical Foundations and Economic Properties*, Policy Research Working Paper 1302. Washington: The World Bank, 1994

[22] Wahl and Baxter, 2008, 72

How can we do this with respect, without destroying what has been developed already? To realize this vision, we need an understanding and admiration for what has been developed at a local, regional and national scale, and to help jointly to transform it into a contemporary expression that does not violate the makers' acquired abilities, but rather enhances them.

A design thinking dialogue that encompasses the aforementioned points of view has been the key starting point for my project's first research question: What are the challenges in seeking to make a new and sustainable material from the waste products of the pineapple agriculture in the Philippines?'

Questions such us:

- How can I, as a designer, develop a vision and find the way to work with local communities, using a by-product of the pineapple harvest as raw material?
- How can I develop a new material and new ways of processing these fibres in an ecological manner?
- How can I ensure that the processes developed carry an economic value for all the people involved, as well as being in tune with the needs of the earth?

How I respond to these questions as a designer, maintaining my integrity as a professional and seeking sustainable solutions within the context of the pineapple fibre transformation forms the core of Chapter Three: 'The case for Piñatex- How a new textile material was born'.

The second contribution stems from the question: 'How can a design practice link elements of materiality (artifacts) with the immaterial elements (value systems) in order to improve sustainable, social and economic development?'

Throughout the project, the design thinking has been focused on the processes as well as the product development. This part hinges on how my design model relates to Wahl and Baxter's conceptual model 'The Designer's Role in Facilitating Sustainable Solutions'[23] which I am using throughout my thesis as an analytical tool. The aim of the latter is to understand, link and map design in relation to materials, artifacts, patterns of production and

[23] Ibid.

consumption (the *Downstream* end of the design process) to the immaterial concepts, value systems, world views and aspirations reflected in the *Upstream*, the immaterial dimension of design.

This PhD thus is first a contribution to the process of rethinking how we think about design in the context of dilemmas for sustainable solutions in the face of current situations and rapid changes. Second, it is a contribution about how the *Upstream* and *Downstream* framework may be used as a practical tool in facilitating guidelines beyond my own project for future material designers.

1.3 Main research questions

What are the challenges in seeking to make a new and sustainable material from the waste product of the pineapple agriculture in the Philippines?'

How can a design practice link elements of materiality (artifacts) with immaterial elements (value systems) in order to improve sustainable, social and economic development?'

1.4 Contribution to knowledge

This PhD's contribution to knowledge is stated below:

A product that aims to sustain the environment and the community throughout its intended closed-loop cycle through fair economics

A transferable technology based on the above findings

A design methodology (through mapping), which is inclusive of ethical, ecological and economic practices as an integrated model for material designers

1.5 Summary of chapters

This PhD by practice has been started from an academic perspective based on the conceptual model, *Upstream* and *Downstream*. This model has been used as the link and the common thread between the academic aspect and the practical aspect throughout the whole thesis.

CHAPTER ONE – Introduction to the project

Chapter One lays out the contextual overview of sustainable development and how we think about design in the context of today's dilemmas for sustainable solutions. It states the main research questions and contributions to knowledge of the thesis.

CHAPTER TWO - The *Upstream and Downstream* model of Sustainable Design

Chapter Two is divided in two sections: 1) The *Upstream and Downstream* model of Sustainable Design and 2) Narratives of Innovation: Three Case Studies.

Section One sets out the principles of the thesis by introducing the concept of the *Upstream* and *Downstream* model. The impetus for this came from Wahl & Baxter's *The Designer's Role in Facilitating Sustainable Solutions* (2008). I then show how this conceptual model has been developed into a mapping system, which has enabled a better understanding of the selected case studies (Chapter Two) and my own practice (Chapters Three & Four).

Mapping in Section One: The *Upstream and Downstream* model initial studies

Section Two: Narratives of Innovation; Three Case Studies

Section Two starts by analysing in depth three selected case studies in the context of social, ecological and commercial values, and their contribution to my own practice. These are followed by the development of a visual mapping of the three case studies, based on the model *Upstream* and *Downstream*.

Mapping in Section Two: The evolution of the mapping through the three case studies.

CHAPTER THREE – The Case for Piñatex™: How a new textile material was born.

Chapter Three constitutes the main bulk of this PhD by practice. It follows the development of a new material from its source, pineapple leaf fibres in the Philippines, to the final and patented product Piñatex™, studying and developing its life cycle, social and ecological responsibilities and commercial viability. In-depth scientific research has been carried out to corroborate Piñatex's commercial viability and ecological footprint.

In addition, the start-up company Ananas Anam, (2012) founded as a consequence of the above findings, is discussed in terms of its conception and values.

CHAPTER FOUR – Mapping the Way to Sustainable Design

In Chapter Four, the conceptual model *Upstream* and *Downstream* is applied to understanding my own practice, from a sustainable design perspective. In addition,

Chapters Two and Three are brought to bear on guidelines for other material designers engaged in sustainable practice.

Mapping in section four: From the *Upstream* and *Downstream* model to the *In Flow* and *Out Flow*

CHAPTER FIVE - Final reflections and projections into the future

This reflects on the previous chapters, summarizes and looks towards further challenges and potential for the future.

CHAPTER TWO: The *Upstream* and *Downstream* Model of Sustainable Design and case studies

> 'The transition towards sustainability is about co-creating a human civilization that flourishes within the ecological limits of the planetary life support system'[24]

Chapter Two has been based on the interpretation of a theoretical concept based on a sustainable theory called 'The Upstream and Downstream Model of Sustainable Design'. The aim has been to understand this theory, and transform it into a practical tool, using maps, to help understand and analyse three selected case studies and my own research work.

In this section I move from my own experience, as a maker of Piñatex the new material whose development is the foundation of this PhD, to wider considerations and a perspective derived from Daniel C. Wahl and Seaton Baxter's work on the sustainable theory mentioned above.

It introduces a new framework based on the study and understanding of the aforementioned theoretical concept, which may be used as a critical path to comprehend the processes through which an idea or a product is transformed from an ideology, or 'proof of concept' into a product and/or a process. By visualizing the movements along the *Upstream* and *Downstream* pathways we can start to understand, critically analyse and implement the next steps needed to develop a more encompassing system of product development and manufacturing which is grounded in present and future global needs, (e.g. using available agro-waste by-products in our search and choice for raw materials).

[24] Wahl and Baxter, p. 72

Reflective practice[25]

Questions and more questions

How do you shift from having developed a manufacturing company from scratch, which successfully makes luxury leather goods, to a more all-encompassing model, which includes the welfare of people and the earth, as well as the economic side of a sustainable enterprise?

What relationship can we build between planning and working for business success and the incorporation of ethical success?

What are the conflicting points in this transition?

The aforementioned experiences have brought about a new way of thinking and skills, which have been paramount in my move from the business world into the academic world through this PhD. In this latter space it is perfectly acceptable to pose difficult questions, to doubt, ponder and follow thoughts that may lead nowhere today but somewhere tomorrow, the questions becoming the crossroads where crucial decisions can be made, thus, building the foundations for a better and more in-depth way of thinking and doing.

This PhD has been conducted in order to raise these questions and many more, in a drive to solve this personal and professional riddle. Becoming a researcher and living with and through research questions has been the bridge from making a profit through designing and selling products to developing a start-up company that designs products and processes taking into account ethics and questions of ecological and economic sustainability. This PhD is in part about this research journey.

[25] A segment of this thesis, which I call Reflective Practice, has been used throughout the thesis to delineate personal thoughts, experiences and reflections that have shaped my personal and professional life. They are pointers that in retrospect define how I feel and interact with the world through thinking and doing.

2.1. The Concept of Upstream and Downstream

The concept of the *Upstream* and *Downstream* view has been inspired mainly by reading the paper 'The Designer's Role in Facilitating Sustainable Solutions'.[26] Wahl et al. discuss 'Design being fundamental to all human activities. At the nexus of values, attitudes, needs and actions, designers have the potential to act as transdisciplinary integrators and facilitators.' They argue: 'The transformation towards a more sustainable human civilization requires a process of inclusive and participatory dialogue that ultimately will turn visions of sustainability into reality'.[27]

This design discourse has found resonance in my search for clarity and how I can link the personal experiences of being a material designer with more ethical considerations such as moral integrity and social and ecological values.

Definition of *Downstream*

The end of a design process through interactions and relationships is called *Downstream*. At the *Downstream* end of this process we encounter our cultural artifacts, institutions, patterns of production, and consumption, and they express 'intentionality materially'.[28]

This end of the design process, the intentionality behind design, is expressed through the interactions and relationships formed by consumer products, transport systems, economies, systems of governance, and resource and energy use, being integrated with the complexity of social and ecological processes. This intentionality is exemplified by product and industrial design, architecture, methods and cycles of manufacturing processes, patterns of resource and energy use, where design is the tool employed to make things happen.

Definition of *Upstream*

This is what Wahl has to say about *Upstream*: 'in the immaterial dimension, the "metadesign" of our conscious awareness, value systems, worldviews, and aspirations defines the intentionality behind materialized design'. [29] The *Upstream* can be expressed

[26] Wahl and Baxter, 2008

[27] Ibid., p.72

[28] Ibid., p.73

[29] Ibid.,

through our ideas and value systems, concepts and experience in the cultural, ecological and social realms. So for example, the three 'guiding principles' of Cradle 2 Cradle®[30] are expressed as follows:

1. waste = food[31]

2. Use renewable and inexhaustible energy sources, such as the sun

3. Celebrate diversity; greater diversity leads to a more resilient ecosystem[32]

These principles exemplify the concept of upstream immateriality, providing a structure by which to turn value systems into closed-loop cycles in design and manufacturing processes.

Wahl notes that 'Rather than believing that we can design universally applicable blueprints to bring about sustainability by prediction and control-based, top-down engineering, it may be more useful to think of the design outcome as an emergent property of the complex but dynamic systems that encompasses culture and nature and of which we are all integral participants'.[33]

This theoretical model is being used as a design methodology throughout the thesis. The views above, coupled with the dialogue of participation with everyone encountered in the value chain developed through this PhD has been the basis for a design thinking directed towards sustainable solutions. The development of a system of mapping, which follows my experiences and encounters as we move through the *Upstream* and *Downstream* flow forms the visual journey.

[30] Cradle to Cradle® and C2C® are registered trademarks of EPEA Internationale Uweltforschung GmbH and McDonough Braungart Chemistry, LLC

[31] This principle envisages an infinite cycle in which products are designed and produced in such a way that they ultimately produce new products, or can be reintroduced to the biological or technological cycle

[32] Hupperts, 2011.

[33] Wahl and Baxter, p. 73

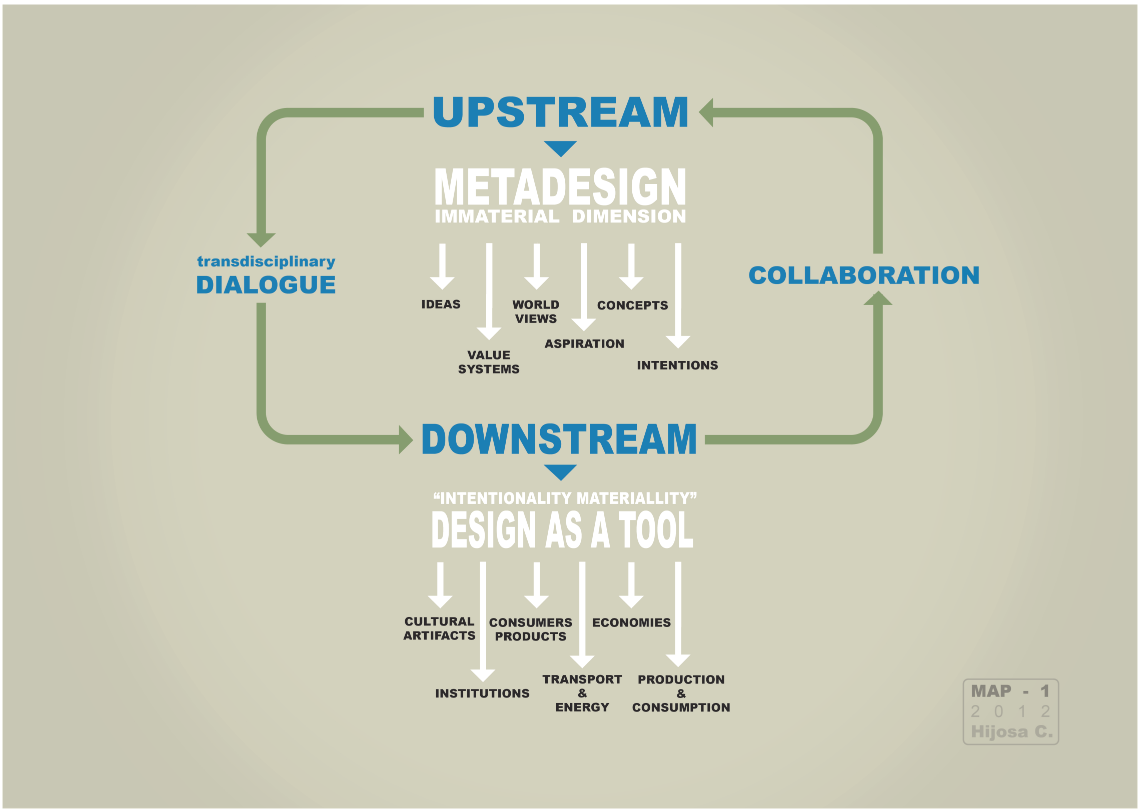

Fig. 2.1 MAP 1, *The Upstream and Downstream mapping,* Hijosa C., 2012

The *Upstream* and *Downstream* mapping (fig 2.1, Map 1) has been used as an analytical tool to understand the movement from materiality to immateriality and vice versa.

When applied as a mapping form, it shows in a clear, succinct manner where a particular design methodology or concept starts in their outset, either from an ideology or a material / process. As this concept moves *Upstream* or *Downstream*, we can learn from their start-up views, follow-up practices and methods how to move in a comprehensive and encompassing manner from the *Upstream* to the *Downstream* and vice versa.

2.2 Three Case Studies: Narratives of Innovation

This section introduces three case studies as a blueprint to understand the *Upstream* and *Downstream* model as a way of thinking that encourages mutual understanding and collaboration between different modes of association.

The three case studies chosen are, 1) SEKEM: a sustainable economy in the Egyptian desert, 2) the Cradle to Cradle approach established by McDonough and Braungart and 3) Gawad Kalinga: Building communities to end poverty (Philippines). These case studies are being researched for their inspirational, practical and analytical perspectives. Their lessons and practical solutions, as well as key similarities, have helped by bringing inspiration and know-how to my own project.

Each case is unique in its own way, with their own input and ideology; however, they all have something in common: either through design policies, focusing on human needs and the environment, or economic and social issues, they are all helping to transform the world through individual visions to a landscape of sustainable and ethical realities.

The quotation from Wahl encapsulates the point above:

> The transformation towards a more sustainable human civilization requires a process of inclusive and participatory dialogue that ultimately will turn visions of sustainability into reality. This will require the individual and collective participation of everyone. In the face of climate change, national and international inequity, social and ecological disintegration, and rapid resource depletion, nothing less than a societal and civilizational change—without precedence in scale and profundity in the history of our species—is urgently required. It has to occur during the next few decades if humanity wants to avoid ecological and social meltdown.[34]

[34] Wahl and Baxter, p. 74

Case study one - SEKEM: A Sustainable Community in the Egyptian Desert

> 'It was my wish for this initiative to embody itself as a community in which people from all walks of life, from all nations and cultures, from all vocations and age groups, could work together, learning from one another and helping each other, sounding as one in a symphony of harmony and peace.'[35]
>
> Ibrahim Abouleish

My first case study is SEKEM, based in Egypt and founded by Dr Ibrahim Abouleish in 1977. I had the opportunity to visit SEKEM in 2003 as a result of an encounter in the Philippines with Nicanor Perlas[36] in 2002, who shared with Abouleish the Alternative Nobel Prize in 2003. I had met Nicanor Perlas through my research work into alternative natural fibres and biodynamic agricultural methods in the Philippines. I have chosen SEKEM because their ideology brings together the three key points in a sustainable process: brotherhood in the economic field, equality in the social sphere and freedom in the cultural life. This is what Rudolf Steiner termed in 1919 the 'threefold social order',[37] which has been the base of SEKEM's model (Fig 2.2).

[35] Ibrahim Abouleish, The Right Livelihood Awards, Stockholm, 2003, acceptance speech

[36] Nicanor Perlas is the president and executive director of the Centre for Alternative Development Initiatives in the Philippines, from where he guides research and policy work and develops initiatives on globalization and their impact on civil society, cultural power and sustainable development. He pioneered the introduction of large-scale commercial biodynamic and organic agriculture in many provinces in the Philippines.

[37] Rudolf Steiner, *The Threefold Social Order* (1919), New York: Anthroposophic Press, 1972

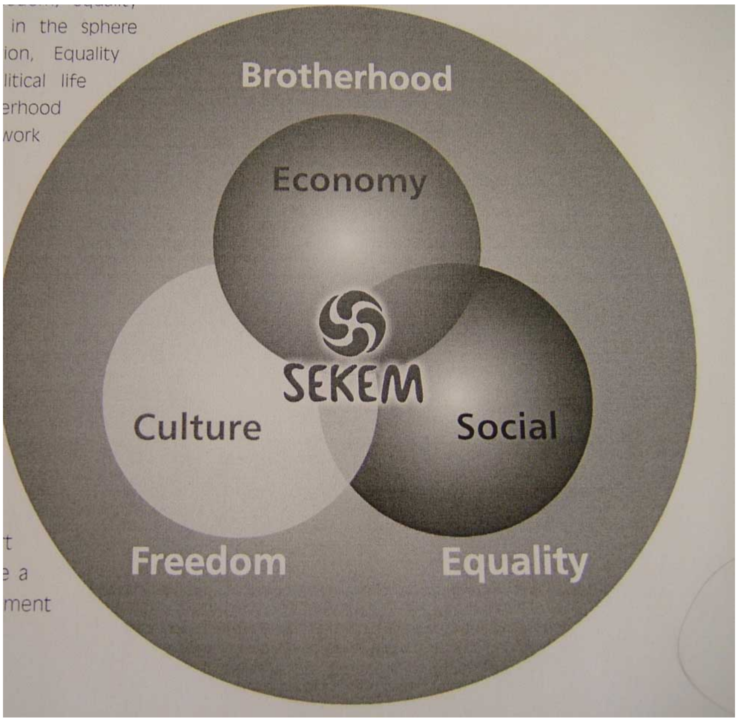

Fig. 2.2 Threefold social order. Courtesy of SEKEM. (2005)

SEKEM is a social business model that springs from within a global trend and recent phenomenon where individuals such as Papanek (1985), Ray Anderson (2009), and Michael Braungart and William McDonough (2002), mainly out of their life or work experiences, have come to realize that there is more to design, manufacturing and doing business than making a profit, and that it is imperative for any idea or commercial enterprise to take on board sustainability and social issues in order to face the challenges of the twentieth century.

According to Dr Ibrahim Abouleish, SEKEM's founder,

> SEKEM builds communities through their way of working with the land, through biodynamic farming methods in an all-inclusive manner. These methods are based on the premise that organic cultivation improves agro-biodiversity and does not produce any unusable waste. All products of the system can be either sold or re-used in cultivation, thereby creating a sustainable process, thus establishing a blueprint for a healthy corporation of the 21st century.

SEKEM is a unique example of a restorative and collaborative economy, not just a 'sustainable proposal but a life giving proposal'.[38] The way in which it addresses the question: 'How can an efficient economy, a healthy social fabric and a living culture be developed together'? encapsulates Hawken's 'restorative economy' hypothesis.[39]

SEKEM's approach to sustainable development

As already mentioned in this chapter, the SEKEM Foundation was founded by Dr Ibrahim Abouleish to realize his vision of sustainable human development.[40]

SEKEM's approach to sustainable development unites social, cultural and economic components, all interacting in harmony with nature. The company was founded in 1977 in the desert near Belbes in Egypt (Abouleish's birthplace). It was started by planting trees, turning desert land into fertile soils with the practices of biodynamic agriculture. By 1983 the first crops of organic produce were exported.

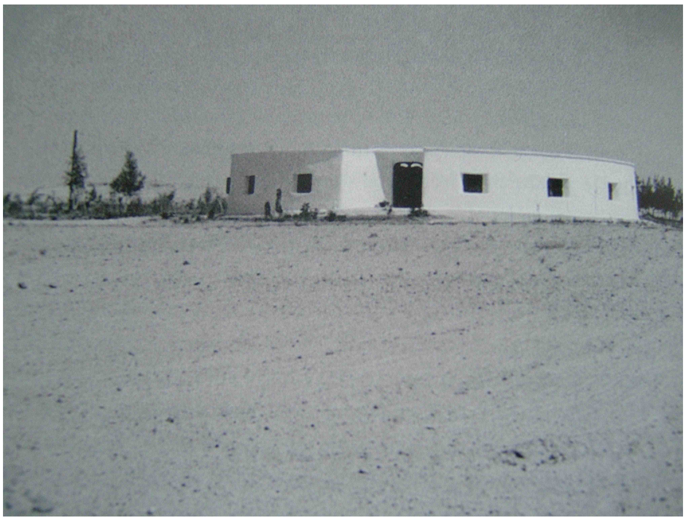

Fig 2.3 SEKEM's first building. Courtesy of SEKEM.(1978)

[38] SEKEM 2005 Report for Sustainable Development, Cairo: SEKEM, 2005

[39] Hawken, 1993

[40] S. Anand and A. Sen, *Sustainable Human Development: Concepts and Priorities*, (Human Development Reports), New York: United Nations Development Programme, 1994

Fig 2.4 SEKEM Academy, entrance. Courtesy of SEKEM, 2000

Today, these soils form the very basis for the successful cultivation of herbs, fruit, vegetables and cotton. The raw materials are further processed by the companies within the SEKEM Group to create high-quality food, medicines, textiles and clothing, which are sold on the national and international market. The returns from these companies are partly reinvested in social and cultural activities. (Fig 2.5)

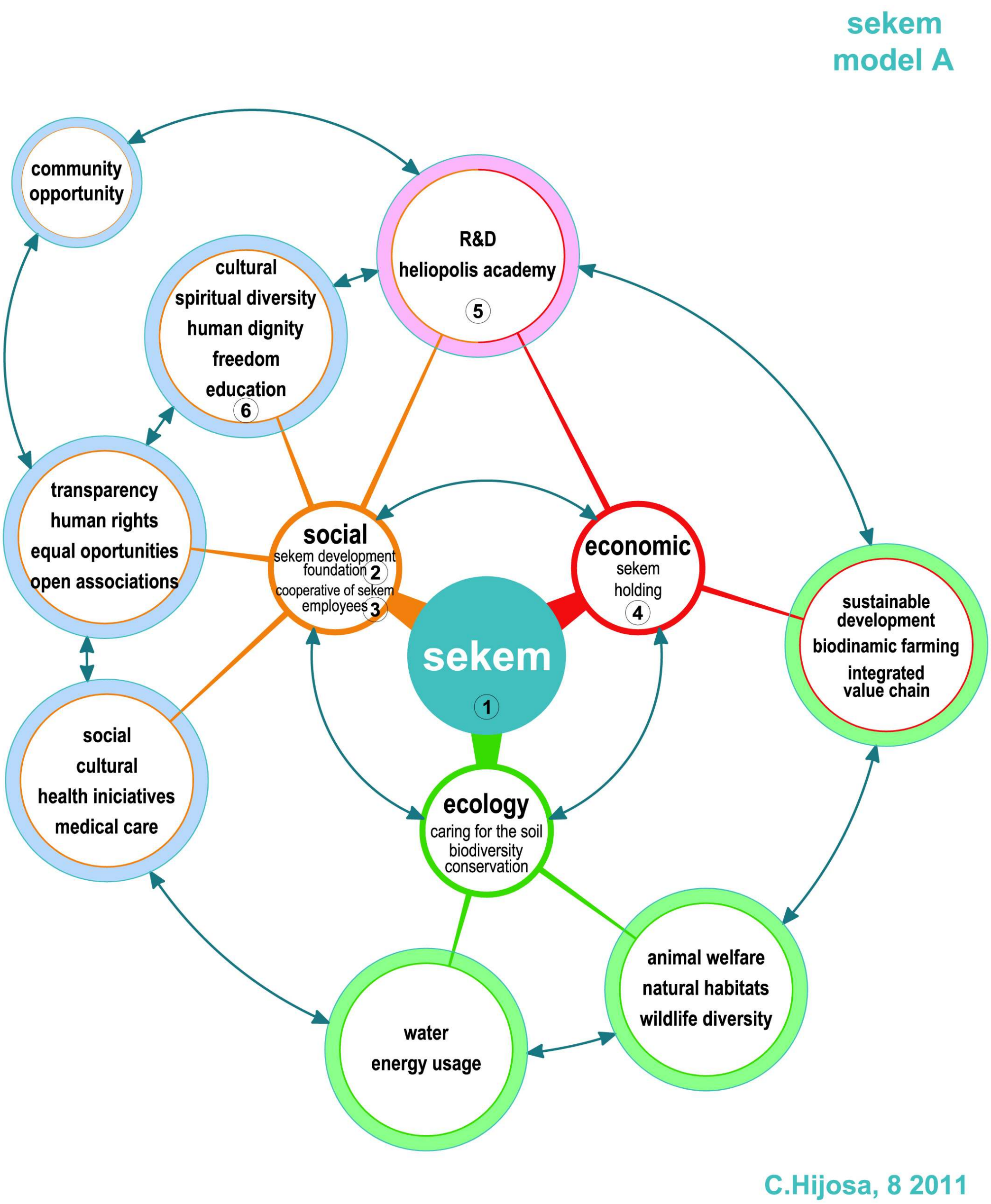

Fig. 2.5 Hijosa C., 2011 Chart of SEKEM's model, based on SEKEM's threefold sustainable development

SEKEM's goals are to 'restore and maintain the vitality of the soil and food as well as the biodiversity of nature' through sustainable, organic agriculture while supporting social and cultural development in Egypt. Through its diverse community of businesses and organizations SEKEM has been able to demonstrate that organic farming practices can be undertaken on a commercial scale, and that improving the local environment can be done at the same time as opening up lucrative export markets for local farmers and their families.[41]

Since its inception, SEKEM has grown into a rich community of businesses, schools and non-profit societies. SEKEM Holding, (fig 2.5, No 4) operates several businesses and the SEKEM Development Foundation, (fig 2.5, No 2) is responsible for social, cultural and health initiatives. SEKEM has also established the Centre for Organic Agriculture in Egypt, and the Egyptian Biodynamic Association (EBDA).

Fig. 2.6 a) SEKEM Circle. 2004

Fig. 2.6 b) SEKEM in 2005

SEKEM is inspired by the all-inclusive 'threefold sustainable development',[42] in which *economic success rides on the back of social and principled projects, and supports an*

[41] SEKEM 2009 Report for Sustainable Development, Cairo: SEKEM, 2009

enriching and manifold cultural life. Through it, SEKEM delivers a blueprint of how a restorative project, started in one of the harshest environments we can imagine (the sands in the middle of the Egyptian desert), can succeed in building a sustainable community by incremental efforts, starting in agriculture and moving onto economics and commerce: precisely the fundamental building blocks for lasting social change, (Fig 2.6).

SEKEM holds individual development at the centre of its mission, upholding human dignity as a given right to all employees. This philosophy encapsulates its maximum social sustainable development and creates a blueprint that could be implemented in places such as the Philippine pineapple growing communities, where my project is being initiated.

Case Study Two: Cradle to Cradle®

> 'Imagine a world in which all the things we make, use, and consume provide nutrition for nature and industry, a world in which growth is good and human activity generates a delightful, restorative ecological footprint.'
>
> Braungart & McDonough[43]

The sustainable development debate is based on the assumption that commercial enterprises need to manage three types of capital (economic, social, and natural), which may be non-substitutable and whose consumption might be irreversible. These three types of capital need to be linked in an equalizing manner, representing the ecology of human concerns, economy and equity. This concept is embodied in the fractal triangle, which is used as a tool by Cradle to Cradle® as a way to apply triple top line thinking throughout the design process, (see Fig 2.7).

[42] Steiner, (1919) , 1972

[43] W. McDonough and M. Braungart, 'The Cradle to Cradle alternative' in: *State of the World 2004,* New York: Worldwatch/W.W. Norton, 2004

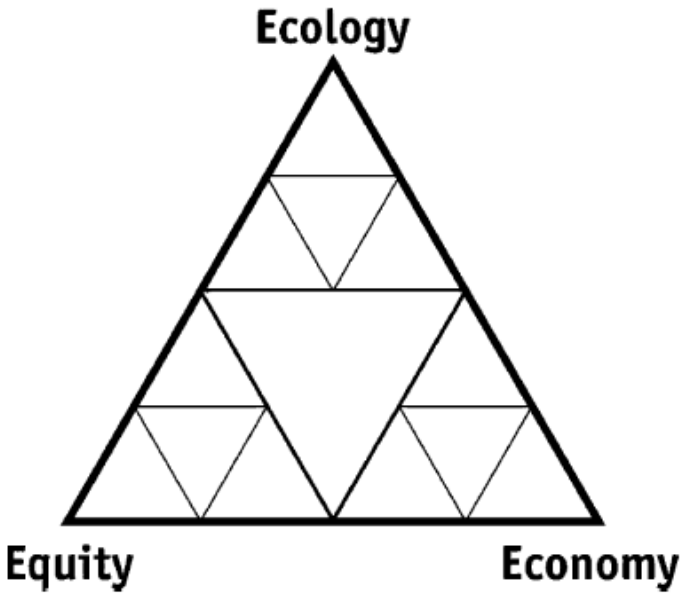

Fig. 2.7 Fractal Triangle, Cradle to Cradle: Design for the Triple Top Line. 2002

Michael Braungart and William McDonough (from Germany and the US respectively) joined together in 1991 in order to develop a new philosophy they called 'Cradle to Cradle. C2C is an innovation framework developed for designing products and systems that are explicitly beneficial to the individuals involved, as well as to the natural environment and society at large. Their philosophy was made accessible to the public through the publication of their book *Cradle to Cradle: Remaking the Way we Make Things*.[44] According to Braungart and McDonough, C2C is a manifesto calling for the transformation of human industry through ecologically intelligent design, offering practical steps on how to design products and services which are beneficial in economic, health and environmental terms.

Cradle to Cradle seeks to create systems that are not just efficient but essentially waste-free. It models human industry on nature's processes in which materials are viewed as nutrients circulating in healthy, safe metabolisms. This research started in the 1980s, is continuing today at the Environmental Protection Encouragement Agency (EPEA) in Hamburg, Germany, for designing beneficial economic, social and environmental features into products, processes and systems.

[44] McDonough and Braungart, 2002

Cradle to Cradle® principles

The concept of sustainable growth depends on product design that is geared to enabling constant re-use of the initial resources absorbed. Cradle to Cradle rather than Cradle to Grave principles can be described in practical terms:

1) **Waste equals food**: products and by-products are designed to act as defined 'nutrients' in a biological or a technical 'metabolic system': everything is a nutrient for something else.

2) **Use current solar power income**. Energy requirements must be met using sources derived from current solar income (either direct or derived, thus including geothermal and kinetic energy).[45]

3) **Celebrate diversity** (biodiversity, cultural diversity, and conceptual diversity).

For example, when developing a C2C carpet, materials are selected according to their healthiness during use as well as their compatibility with defined future uses. Both the production and recycling of carpets involve using a range of renewable energies. Applying the principles in an integrated manner also means that these renewable energy production systems are designed according to the 'waste equals food' principle. The objective of a beneficial environmental footprint is fundamental to the C2C approach. C2C aims for products and processes that improve the environment and society, add value and are 'eco-effective'.

The overall idea behind Cradle to Cradle is that waste equals food. This means that all products must be able to return to the earth's lifecycles, either biological or technical. Furthermore, the C2C philosophy is based on interdisciplinary co-operation and knowledge-pooling through sharing of information.

Goal-setting is at the heart of the C2C design and innovation framework. It is the process through which the core principles are applied to a product or process using the C2C Roadmap[46] as a tool that describes the pathway that the organization will take to achieve its

[45] The Cradle to Cradle concept assumes a reliance on renewable energy sources that ultimately originate from the sun, i.e. solar energy, wind energy, water and various innovative bio-based sources which do not compete with food crops. For further explanation see Douglas Mulhall and Michael Braungart, *Cradle to Cradle© Criteria for the Built Environment,* Nunspeet, The Netherlands: Duurzaam Gebouwd/CEO Media BV, 2010

[46] Troldtekt A/S, *Cradle to Cradle Roadmap*, http://www.troldtekt.com/en/About-us/Cradle-to-Cradle-roadmap

goals. This will include clearly identifiable and measurable milestones, which can be used to assess the intended goals.

Case Study Three: Gawad Kalinga. Building communities to end poverty

> 'The myth of growth has failed us. It has failed the two billion people who still live on less than $2 a day. It has failed the fragile ecological systems on which we depend for survival. It has failed, spectacularly, in its own terms, to provide economic stability and secure people's livelihoods'.[47]

> ' Poverty is not an economic problem, but a behavioural one. The environment degradation is greatly linked with poverty. Poverty forces people to abuse natural resources to meet their basic necessities. Save the poor and you are able to save the environment.'[48]
>
> Tony Meloto, Gawad Kalinga Founder, 2011

Gawad Kalinga (GK), the third case study I have chosen is a social development model from the Philippines which focuses on building communities to end poverty through a culture of caring and sharing by empowering poor communities to become self-reliant and sustainable.[49]

[47] T. Jackson, *Prosperity without Growth? The Transition to a Sustainable Economy,* London: Sustainable Development Commission, 2009, p.

[48] Gawad Kalinga, http://gk1world.com

[49] Ibid.

Fig. 2.8 Enchanted farm, Gawad Kalinga village. Author's archives, 2013

According to Gawad Kalinga, 'paradise lost' is an epithet frequently applied to the Philippines. Since obtaining independence in 1992, the country has made considerable efforts to alleviate the incredible poverty of its people. Joblessness and life in temporary corrugated-iron huts in the slums of the big cities makes survival for millions of people a daily challenge. Natural catastrophes also take a heavy toll. We only have to remember the last typhoon in 2013[50] to fully comprehend the nature of the catastrophes that plague the Philippines and the extent of the damage inflicted.

Gawad Kalinga believes poverty is not so much about the scarcity of resources as it is about the loss of human dignity. Living in a slum environment keeps people unproductive and desperate, making it the perfect breeding ground for crime and violence. Poverty strips people of their dignity and allows prejudice to breed, as others tend to look down upon the poor with pity, shame or fear.

Gawad Kalinga means to 'bestow care' in Tagalog, the Filipino language. GK started as a non-profit organization to 'give food for the hungry, land for the landless and homes for the homeless' (footnote 48) as the main weapons with which to fight the poverty that prevails in the Philippines. In the words of Tony Meloto, GK's founder, 'GK's aim is to bring honour, hard work and honesty to the broken human beings living in the slums, that have no hope, no faith and no future'. By putting land against what he calls 'sweat equity', the men coming from such backgrounds and moving into new homes use their own labour to build the house of their neighbour and vice versa. (See Fig 2.8) This creates a common cause and helps

[50] Typhoon Haiyan, known in the Philippines as Typhoon Yolanda

build social awareness where there was none, as the first building block to a community. Meloto says that this ‘gives back to the people the capacity to dream’.[51]

I have chosen GK because it is based in the Philippines and is a unique example of how to deal with the real problems of an underdeveloped country from a humane and a business entrepreneur’s point of view: GK brings people out of poverty and homelessness by giving them a chance to build their own houses, through what GK calls ‘sweat equity’; then they are taught how to work the land, with some of them having the opportunity to become independent social entrepreneurs and run their own business, with GK as their partners.

2.3 Mapping of the Case Studies in the Upstream and Downstream Model

This section examines theoretical and empirical evidence to determine whether the *Upstream* and *Downstream* model discussed in Chapter Two, section 2.2, can be used as an analytical tool to examine the three selected case studies in the context of social, ecological and commercial values.

In order to make a critical study real, we need to ‘develop a roadmap with milestones to achieve progressively the match between intentions and the reality’.[52] The maps being developed as a key part of this PhD have been used as a tool in facilitating the understanding of transdisciplinary design dialogue. Such dialogue will help to integrate the multiple perspectives and diverse knowledge encountered in the *Up* and *Down* flow, based on different disciplines, value systems, and stakeholders.

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[51] Author’s conversation with Tony Meloto, London, 2012

[52] Bor, A.-M. [et al.], *Usability of Life Cycle Assessment for Cradle to Cradle Purposes* (Position Paper) Utrecht: NL Agency, NL Environment and NL Energy and Climate, 2011, Table 4

Reflective Practice

Drawing concepts that are too academic or complex to my immediate understanding is very much a part of my way to try to clarify what is clouded and unclear in my mind. The pencil, doodling away as I read and think, seems to have a mind of its own and never ceases to surprise me, as out of the scribbles something comes about, which becomes a visual and succinct picture of the rather difficult narrative being read. The paper 'The Designer's Role in Facilitating Sustainable Solutions' has caught my imagination from the first page. Sustainable solutions are a key subject in my project's thinking and doing; and from this paper, it was the *Upstream* and *Downstream* concept that I visualize straight away. Doodling/mapping became a way for me to interpret this paper. Moving away from the paper and into my own visual world has been a fluid continuation and a revelation that has become the golden thread linking the academic part of my thesis with the practice. I have struggled for a long time to come to terms with the understanding of how to link both subjects. They are meant to grow together and support each other – they just have not grown that way – they seem to grow more like teenagers in burst and jolts, quite ungraceful, I must say.

Mapping, however, has grown steadily and has become the framework used for understanding, acknowledging and weaving together different perspectives and views, and through it, people and places. This is what I wish to build through my work, a mapping system for understanding where we as designers/makers come from and are going to. How we are going in, inside ourselves, into our hearts and listen to what we know needs to happen, and from there, with greater and growing knowledge of ourselves and our responsibilities, outwards, to face the world, (see Map, 9*, Mapping the concept From the Upstream and Downstream to the In and Out.)*

Selection of approach to the three case studies

There is a design discourse to understanding design using a framework that helps to conceptualize different value systems and assumptions behind the materiality of design; how the movement from the values (*Upstream*), to the materiality (*Downstream*), may change our experience of reality and therefore the 'intentionality behind design', as described by Wahl and Baxter.

This conceptual model has been studied, and its thinking applied to the understanding of the three case studies and my own work (Chapter 3) from a sustainable design perspective. The results have been used to develop a mapping system to analyse how different disciplines, value systems, and stakeholders may contribute to develop a dialogue that will help integrate the multiple perspectives in the *Upstream* and *Downstream*, creating a new space, a new model. This new fluid space that comes about through the active movement in the *Up* and *Down* is where things can be realized, according to Wahl and Baxter 'in a constantly changing environment, where sustainability is not some ultimate endpoint, but instead is a continuous process of learning and adaptation'.[53]

This new mapping concept brings us from the academic sphere of the *Upstream* and *Downstream* model to the real world of collective participation, and has been developed as a tool in understanding the linking of our values and responsibilities with the materiality of making. This is a practical, fluid and less academic model, which can be used as a working tool in design, first to visually understand the workings of the case studies, and second to find the middle ground, where things can and are allowed to happen. Here, ideas, people, processes move from the '*Up* and *Down*' through the '*In* and *Out*' zone, creating myriad pathways of creative and interdisciplinary dialogue. The second point will be dealt with in Chapter 4: Mapping the Way to a Sustainable Design.

SEKEM: A sustainable economy in the Egyptian desert in the *Upstream* & *Downstream*

As already mentioned in this chapter, doctor and chemist Dr Ibrahim Abouleish is the founder of SEKEM. He started SEKEM by turning desert land into fertile soil and developing organic farming in what we can call the *Downstream* model. Dr Abouleish's vision is to develop a sustainable economy, having questioned and having to face the social issues that his downstream practice had brought about. What can this mean to society, for the social network around the practice to be developed? What can such a model bring back to the local community? The answer to these questions can be interpreted as being realised through a move *Upstream*. In other words, by the development of a social and cultural life through SEKEM schools, from kindergarten to the Heliopolis Academy and University for Sustainable Development,[54] SEKEM is empowering people through education and social advantages, such as health care and children's schooling, clean water and better housing. The

[53] Ibid., 72-3

[54] Heliopolis University for Sustainable Development is the first non-profit university in the Middle East declaring sustainable development as its overall guiding principle http://www.hu.edu.eg/

people who are now part of the SEKEM umbrella of social advantages and companies, are encouraged via jobs, better living conditions, education and a better future to move downstream and become members of the SEKEM Holding.[55] This in turn helps develop and grow the various companies that form the SEKEM Holding, whether working on the farm with animals, making products from the fruits of the land, such as food and herbs, or manufacturing clothes made from their organic cotton. SEKEM has developed a sustainable model that works economically as well as being self- sustaining.

Mapping SEKEM in the *Upstream* and *Downstream* model

SEKEM is a business-led sustainable model, which focuses on community building by putting people at the centre of every stage of business development through social and cultural development. SEKEM's income comes from the products directly produced and sold under The SEKEM Holding Group umbrella, being a fully integrated business model.

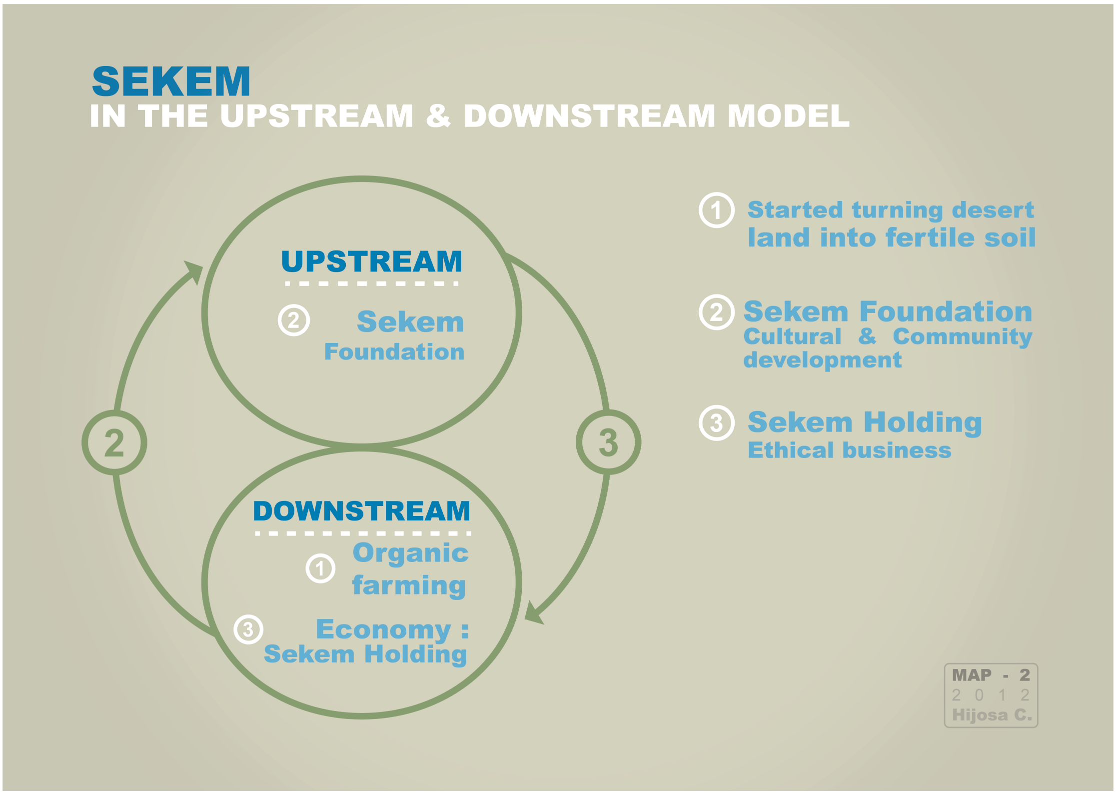

Fig 2.9 MAP 2, SEKEM in the *Upstream* and *Downstream* model. Hijosa C. 2012

SEKEM started by growing products through organic, biodynamic agriculture, Fig 2.9 (1) and consequently developing a model to improve the quality of people's lives through cultural and community development via the SEKEM Foundation (2), with all products being sold or re-used in cultivation through the SEKEM Holding business development (3).

[55] SEKEM Report for Sustainable Development 2009, Cairo: SEKEM, 2009

The significance of these is the blueprint that SEKEM has developed for how to establish a successful business strategy, based on the premise that organic cultivation not only can become the starting point for a healthy and profitable business, but can also improve agro-biodiversity and the local and social environment, as well as opening up successful local and export markets for the benefit of all involved.

The Cradle to Cradle® framework in the *Upstream* and *Downstream* model

Cradle to Cradle® is a framework for design and innovation. It starts with a philosophy, guiding principles and application tools. C2C® starts *Upstream*, having developed the concept of everything being seen as a nutrient (Fig 2.10, No.1). As William McDonough says, 'Whether biological or a technical nutrient, the framework has reversed logistics: it is powered by solar or renewable energy; the water is clean, and the people are treated fairly in the process'[56]. When applied to a product, a building, a city, the concept moves *Downstream*, (Fig 2.10, No. 2) to incorporate the development of new materials, processes, products and systems,[57] thus linking the innovative thinking with the materiality of products. C2C has a system of accreditation, a stamp of approval awarded when a company complies with the C2C standards for processes and usage of materials used. Thus, the business moves upstream again, ending with a certified product. (Fig 2.10, No. 3)

Mapping the C2C in the *Upstream* and *Downstream* model

As previously stated, **C2C®** is a consultancy-led company which focuses on the transformation of human industry through ecologically intelligent design.

[56] William McDonough, interviewed by Brent Toderian at the Danish Architecture Centre May 2009, in: Danish Architecture Centre, DAC & Cities, *Sustainable cities,*[online], available at: http://www.dac.dk/en/dac-cities/sustainable-cities-2/experts/william-mcdonough--from-products-to-cities/?bbredirect=true,

[57] Bor, A.-M. [et al.], pp. 72-3

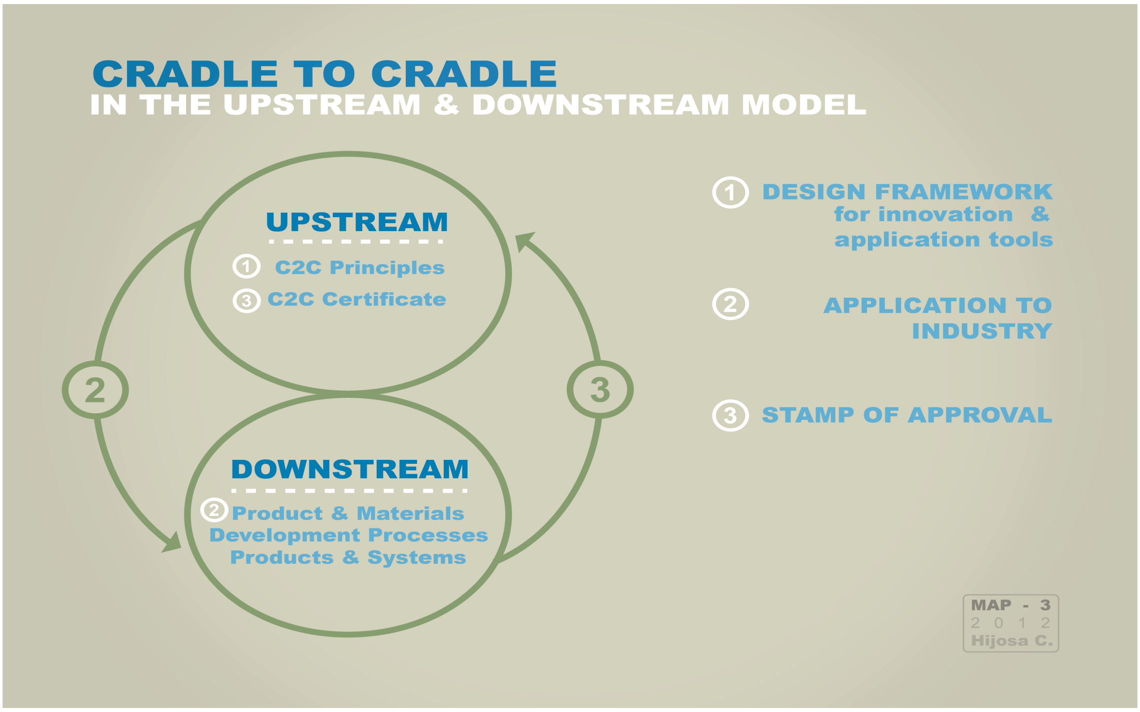

Fig 2.10 MAP 3 Cradle to Cradle® in the *Upstream* and *Downstream* model. Hijosa C. 2012

Through McDonough Braungart Design Chemistry (MBDC)[58] the company helps other companies to implement the Cradle to Cradle strategy and provides Cradle to Cradle certification to products and processes/systems. The Cradle to Cradle certification provides a company with a means to tangibly measure achievement through environmentally-intelligent design, and helps customers purchase and specify products that are pursuing a broader definition of quality.

Gawad Kalinga in the *Upstream & Downstream* model

Gawad Kalinga (GK) was founded in the Philippines ten years ago. It started *Upstream* and for seven years built villages for poor people who were living in slums. While GK gives to the people something solid (houses, jobs) it is not a material-based economy, but it is the hope for better quality of life that carries weight; thus they start being *Upstream* (Fig 2.11, No. 1). After seven years they have started building social enterprises by designing and making products based on local resources and skills. In this way GK moves *Downstream,* (Fig 2.11, No. 2) into the social business realm. Seeing the need to educate their social entrepreneurs, they have started an academy for the development and running of sustainable

[58] McDonough Braungart Design Chemistry, http://www.mbdc.com [Accessed January 2012]

business, thus moving back *Upstream* and continuing the cycle of *Upstream* and *Downstream,* (Fig 2.11, No. 3).

Mapping Gawad Kalinga in the *Upstream* and *Downstream* model

GK started *Upstream:* building communities to end poverty – land – home – food. It brings social awareness where there was none, empowering people though ownership and social responsibility (through 'social equity'). However, even if they give the people something solid (houses) this is not offering materials or regular work at the start.

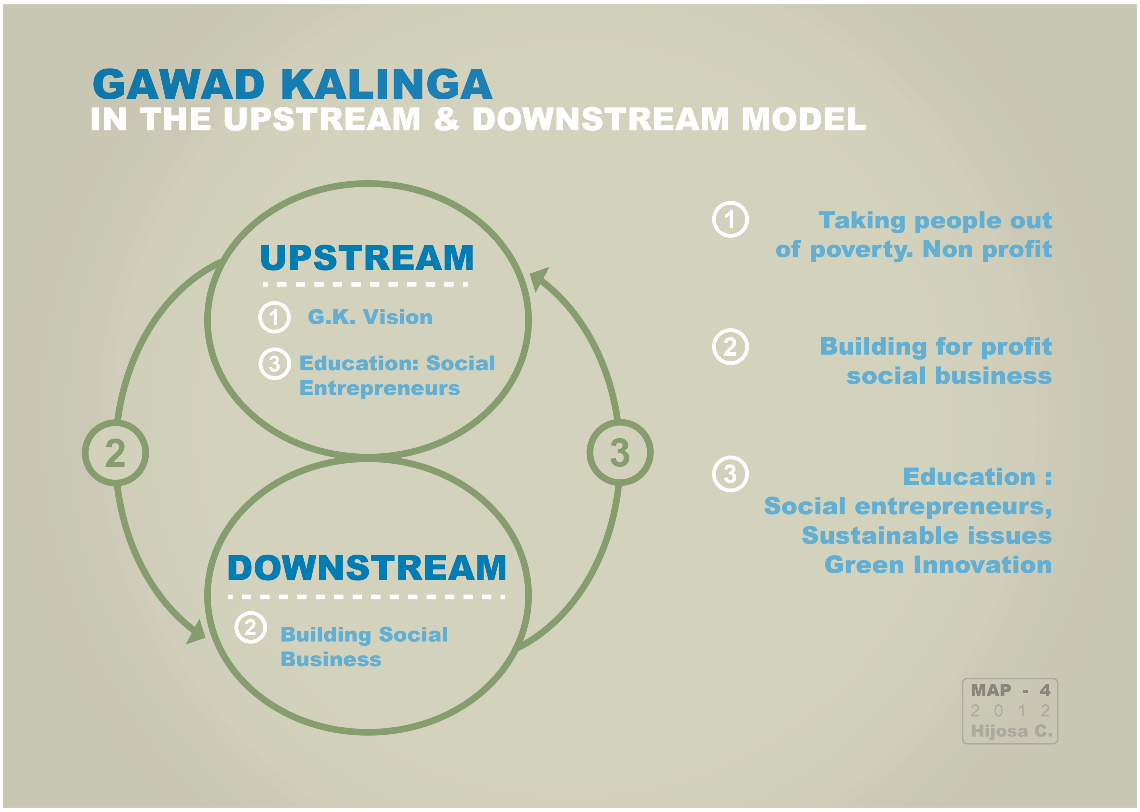

Fig 2.11 MAP 4, Gawad Kalinga in the *Upstream & Downstream* model. Hijosa C., 2012

Once the people have a home, a solid base to grow from, GK needs to bring jobs into these new communities. After seven years they have started the next phase of development, the material cycle (making and selling products through social enterprise (*Downstream*). However, in order for this stage to be successful they need to educate people in acquiring social enterprise skills and a work ethic, thus moving *Upstream*, developing a strong system of business through the security of belonging, having a home, and social and economic security.

Exploring the conceptual model *Upstream* and *Downstream* by studying the relationships between ideas, concepts and products or processes through the three selected case studies has helped in understanding how an idea or concept can move from a principle, such as Cradle to Cradle, to an ever increasing metadesign intentionality: how this intentionality is manifested in products or processes and the consequences this may have in the understanding of how to develop a clear cycle of idea-product or product-idea.

2.4 Conclusion of Chapter Two

In Chapter Two I have studied a theoretical concept and transformed it into a practical tool to help understand and analyse three selected case studies that have inspired my own research work.

- The SEKEM model's nexus of activity is the building together of an efficient economy based on a healthy social and cultural impulse, placing the human being at its centre
- The C2C model is based on a framework to make a product/process lifecycle sustainable through careful design processes
- The GK model states that poverty is about the scarcity of resources. By tackling poverty at its root, people are giving the opportunity to become, once more, part of society

Based on these findings, I am bringing these philosophies together with my own research in a process of integration and selection, learning from them, taking from their models what can be used in my own. I am acknowledging their influences and looking at the gap between them, working out how the best of these practices can be brought into my own model of material practice. My contribution will be to find out what is missing that I can contribute to in my particular field. This will lead into the development of a new model as a form of selected maps, (this will be dealt in Chapter 4) which can be used as a precedent for material designers.

CHAPTER THREE: The case for Piñatex®: How a new textile material was born

In this chapter I will demonstrate the birth of a new textile material: its advent, research and development and its potential place in the market alongside leather.

Chapter Three follows the development of a new material in the context of the researcher's previous background in leather, from its source, pineapple leaf fibres in the Philippines, to the final and patented product Piñatex, studying its life cycle, social and ecological responsibilities and commercial viability. Furthermore, comprehensive scientific research and relevant tests have been conducted into pineapple leaf fibres (PALF), its consequent nonwoven substrate and final product, Piñatex. In addition, the textile world of nonwovens has been studied in order to understand where Piñatex fits within the textile world. Finally I will demonstrate the potential of Piñatex, from first samples to its potential place in the market. A brief about Ananas Anam Ltd., the company founded as a result of this research, which encompasses the researcher's experiences from a project idea to a business proposition, is included in the appendix.

Reflective Practice

In the late 90s I was asked to do a design consultancy by the Product Development and Design Centre of the Philippines.[59] The brief given was 'To upgrade the leather goods industry present quality and design'. The aim was to create prototypes that would then be used as key pointers by the leather goods industry, as products that would help to break into

[59] The Product Development and Design Center of the Philippines (PDDCP) is a technical agency of the Department of Trade and Industry. PDDCP is mandated to increase the quality and competitiveness of Philippine products through design. Its mission is to provide innovative and competitive designs for global marketplace. http://www.pddcp.gov.ph)

higher added value markets, possess some uniqueness that would be seen as 'Filipino' and help to increase exports in the Philippines. This role came about from the experience I had designing, manufacturing and selling leather goods through my previous company in Ireland.[60] After preliminary research I found out that the best quality bags made in the Philippines were manufactured using imported materials, especially leather. Collaboration with tanneries in the Philippines was sought, to see if we could come up with a raw material up to the required international standards of the market. An in-depth study of the then current status of the local leather industry pointed to a leather quality that would not have come up to the required standard needed to upgrade the product market positioning. It did not take long to realize that this aspect of the project, (to upgrade the leather quality as the main raw material) was well beyond the team's capabilities, quality requirements, project budgets and time needed for the long-term success of the project. My own findings, together with the statements from leather manufacturers and leather goods producers, led me to conclude that there was a need to re-consider alternative sources of raw materials which would be local, readily available and not dependent on skills, chemical products and technology coming from outside the Philippines. Consequently, the search turned inwards, into the Philippines, a world previously unknown to me, and natural fibres became the focus as the obvious choice in terms of creating a new and more viable avenue of raw materials.

3.1 Researching into additional materials to complement leather; Leather production

Research into leather tanning (in 1998) showed a complex life cycle and lengthy stages that a hide needs to go through to become desirable leather, the raw material demanded by the market and our needs as consumers of leather products. It also brought to the fore how long, complex, and energy-and-resources-consuming these processes are (as shown in Table 3.1). A raw hide (animal skin) goes through four major stages, starting with a preparatory stage, to tanning (carried out mainly with mineral methods), crusting and surface coating or finishing. These processes are selective depending on the requirements of the final product.[61]

[60] Co-founder and designer at Chesneau Leathergoods, 1977-1993

[61] Heidemann, E., *Fundamentals of Leather Manufacture,* Darmstadt: Roether, 1993

LEATHER TANNING PROCESS

PREPARATORY STAGES Raw Hides	TANNING (stable material)	CRUSTING Thinned retanned	SURFACE COATING Finishing
Preservation	Mineral methods (Chromium)	Lubricated	Oiling
Soaking	Vegetable methods	Wetting back	Brushing
Liming		Sammying	Padding
Unhairing		Splitting	Impregnation
Fleshing		Shaving	Buffing
Splitting		Neutralisation	Spraying
Reliming		Retanning	Roller coating
Deliming		Dyeing	Curtain coating
Bating		Fat Liquoring	Polishing
Degreasing		Filling	Plating
Frizing		Stuffing	Embossing
Bleaching		Stripping	Ironing
Pickling		Whitening	Combing (hair on)
Depickling		Fixation	Glazing
		Setting	
		Drying	
		Conditioning	
		Softening	
		Buffing	

2012 Hijosa C.

Table 3.1 Leather tanning processes according to Heidemann ,(1993). Table by Hijosa C. (2013)

In addition to environmental end-of-use issues, (e.g. recycling, waste management) these production processes have a high environmental impact, most notably due to:

- The use of polluting chemicals and heavy metals in the tanning processes, such as chromium.[62] 'Chromium is environmentally persistent, it cannot be destroyed and it will always be present in some form within the environment'[63]
- Air pollution due to the transformation processes of some chemicals
- Water pollution
- Solid waste pollution (up to 70% of the weight of the original hides)[64]

As more astringent environmental controls are put in place in the developed world, and leather production decreases in these parts, world production is moving to other countries where environmental norms are just starting to be acknowledged and dealt with, and labour

[62] Chromium being the basis of virtually all light leather manufactured, except the fully vegetable tanned leather

[63] Leather Technology Centre UK, 2006 (online) available at http://www.blcleathertech.com/

[64] Amanda Long, Chromium free trends in footwear *Journal working for the leather industry, July August 2006, p 7*

is cheaper. China and India, world's first and third producers and exporters of leather,[65] are good examples of this. In Pakistan, (12th largest producer in the world) leather tanning is being encouraged by the government to increase exports. This is causing severe environmental degradation and health hazards, as well as destroying local economies that depend on clean air and water, e.g. shrimp production, which is a key local income earner (Augustus, 1996).

The International Standards Organization (ISO) and the European Standards Body (CEN) are in the process of ratifying and adopting most of the standards and test methods developed for leather by the International Union of Leather Technicians and Chemists (IULTCS). The case study of China, below, gives a good idea of the position of the leather industry today (2013).

Chinese leather industry as a strategic case study

> 'China has become the world's largest production base and exporter of shoes, thanks to the fast growing shoe industry. In 2009, China's leather industry export value reached more than 56 billion USD. The Chinese shoe producers can make more than 10 billion pairs of shoes annually, making up nearly 70% of the world's total output. Bolstered by China, Asia has become the world's manufacturing center of shoes and is still enlarging its market share'[66]
> (China Shoes Market Report, 2008)

The dominance and growth of China's leather industry is illustrated in Table 3.2.

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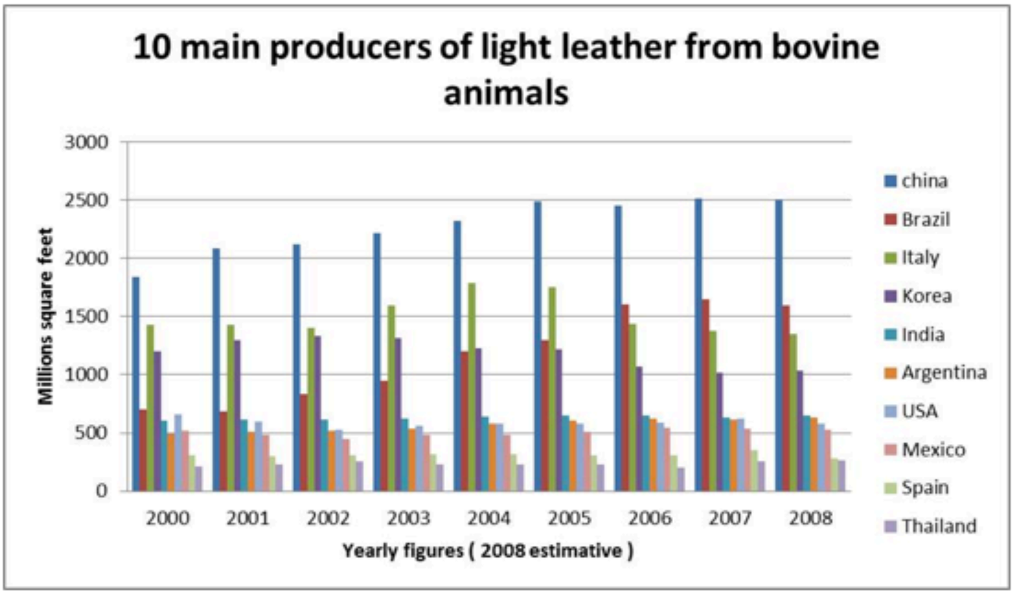
[65] World Statistical Compendium for raw hides and skins, leather and leather footwear 1993-2012, Food and Agriculture Organization of the United Nations (FAO), (2008)

[66] *China Shoes Market Report 2008*, Research and Markets, 2008 (online), available at: http://www.researchandmarkets.com/reports/613715/ (Accessed august 2012)

Table 3.2 *Ten main producers of light leather from bovine animals. FAO (2010).*



Source: World Statistical Compendium for Raw Hides and Skins, Leathers and Leather Foot wear, FAO, 2010

Historically, it seems that the development of China's leather industry came at a cost to the environment, as thousands of small manufacturers competed fiercely for raw materials and cheap labour, paying little attention to the environmental degradation resulting from their activities. Tanneries in particular were 'widely regarded as polluting in China and even today they are thought to be one of the most polluting light industries in the country'.[67] As the 2009 report by China Water Risk (a non-profit initiative designed to understand the risk around water) emphasizes , 'the leather industry in China discharged more than 249million m^3 of waste water'. Consistent with this report, China's most recent Statistical Yearbook (2011) claims that 'the industry is amongst the country's top twenty water dischargers by volume'.[68] A later report in 2011 from China Water Risk claims 'untreated tannery effluents can be highly polluting, containing high concentrations of toxic heavy metals as well as nitrogen compounds and high concentrations of Chemical Oxygen Demand (COD)69 and Biological Oxygen Demand (BOD)'.70

[67] Institute of Public and Environmental Affairs, Beijing, China, 'SRL Company (Fuguo) Case Study', 2010, available at http://www.ipe.org.cn/Upload/Case-Study-SRL-Fuguo-EN.pdf

[68] China Water Risk, 'Sustainable leather: more steps to go', available at http://chinawaterrisk.org/resources/analysis-reviews/sustainable-leather-more-steps-to-go

[69] Tests quantifies the amount of organic pollutants in water (expressed in mg per litre)

[70] Another indicator f water quality (expressed in mg of oxygen consumed per litre of sample during 5 days of testing

A 2010 report from the Beijing-based Institute of Public and Environmental Affairs (IPE), claims that some 850 pollution violations were listed on its site in relation to tanneries.[71] Not surprisingly, the Chinese government has also recognized the pollution problems facing the sector and a range of initiatives, as well as rising labour costs, appear to be changing the industry's legacy. In 2009, the Ministry of Industry and Information announced guidelines for the leather industry, which indicated the intention to shut down small polluting tanneries. In 2010 it was reported that the Ministry had shut down numerous 'dirty tanneries' and had required the industry to meet the following targets:

> by the end of 2011, 50% of the water used in the leather factories should come from recycled water,
>
> by 2010, COD (chemical oxygen demand) discharge should decrease by 10% compared to 2007,
>
> by 2010, water use and efficiency should be increased by 10% compared to 2007.[72]

At the end of 2009, the Ministry also introduced an important policy guidance document, entitled 'Guiding Options of Tanning Industry Structural Adjustment'. The guidelines stated that tanneries whose production scale was under 30,000 pieces of standard cattle hide per year must be shut down, and for those producing under 100,000 pieces of standard cattle hide per year would be subject to limits.[73]

The overall effect has been that fewer small-scale tanneries are operating in China.

Based on these facts it is clear that the powerful organization of the leather industry in China is trying to clean up an industry that has been, from its outset, a very polluting industry. The consequences of these policies will have a very positive effect on countless people's lives and the earth at large, positioning the leather industry into a new phase of cleaner and more sustainable practices.

Indeed it is not only in China that the tanning industry has been 'cleaning up its act', as shown by an extract from Dr Mike Redwood's paper 'Corporate Social Responsibility and

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[71] Institute of Public and Environmental Affairs, Beijing, China, 'SRL Company (Fuguo) Case Study', 2010, available at http://www.ipe.org.cn/Upload/Case-Study-SRL-Fuguo-EN.pdf

[72] *Ibid.*

[73] Ibid.

the Carbon Footprint of Leather', which sums up this hope for the future of the tanning industry:

> A number of points can be made from all this. First that the manufacture of leather by modern methods where proper consideration is given to the management of all wastes and the use of inputs including water, energy and all chemicals can be characterized as a good and defensible manufacturing process. The historical image of tanneries as dark satanic places doing harm to the planet in multitudinous seen and unseen ways is entirely false. The chemistry is now well understood in terms of all the materials that are used and how they should be handled. As such, attacks on tanners as polluters, users of toxic chemicals, and huge consumers of water can be rebuffed by an industry that has been transformed over the last fifty years.[74]

Leather's social and cultural associations; creating employment in the developing world

Leather has played an important role in the development of civilization, alongside traditional leather practices, from prehistoric times to the present. In recorded history, pieces of leather dating from 1300 BC have been found in Egypt. In the nineteenth century, vegetable tanning (involving mainly tanning with oak and pine bark) was supplemented by chrome tanning. These major changes brought the leather industry to today's present position. Leather has been and remains a desirable product in spite of the possible health and environmental consequences of its processing and lack of strict guidelines in some countries, to make its production cleaner. It is still a key fashion item, and in spite of anti-leather lobbies coming up every now and again, and designers like Stella McCarthy advocating the avoidance of leather, leather continues to have a strong voice as a key raw material in the world of fashion, accessories, interiors and the automobile industry. However, as leather is becoming more scarce, there is a need to develop a material that can fill the gap in the market, as already stated by Redwood in 3.1.[75]

[74] Dr M. Redwood, 'Corporate social responsibility and the carbon footprint of leather', *Journal of the Society of Leather Technologists and Chemists*, 97 (2), 2013, 47-55.
[75] In conversation with Dr Mike Redwood, international leather expert (February, 2013. RCA)

Summary and conclusions of 3.1

In this section I have shown that there are pressing environmental and economic problems associated with a segment of the leather industry, and how concerted efforts are being made to clean up some of the issues encountered. In the near future, leather is likely to be reserved entirely for exclusive leather products due to its high cost and insufficient supply.

What I am advocating through my research is to look for a viable alternative that would be produced alongside the leather industry, which may contribute to employment in the developing world by creating a new material that does not use land (as it employs a by-product of the food industry), water, fertilizers and pesticides for the procurement of its base raw material. All aspects of the pineapple harvest are already geared to the food crop, with no additional requirements for the leaves, being an agro-waste, as already mentioned.

3.2 The Birth of Piñatex; from natural fibres to a new material

In this section I will introduce natural fibres in the context of their historical, cultural, and economic importance in the world.

My knowledge and experience of the leather industry, as I found it in the late 90s during my work with the Design Center Philippines, brought about an awareness of the need for alternative materials.[76]

It became my personal quest to source an alternative using the natural resources, skills, technology and local business we had available in the country. Hence the project I was heading in the Philippines moved from trying to use leather to exploring the possibilities of using natural indigenous materials and local skills, that could be used in the field of bags and accessories.

Reflective practice

Imagine yourself in one of the highest plateaus in the world, the Altiplano in Bolivia. Wind-swept, treeless, warm days and cold nights – a sky so blue and clear you feel it is just there to be touched if you stretched your arm – so full of stars at night you get transported into an all-embracing world, alive with magic and enchantment. This is where the Quechua and Aimara live, the indigenous native communities from the Andes. I worked with them in the late '80s, and with them started my appreciation for natural fibres.

The women fascinated me with their colourful full skirts, bowler hats, children on a sling and those magnificent Indian faces with so much dignity and pride in their demeanor. But what really caught my imagination was that whatever we were doing they always came with their hand spindle and the fine, deep brown wool from the llamas (family of the Cameloids)

[76] Today, the Department of Industry (DA) is trying to develop a tannin-degreasing agent to help manufacturers comply with world standards, J. K. Galvez, *The Manila Times*, 28 August 2012 Leather tanneries in the Philippines

in what looked to me like a huge brown bundle at the top of a stick. As we were talking and preparing things they were spinning wool to a fineness I had not seen before – I was mesmerized to the point of distraction by their expertise, the beautiful yarn coming out and the ease and familiarity with which they worked. Eventually I learnt how to make a yarn with a spindle and they made me a beautiful hand-spun, hand woven scarf that I still have and treasure. I have never managed to make a yarn half as fine as what I have seen in the Altiplano, but the attempt brought about an empathy, an appreciation and closeness for what it means to try to make something starting from a soft bundle of natural fibres.

Natural fibres historical and scientific overview

The use of natural fibres for textile materials began before recorded history. Remains of flax fibres have been found dating from 5000 BC and silk from 2700 BC. The discovery of flax and wool fabrics at excavation sites of the Swiss lake dwellers (7th and 6th centuries BC) make these findings one of the oldest indications of the use of these fibres.[77]

In the 18th and 19th centuries the Industrial Revolution changed the way textiles were produced in the world: indeed textile manufacturing was one of the drivers of the said revolution. The invention of the Spinning Jenny (Fig 3.1), a hand-powered multiple spinning machine, by James Hargreaves in 1764, opened up industrial possibilities and encouraged a surge for large-scale production of fibre and resulting textiles. This changed the world of textiles from a cottage industry type-based hand production to industrial production carried out in textile mills. The face of textile production has never been the same.

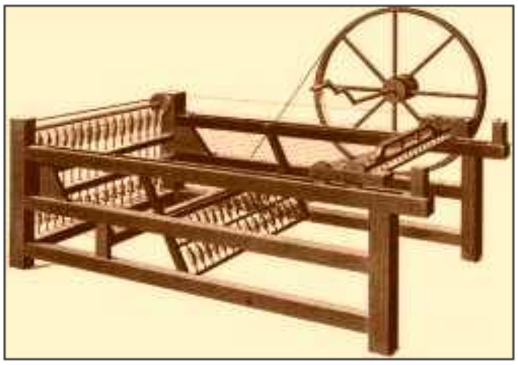


Fig 3.1 Spinning Jenny (c. 1700s)

[77] Bcomp Ltd., Natural Fibre Composites, Fribourg, Switzerland, http://www.bcomp.ch

Textiles become accessible, cheaper and a source of great revenue for some countries such as the UK. However, the same Industrial Revolution that brought cheap textiles to the masses also brought cheap imports to countless other nations, decimating local industries and obliterating the planting and use of many local fibres and consequent local textile industry (the Philippines being one of these countries).

By 1892 we see the introduction of regenerated cellulosic fibres (fibres formed of cellulose material that has been dissolved, purified, and extruded), such as rayon, followed by the invention of completely synthetic fibres, such as nylon, which challenged the monopoly of natural fibres for textile and industrial use.

Since the 1960s, the use of synthetic fibres has increased dramatically, causing the natural fibre industry to lose much of its market share. In December 2006, the United Nations General Assembly declared 2009 the International Year of Natural Fibres (IYNF); this was a year-long initiative focused on raising global awareness about natural fibres, with specific focus on increasing market demand to help ensure the long-term sustainability for farmers who rely heavily on their production. The last conference of the Year of Natural Fibres happened in London, specifically in the Institute of Materials, Minerals and Mining (IoM3), where I had the opportunity to present my first paper about pineapple leaf fibres[78] (Fig 3.2).

Fig 3.2 Natural fibres conference catalogue, London. IoM3. (2009)

In spite of these efforts, and the considerable improvements achieved to increase production, natural fibres' actual share of the market has decreased with the influx of the cheaper, synthetic fibres requiring fewer man-hours for production, cheaper raw materials and consistency of supply and quality (Table 3.3).

[78] C.Hijosa, 'Jungle to People: Pineapple Leaf Fibre Leather Substitute', London: Royal College of Art, 2009

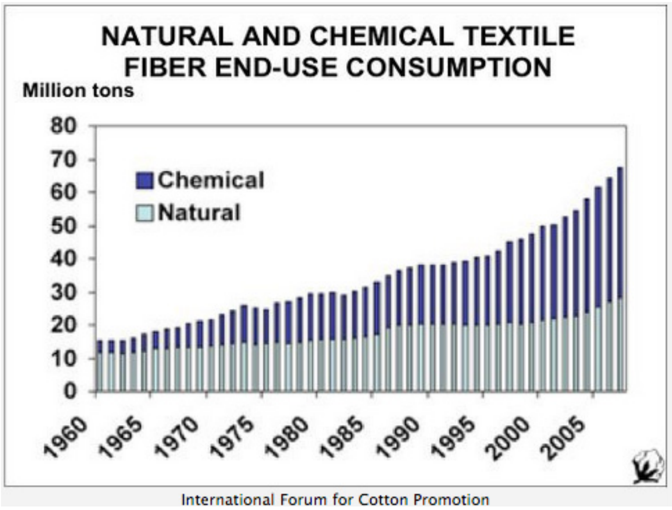


Fig 3.3 International forum for cotton production. Ecotextiles. (2010)

Over the past half-century, natural fibres have been displaced in our clothing, household furnishings, industries and agriculture by man-made fibres such as acrylic, nylon, polyester and polypropylene. The success of synthetics is due mainly to cost. Unlike natural fibres harvested by farmers, commonly used synthetic fibres are mass-produced from petrochemicals to consistent quality (e.g. uniform strengths, lengths and colours). However, the continuous decrease in crude oil as the natural resource needed to develop synthetic fibres will have an effect on their long term viability, that is, unless we ensure that these resources are re-used and kept in the upcycle loop. Some companies, such as Puma, are dealing with this issue as seen in their launch (2013) of 'InCycle', the Brand's First "Cradle to Cradle Certified[CM] Basic" Collection of Biodegradable and Recyclable Products'.

Fig 3.4 Puma's InCycle Backpack Recyclable. (2013)

Definition, properties and classification of natural fibres

Natural fibres can be defined as substances in the form of long, thin strands which are directly obtainable from an animal, vegetable, or mineral source and convertible into nonwoven fabrics such as felt or paper or, after spinning into yarn, into a woven cloth. A natural plant fibre may be further defined as 'micro-composites consisting of cellulose fibres in an amorphous matrix of lignin and hemicellulose and often with a high length to diameter ratio, called the *aspect ratio*, of greater than 1000'. The diameter of natural fibres varies with species but generally in the range of 10-60 μm.[79]

Table 3.3 Properties of synthetic fibres. Matthews & Rawlings. (1999)

	Density ρ (Mg/m^3)	Young's modulus, E_f (GPa)	Tensile strength, (MPa) $\hat{\sigma}_{Tf}$	Failure strain (%)	E_f/ρ	$E_f^{1/2}/\rho$	$\hat{\sigma}_{Tf}/\rho$
Asbestos	2.56	160	3100	1.9	63	4.94	1213
E-glass	2.54	70	2200	3.1	27.6	3.29	866
Aramid (Kevlar 49)	1.45	130	2900	2.5	89.7	7.86	2000
SiC (Nicalon)	2.60	250	2200	0.9	96.2	6.08	846
Alumina (FP)	3.90	380	1400	0.4	97.4	4.99	359
Boron	2.65	420	3500	0.8	158.5	7.73	1321
Polyethylene (S1000)	0.97	172	2964	1.7	177.3	13.5	3056
Carbon (HM)	1.86	380	2700	0.7	204.3	10.5	1452

Table 3.4 Comparative properties of natural fibres and conventional synthetic fibres. Elsevier B.V. (2012)

Fibers	Density (g/cm^3)	Tensile strength (MPa)	Young's modulus (GPa)	Elongation at break (%)
Ramie	1.5	400–938	61.4–128	1.2–3.8
PALF	1.44	413–1627	34.5–82.5	1.6
Flax	1.5–3	450–1100	27.6	2.7–3.2
Jute	1.3–1.45	393–773	13–26.5	7–8
Hemp	–	690	–	1.6
Sisal	1.45	468–640	9.4–22	3–7
Cotton	1.5–1.6	287–800	5.5–12.6	7–8
Coir	1.15	131–175	4–6	15–40
E-glass	2.5	2000–3500	70	2.5
S-glass	2.5	4570	86	2.8
Aramid	1.4	3000–3150	63–67	3.3–3.7
Carbon	1.7	4000	230–240	1.4–1.8

The densities and mechanical properties of a selection of natural and synthetic fibres are presented in table 3.3 and 3.4. These demonstrate that in general natural fibres have lower resistance and inferior modulus and strengths than synthetic fibres. However when the modulus and strengths values are divided by the density to give the specific modulus and

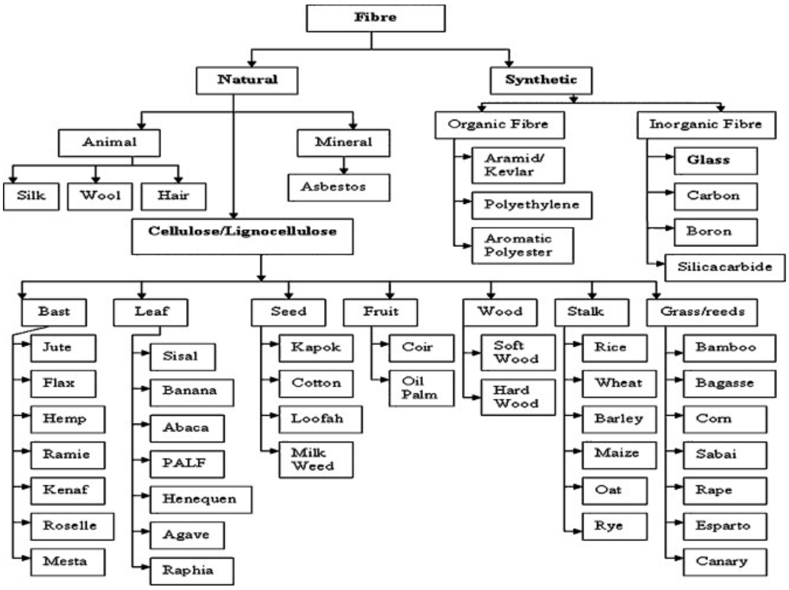
[79] F.L. Matthews and R.D. Rawlings, *Composite Materials: Engineering and Science*, Cambridge: Woodhead, 1999, p. 31

specific strength respectively, these parameters for natural fibres approach those achieved by synthetic fibres (see table 3.3 and 3.4).

Classification of natural fibres

Natural fibres are classified according to their origin into three classes. The vegetable, and thereby plant or cellulose-base class, which includes fibres such as cotton, flax, and jute; the animal, or protein-based: wool, mohair and silk; and the mineral class as exemplified by asbestos. See table 3.5 for detailed classification of fibres.

Table 3.5 Global Fibre Supply Study: Context, method and modeling the future. FAO's. (2011)



(Note: Raphia in Table 3.5 same as Raffia)

For the purpose of this research we are concentrating on cellulose fibres.

Cellulose fibres are categorized by the part of the plant used: seed, stem or leaf. Cotton is a *seed fibre*, a fibre that grows within a pod or boll from developing seeds. Flax, hemp and ramie are *bast fibres,* from the stem of the plant. *Leaf fibres* are removed from the veins or ribs of a leaf. Pineapple leaves or *piña* fibres, sisal (a type of agave plant) and abaca (from the banana tree family) are examples of *leaf fibres*.

The main commercially used cellulose fibres are cotton, flax/linen, hemp, and ramie. All the cellulose fibres share some desirable qualities – they are good heat conductors making them cooler than protein fibres for summer clothing; they can withstand high temperatures; they do not build up static electricity and have good absorbency.

The key advantages of natural fibres are their high strength and stiffness per weight, known as specific strength and specific stiffness, length, pliability, abrasion resistance, absorbency, acoustic isolation, rapid production and potentially lower cost, an economic consideration.[80]

Natural fibres and their contribution to the global economy

Each year, farmers harvest around 35 million tones of natural fibres from a wide range of plants and animals; from sheep, rabbits, goats, camels and alpacas, from cotton bolls, abaca, pineapple and sisal leaves and coconut husks, and from the stalks of jute, hemp, flax and ramie plants. These fibres form fabrics, ropes and twines that have been fundamental to society since the dawn of civilization (See fig 3.5).

a) b) c)

Fig 3.5 Selection of natural fibres. **a)** Abaca fibres**, b)** Manila rope, **c)** coir fibres

The production, processing and exports of natural fibres and their products are vital to the economies of many developing countries and the livelihoods of millions of small-scale farmers and low-waged workers. Almost all fibres are produced by agriculture, and the major part is harvested in the developing world. For example, more than 60% of the world's cotton is grown in China, India and Pakistan. In Asia, cotton is cultivated mainly by small farmers and its sale provides the primary source of income of some 100 million rural households.[81] Today, many of those economies and livelihoods are under threat: the global financial crisis has reduced demand for natural fibres as processors, manufacturers and consumers suspend purchasing decisions or look to cheaper synthetic alternatives. However, there is hope for natural fibres in the long run as many industries search for new usages of more traditional, non-synthetic materials.

There is a segment of industry where natural fibres are already replacing synthetic fibres; e.g. in the car industry, abrasive glass fibre is being replaced by hemp and abaca as the

[80] Bcomp
[81] United Nations Food and Agriculture Organisation, International Year of Natural Fibres http://www.naturalfibres2009.org/en/iynf/index.html

reinforcement in polymer matrix composites. (See Fig 3.6). The use of natural fibres in the moulding process consumes less energy than that of fibreglass and produces less wear and tear on machinery, cutting production costs by up to 30%. Other advantages are good acoustic insulation and biodegradability.[82]

Since natural fibres are lighter in weight (See tables 3.3 & 3.4) than glass fibres, fuel consumption is reduced and with it carbon dioxide emissions and air pollution.

• Daimler-Chrysler has developed a flax-reinforced polyester composite, and in 2005 produced an award-winning spare wheel well cover that incorporated abaca yarn from the Philippines.[83]
• Vehicles in some BMW series contain up to 24 kg of flax and sisal.[84]
• Mercedes Benz has used a mixture of polypropylene thermoplastic and abaca yarn in automobile body parts. Production of abaca fibre uses an estimated 60% less energy than production of glass fibre.[85]

Fig 3.6 Key car manufacturers usage of natural fibres

The construction industry worldwide is moving to natural fibres for a range of products, including light structural walls, insulation materials, floor and wall coverings, and roofing.[86]

In India, a growing shortage of timber for the construction industry has spurred the development of composite board made from jute veneer and coir ply – studies show that coir's high lignin content makes it both stronger and more resistant to rotting than teak. In Europe, hemp fibres are being used in cement and to make particle-board half the weight of wood-based boards. Geotextiles are another promising new outlet for natural fibre producers.[87] Originally developed in the Netherlands for the construction of dykes, geotextile nets made from hard natural fibres strengthen earthworks and encourage the growth of plants and trees, which provide further reinforcement. Unlike plastic textiles used for the same

[82] Common Fund for Commodities, *Annual Report 2009*, available at: http://www.common-fund.org/fileadmin/user_upload/Publications/Annual_report/ANRPT_2009.pdf

[83] B.C. Suddell, 'Industrial fibres: recent and current developments', in: *Proceedings of the Symposium on Natural Fibres*, available at: *ftp://ftp.fao.org/docrep/fao/011/i0709e/i0709e10.pdf*

[84]. M. J. John and S. Thomas , (eds.) *Natural Polymers,* (3 vols) London: Royal Society of Chemistry, 2012.

[85] Fibre Industry Development Authority (FIDA) Philippines, 2012

[86] International year of Natural Fibres

[87] 'Natural Fibres 09', (conference) Institute of Materials, Minerals and Mining, London, 14-16 December 2009, http://www.iom3.org/conference-proceeding/natural-fibres-09

purpose, natural fibre nets – particularly those made from coir – decay over time as the earthworks stabilize. (I will take up this subject in relation to Piñatex later in the Thesis).

But where natural fibres really excel is in the disposal stage of their life cycle. Since they absorb water, natural fibres decay through the action of fungi and bacteria and products can be composted to improve soil structure, or incinerated with no emission of pollutants and release of no more carbon than the fibres absorbed during their lifetimes. However, this characteristic of sensitivity to water is also their weakness during service under certain conditions.

Summary and conclusion of 3.2

I have discussed the structure and properties of natural fibres in detail in this section. I have shown how these characteristics and the carbon footprint of natural fibres make them promising constituents for new materials. For these reasons, and because of my desire to help the economy in a developing country, I decided to investigate the potential of natural fibres from the Philippines, particularly those from the leaves of the pineapple plant.

3.3 The Philippines and Natural Fibres

In this section I will describe in detail the Philippines as the country that made possible my project. I will look into its history, people, social and economic status. Based on my work experience, I will describe the main natural fibres I have worked with, their use and market potential.

Reflective practice

In 2009, just a couple of months after my arrival in London and the start of my PhD at the Royal College, I had the opportunity to attend and present a paper 'Jungle to People: Pineapple Leaf Fibre Leather Substitute' at the conference 'International Year of Natural Fibres 2009', hosted by the Institute of Materials, Minerals and Mining (IOM3), London. The conference's aim was to raise awareness of the plight of natural fibres, their diverse engineering properties and to take an in-depth look at the research work that is being carried out to quantify and improve the properties of these environmentally sustainable materials in engineering and textile applications.

This event was an eye-opener to me, being the first time that I was participating in a conference based on natural fibres. Even though I had been working with these materials for several years, my learning and experience had been based on my findings in the Philippines and the transferable knowledge from the government institutions I was working with. Listening to experts on subjects like reinforcing concrete, composite materials and growing hemp in Australia gave me a broader appreciation and knowledge of natural fibres. After three days of listening, talking and evaluating information I felt that the world of natural fibres had the resources and links I needed to strengthen my own research and findings. Since then I have kept in touch with IOM3, attending conferences and meeting key experts who have informed my own research and guided my project at key points in its development.

Geography, history, culture and economics of Philippines

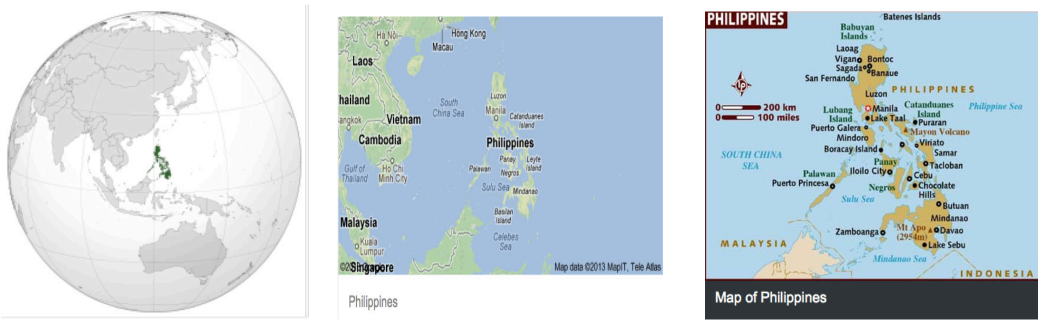


Fig 3.7 Maps of the Philippines. (2012)

The Philippines is a sovereign state in Southeast Asia in the western Pacific Ocean, between Taiwan and Borneo. According to the *CIA World Factbook*, its location on the Pacific Ring of Fire and its tropical climate make the Philippines prone to earthquakes and typhoons but has also endowed the country with natural resources and made it one of the world's mega diverse countries.[88] It has a complex geography, being made up of approximately 7,107 islands, making it one of the largest islands groups in the world,[89] divided into three main geographical divisions: Luzon, Visayas and Mindanao. Luzon, the largest island, is located in the northernmost region of the archipelago, and is home to the country's capital city, Manila, and also the place where the agro-co-operative and the manufacturing plant I am working with are established.

The Philippines was conquered by the Spanish in the 1500s and remained a Spanish colony for 300 years. During this time Manila became the Asian hub of the Manila-Acapulco Galleon trade. The Galleon Trade introduced foods such as corn, tomatoes, potatoes and pineapples from the New World to the Philippines.

In 1898 the Spanish claim of sovereignty was passed to the USA: in 1946 the Philippines was established as an independent nation with a democratically elected government.[90]

[88] 'East & Southeast Asia: Philippines' in:*The World Factbook,* Washington: Central Intelligence Agency, 2013, available at: https://www.cia.gov/library/publications/the-world-factbook/geos/rp.html

[89] General Profile of the Philippines: Geography, Manila: Philippine Information Agency, 2013

[90] Zaide, G. F. *Philippine Political and Cultural History* Manila: Philippine Education Co, 1957

With a population of more than 92 million people, the Philippines is the seventh most populated Asian country and the 12th most populated country in the world.[91] There are 111 official racial groups, each with their own language, culture and traditions. Trade and subsequent Chinese settlement have also introduced Chinese cultural elements, which remain strong to this day. Tagalog and English are the official languages of the country. The literacy rate in 2008 was 95.4 %, being about equal for males and females.[92]

This point gives the Philippines strong leverage when it comes to building a business bottom up, taking into account social and ecological responsibilities. In all my meetings from the farmers' co-operatives to working in the Design Center Philippines, to dealing with governmental and financial institutions, women are at the forefront of key national and regional organizations. I have encountered empathy for my quest and a willingness to help that I have not seen anywhere else.

The country is estimated to have the second-largest gold deposits after South Africa, and one of the largest copper deposits in the world. Despite this, poor management, high population density, and environmental consciousness have resulted in these mineral resources remaining largely untapped.[93]

On the other hand, geothermal energy, the by-product of the country's volcanic activity, has been harnessed more successfully. The Philippines is the world's second-biggest geothermal producer behind the US, with 18% of the country's electricity needs being met by geothermal power.[94]

In contrast, in spite of the sunny weather, the use of solar power is not widespread.

With a tropical climate that is hot and humid, the land is fertile and appropriate for growing all sorts of tropical fruits and vegetables. This makes the Philippines the biggest producer of pineapples in the world (see table 3.6).

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[91] 'Philippines population', National Statistics Office, Republic of the Philippines. Available at http://web0.psa.gov.ph/ Accessed March 2013

[92] http://en.wikipedia.org/wiki/Education_in_the_Philippines

[93] Greenlees, D.'Miners shun mineral wealth of the Philippines' *The New York Times,* 14 May 2008.

[94] Davies, Ed and Karen Lema. (2008) "Pricey oil makes geothermal projects more attractive for Indonesia and the Philippines" The New York Times (retrieved 03 2013)

Table 3.6 World's top 5 pineapple producers in 2010 (in Million Tonnes). FAO, 2010

The Top 5 Pineapple Producing Countries

	Country	Pineapple Production 2010	% of World Total	% Change from 2009
1	Philippines	2,169,230 m/t	13.72%	- 1.331 %
2	Brazil	2,120,030 m/t	13.41%	- 3.918 %
3	Costa Rica	1,976,760 m/t	12.51%	+ 17.522 %
4	Thiland	1,924,660 m/t	12.18%	+ 1.573 %
5	China	1,519,072 m/t	9.61%	+ 2.826 %

(Note from Table 3.6 It is Thailand and not Thiland)

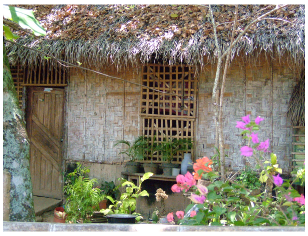
However, as a newly industrialized country, the Philippine economy has been transitioning from one based on agriculture to one based more on services and manufacturing. Of the country's total labour force of around 38.1 million, the agricultural sector employs close to 32% but contributes only about 13.8% of GDP and the daily income for 45% of the population of the Philippines remains less than $2.[95] As a consequence there is a steady emigration from the country to the cities, making the plea to develop local industries related to the land a very important aspect to reduce the exodus from the land to the cities. This PhD project is working (for the procurement and treatment of the pineapple fibres) with a local agricultural cooperative called Labo Cooperative in Camarines Norte, (See fig 3.8) on the main island of Luzon. This cooperative is based on community-building as the key to building local, rural economies.

[95] http://en.wikipedia.org/wiki/Philippines#cite_note-CIAfactbook-5

a) **b)** **c)**

Fig 3.8 a) Labo Coop meeting, **b)** Labo pineapple plantation and **c)** detail of pineapple field, after harvesting fruit, (2013). Authors' archives

Natural fibres from the Philippines



a) **b)** **c)**

Fig. 3.9 a) Abaca fibres, **b)** Rattan, **c)** Pineapple fibres. Authors' archives

Sub-tropical weather and fertile soil makes the Philippines a rich country in natural fibres, both for their abundance and their variety. The potential, richness and social and cultural implications of using these natural resources were the key starting point for the research into this project.

There are some thirty useful fibre crops used locally, thirteen of which have commercial applications, namely, Abaca, Ramie, Buntal, Raffia, Coir, Maguey, Piña, (pineapple), Banana, Kozo, Kenaf, Salago, Kapok and Sericulture.[96] In addition to these fibres mentioned above, there are a number of other natural fibres such as water hyacinth, which are available and have varied usage across different product categories, such as fashion accessories.

For the purposes of the research I have chosen five fibres that I have worked or experimented with during my consultancy work with the Product Development and Design Center Philippines (PDDCP) (1993-1999) in the making of textiles, bags, hats and luggage (Fig 3.10). These are abaca or Manila hemp, coir, buntal and raffia (both fibres are extracted from the same palm: the Bury palm), ramie, and pineapple fibres.

[96] Philippine Fibre Industry Development Authority (FIDA) 2013

a)

b)

c)

Fig 3.10 Selection of products made by the author in the Philippines. Author's photographs

a) hand woven abaca and silk, b) and woven buntal, c) hand woven abaca

Below, in table 3.7 we can evaluate the variation of volume being harvested from some of the main fibres.

Table 3.7 Yearly baling of Philippines commercial fibres (in bales of 125 kg). FIDA (2011)

FIDA. Fibre Statistics. 2011

Abaca	Coir	Salago	Buntal	Raffia	Kapok	Piña	Banana	Kozo	Total
395,000	120,000	2,600	85	139	142	25	28	24	518,043

Abaca

Abaca (*Musa Textilis Nee*), or Manila hemp, is a herbaceous plant that belongs to the family of the *Musaceae.* The plant, native to the Philippines, achieved importance as a source of cordage fibre in the 19th century. Today it is one of the country's best-known export products and the Philippines remains the world's largest producer of abaca, growing it abundantly in 49 of its provinces.

Fig 3.11 Abaca plant, family *Musaceae*.

Harvesting abaca is laborious. Each stalk, which averages from one to three metres, must be cut from the plant, then cut into strips and scraped to remove the pulp. The fibres are then washed and dried.

Abaca fibre is valued for its strength, flexibility, buoyancy, and resistance to damage in salt water. These qualities make the fibre exceptionally suitable for marine cordage. For this reason abaca is chiefly employed for ships' ropes, hawsers and cables, and for fishing lines, hoisting and power-transmission ropes, well-drilling cables and fishing nets. Some abaca is used in carpets, tablemats, and paper. The plant's inner fibres can be used without spinning to manufacture lightweight, strong fabrics, mainly used locally for garments, hats and shoes. However, most of the abaca fibre is made into pulp and used in the making of specialized paper, cigarette filter papers, tea-bags and sausage skins as well as in currency paper (Japan's yen banknotes contain up to 30% abaca).

Fig 3.12 Local Filipino products made with abaca, Source: FIDA 2012

In 2007, the Philippines produced about 60,000 tonnes of abaca fibre; however, almost all abaca produced is exported, mainly to Europe, Japan and the USA. Exports from the Philippines are increasingly in the form of pulp rather than raw fibre.[97]

Coir

Fig 3.13 Coconut tree, family *Cocos nucifera*

Coir (Cocos nucifera), (Fig 3.14) is obtained from the husk of the coconut fruit, a perennial plant found in tropical countries. Native to the islands of the Indian Ocean, where the fibre had been used extensively for cordage, coir was the first hard fibre introduced to European rope-makers.

In the Philippines, records indicated that the country had been producing coir as far back as the 19th century. The traditional retting method of fibre extraction was used, wherein the husks were soaked in streams for eight to twelve months and the fibres were extracted manually by pounding them with mallets against slabs of wood. After drying, the fibres were made into ropes or twines for fishing and farming purposes.

[97] All information supplied by FIDA (Philippines March 2013 field trip)

Today the fibre is made into mats and matting, twines, ropes and cordage; filters and wall covering, brooms brushes, carpets and mattresses and insulation materials.

a) b)

Fig 3.14 a) Coir rope b) Geotextiles

Another important use of coir is in geotextiles, and recently as an inner component in the making of health-conscious shoes, (Fig 3.15).

Fig 3.15 Detail of inner coir foot-mattress from Po-Zu., 2014

Buri Palm

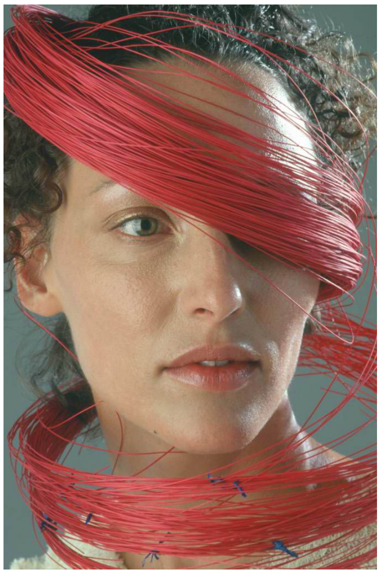
Fig 3.16 Buri palm, family *Lorypha Elata Rox B.*

Buri *(Lorypha Elata Rox B.)* is a large palm, the biggest in the Philippines, with large fan-shaped leaves and stout petioles ranging from two to three metres in length.

The palm reaches heights of 20-40m with a trunk diameter of up to 1-2.5m (Fig 3.16). It is relatively slow-growing and can take many years to form a trunk. It flowers only once, and then the tree dies. Three types of fibre may be obtained from the buri palm: buntal, raffia and buri.

Buntal fibre is extracted from the petioles of the palm by means of hand pulling or retting. They are then washed in water and dried in the sun. Buntal has the unique characteristic of being the only perfectly cylindrical natural fibre, being also strong but flexible, traditionally used in the making of summer hats, see fig 3.17.

a) hand-woven buntal bag



b) body adornment (buntal & raffia) **c)** hand woven buntal bag

Fig 3.17 Buntal products designed by the author during her work with the Design Center Philippines (1993-1999) Authors' photographs

Raffia comes from the unopened leaves at the end of the petiole of the buri palm and needs to be hand extracted before the fan-shaped leaves open. It is then hand-woven into fabrics such as wall-covering, upholstery materials, bags, place-mats and other decorative items. A buri palm which has been trained to yield buntal cannot produce raffia, and vice versa.

Buri is the matured leaf of the palm used to produce products for the local markets, such as shopping bags and sleeping mats. These products change colour as the buri ages, from lush green to soft browns and golden tans.

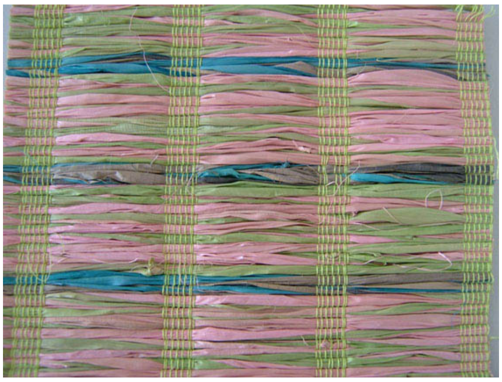
 

Fig 3.18 Raffia hand-woven textiles for interiors (courtesy of Design Center Philippines), 1999

Ramie

Fig 3.19 Ramie plant, family *Boehmeria nivea*

Ramie (*Boehmeria nivea*) is not an indigenous Filipino plant, but is native to East Asia and commonly known as China grass, being a flowering plant of the nettle family, growing to a height of 3m. It is grown for fibre mainly in China, Brazil, and the Philippines. Its bark has been used for millennia to make twine and thread. The fibre is white with a silky lustre, similar to flax in absorbency and density but coarser, being one of the strongest natural fibres, ranging up to 190 cm in length, with low elasticity (See Table 3.4). Coarse ramie fibers are suitable for making twine, rope and nets. Wet-spun, it produces a fine yarn with a high lustre, suitable for a wide range of garments, ranging from dresses to jeans.

Fabrics of 100% ramie are lightweight and silky, similar in appearance to linen. The Korean traditional costume, the ramie *hanbok,* (Fig 3.20) is renowned for its fineness. However, since it has low elasticity and resilience, ramie is usually blended with other textile fibres, thus increasing the lustre and strength of cotton fabric and reducing shrinkage in wool blends.

Fig 3.20 Korean traditional costume

Pineapple leaf fibres

As pineapple fibres are the main subject of my research, we will deal with this subject in depth in section 3.6.

Summary and conclusion of 3.3

In this section I have described the production and uses, with the exception of pineapple leaf fibres, of the various fibres produced in the Philippines. I have shown that there is considerable potential for fibre-based products both in the home and the overseas markets. The current social and economic climate in the Philippines is positive, and therefore ideal for the further exploitation of natural fibres. Taking into account all aspects of the production and properties of these fibres, I have chosen the fibre from the pineapple leaf for specific investigation.

3.4 Documenting the life cycle of the pineapple

In this section I have followed the life cycle of pineapple plant from its origins in the jungles of South America to the Philippines. Furthermore, its botanical and physiological characteristics and adaptations to industrial value as a food crop have been examined and analysed. This information is essential to set my proposal for the development of a product from pineapple leaves into context.

Reflective Practice

During my consultancy work with the Product Development and Design Centre Philippines, (PDDCP) we did a lot of travelling around the Philippines, mainly to source and see natural fibres and work with weavers. Fe Gonzalez, head of the R&D department in the Centre, was my constant companion. In one of the trips and while visiting some weavers, we had to walk through a path cut in the jungle. At one point and while keenly observing our surroundings, Fe bent down and picked up what looked like a grass to me. Twisting it around her fingers and seeing that it had good flexibility and strength she commented: Carmen, I wonder what we can do with this? Let's bring some back to the laboratory and see if we can extract some fibres from it. This keen observation and comment from my colleague brought to me a new way of thinking; nothing is just a grass, everything may be used, we are surrounded by potential, we just have to learn to see things through their inherent qualities and what it may bring to the communities living in those surroundings. Ever since, I have become a keen observer of nature, not just for its beauty, but for the potential it carries to become our ally and sustainer. The seed planted by Fe in my mind that hot and humid day in the middle of the jungle in the Philippines has sprouted and given fruit; my reverence to local intelligence and skills, admiration for the potential that nature has to offer has been with me ever since. This shift on thinking became a pivotal point in my future work, and is being manifested in the work done in this PhD.

Historical background; classification and origins

> 'As London natives, we are obsessed with pineapples in architecture. Take a wonder around the capital, and you will see that the pineapple is a London-wide architectural motive. You can find them everywhere, from the pineapples in Lambeth Bridge, to the finials of St Paul's Cathedral. The pineapple at the centre of the Tutti Frutti installation at Kew this year is the most recent of them all. Bring on the Bromeliacae!'[98]
>
> Royal Botanic Gardens, Kew. 'Pineapple Island', Spring 2013

Fig 3.21 Pineapple island installation. Royal Botanic Gardens, Kew, 2013

The pineapple originates from the area now recognized as Brazil and Paraguay. It is the leading edible member of the family *Bromeliaceae,* of which there are a total of over 2,000 species. These are found mostly in the tropical and subtropical regions of South America, apart from one rogue species, which grows only in West Africa.[99]

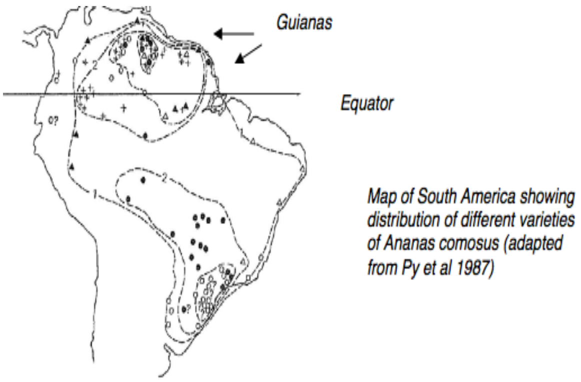
[98] Text documentation from the installation 'Pineapple Island' at Kew Gardens, London, Spring 2013

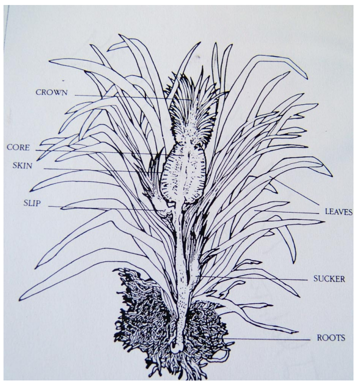
[99] Beauman, F., *The Pineapple: King of Fruits*, London: Chatto and Windus, 2005

The exact origin of the cultivated species – *Ananas comosus var. comosus* – is hard to pinpoint, but *Ananas comosus var. ananassoides* (with very small, seedy fruit and spiny leaves) is considered a wild ancestor of the domestic pineapple.

Fig. 3.22 Bat-pollinated wild pineapple

Domestication is thought to have occurred in Guiana.[100] For several thousand years, superior types of pineapples had been selected, domesticated and distributed by native Indians throughout the tropics and subtropics of South/Central America (notably the Guarani, in whose language 'ananas' meant 'excellent fruit').[101]





a) b)
Fig 3.23 a) The birth of the pineapple, b) Pineapple section

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[100] The pineapple. The Biology of Ananas Comosus Var. Comosus (2008), online image available from http://www.daff.qld.gov.au/__data/assets/pdf_file/0007/66247/Ch1-The-Pineapple.pdf p.3 (Accessed August 2013)

[101] 'Chapter 1: The Pineapple', version 1, Department of Agriculture, Food and Fisheries, Queensland Government, Australia, 2009 (online), Available at http://www.daff.qld.gov.au/__data/assets/pdf_file/0007/66247/Ch1-The-Pineapple.pdf

Westerners first saw pineapples in 1493 on the island of Guadeloupe during Columbus' second voyage to The New World, and on other islands in the West Indies later. It was recorded that King Ferdinand of Spain was eating pineapples as early as 1530. The Spanish saw the fruit's resemblance to a pinecone, and first called it 'Pine of the Indies'. The English called it an apple because of its tasty fruits. The name pineapple comes from the combination of the Spanish *piña* with the English 'apple'.[102]

Incidentally, in the Philippines the pineapple is still called *piña* and the textile made from the leaf fibres is called *piña* cloth.

The Spanish navigators distributed pineapple plants throughout the tropics so early and widely that it was considered indigenous. The fruit was introduced to the Philippines from Mexico as part of the Galleon Trade in the 1500s.

In the eighteenth century this spectacular fruit reigned supreme in Europe. Despite the fact that to cultivate just one cost the same as a new coach, every great house soon boasted its own steaming compost pits filled with hundreds upon hundreds of pineapple plants. A home-grown pineapple was a powerful status symbol, so much so that at first it was extremely unusual to actually eat the fruit. When first cultivated in European greenhouses in the 17th century, it was used only by the wealthy to adorn banquet tables. It thus became a status symbol of the social elite.

The image appeared on gateposts, on tableware, furniture and wallpaper (Fig 3.24).

[102] McKenzie, Gene (2010). "A Little Bit of History". *Journal of the Bromeliad Society* **60** (4): 187–189).

Fig 3.24 Pineapple teapot. Staffordshire, UK, 1770

A new phase opened when growers in the Caribbean began supplying pineapples in the 1840s shortly after the first canning factory was built in Hawaii. The companies Dole and Del Monte began growing pineapples on the island in 1901.[103] Since 1960, pineapple production worldwide has risen by 400 per cent. With the introduction of the 'Gold' variety, developed and patented by Fresh Del Monte in the 1990s, the production of pineapple has grown again by nearly 50 per cent since 1998.[104] Quite a success for a humble wild plant that for hundreds of years was only found in the Amazon jungle!.

Fig 3.25 Dole advertisement for canned pineapple, 1907

Botanical and physiological adaptations

Pineapple is a tropical plant and grows best in a moderately warm climate (16° to 33°C) with low, but regular rainfall. It is estimated that the variety known as Smooth Cayenne requires only 50mm of rainfall per month for optimum growth; however, pineapple in general has some important limitations: namely, it

- cannot tolerate frost
- is intolerant of high temperatures (in excess of 40°C), and sunburn damage to plants and fruit can be severe
- has a fragile root system that needs well-drained conditions

[103] Beauman, 2005, inside cover

[104] United Nations FAO astatistical data, 2009

In spite of the above, the pineapple has several special characteristics that allow it to survive and thrive under low rainfall conditions:

- leaf shape and orientation that maximizes capture of moisture and sunlight most efficiently
- the large cups formed where the leaves attach to the stump are effective reservoirs for nutrient solutions and water
- the ability to absorb nutrients through axillary roots in the leaf bases, and directly through the leaf surfaces, especially the basal white tissue
- low numbers of stomata,[105] and leaves that are insulated to reduce water loss
- water storage tissue that can make up to half the leaf thickness, and is used during periods of low rainfall to help maintain growth
- a specialized metabolic system (CAM) for capturing carbon dioxide at night for use during the day that greatly reduces water loss

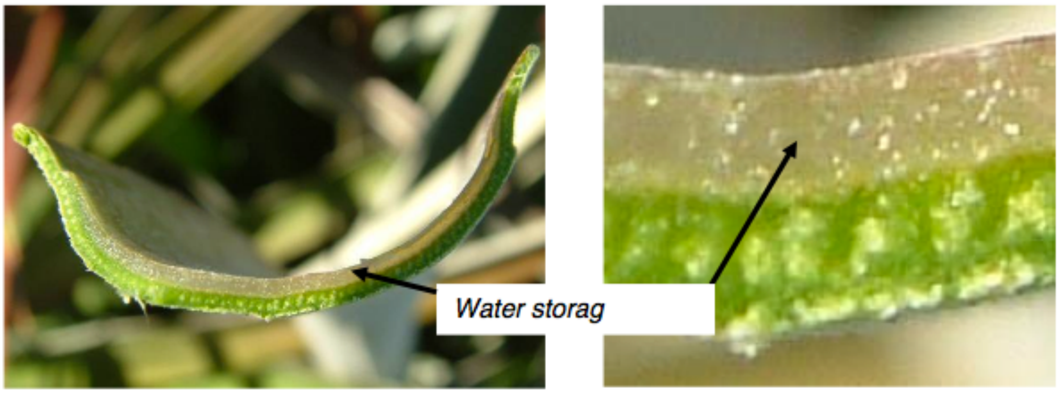

Fig 3.26 Detail, shape and water storage in PALF, *The Biology of Ananas Comosus var. Comosus,* 2008

[105] Botanical term meaning: any of the minute pores in the epidermis of the leaf or stem of a plant, forming a slit of variable width that allows movement of gases in and out of the intercellular spaces

Although the pineapple has many very efficient moisture-conserving systems and has one of the highest water use efficiency among cultivated crops, and can survive severe drought, (Fig 3.26) it still benefits from 'good' rainfall/irrigation. Lack of moisture hinders plant growth and yields are significantly reduced. However, during extended dry periods the plant 'closes down' and crop schedules are upset.[106]

Fig 3.27 Fields of pineapple leaves, after harvesting the fruit. Labo Cooperative, 2013

However, the implications of the many ways in which pineapple is able to conserve water makes it very tolerant to periods of low rainfall, being able to continue to grow under relatively dry conditions.[107]

Industrial value of the pineapple; world pineapple production and cultivation

In addition to the fruit, the pineapple plant also provides fibre which is used in the clothing and the paper industry (this part will be dealt with in detail in section 3.6 of Chapter 3: 'Production and uses of pineapple leaf fibres') as well as the enzyme bromelain. The pineapple is the only known source of bromelain, whose medicinal uses include relief for arthritis sufferers, as a digestive aid, in the reduction of blood clotting, as an anti-inflammatory agent, and for skin debridement[108] associated with burns. Bromelain also has industrial uses, including meat tenderization, clarification of beer, production of vegetable

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[106] The pineapple. The Biology of Ananas Comosus Var. Comosus (2008), online image available from http://www.daff.qld.gov.au/__data/assets/pdf_file/0007/66247/Ch1-The-Pineapple.pdf, (Accessed August 2013) p.7

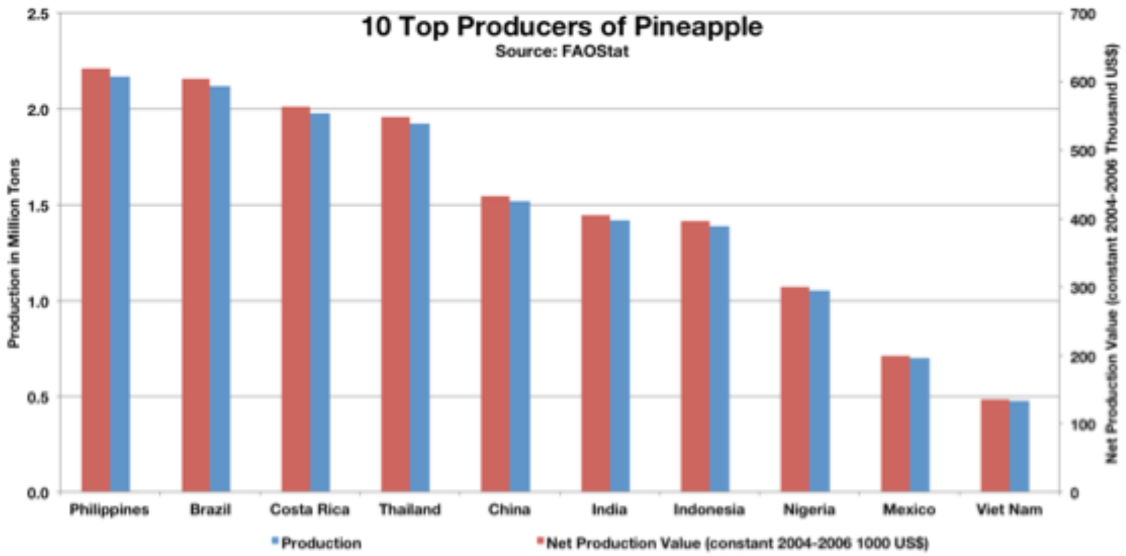
[107] Conversation with Mario Espeso, manager at Labos coop, in the plantation, 2013

[108] Medical term for the removal of damaged tissue or foreign objects from a wound

oils and the dehydration of eggs and soya milk. Bromelain content is known to vary by up to 50 per cent between varieties of pineapple.[109]

The Philippines is (2012) the first pineapple producer in the world, closely followed by Brazil. Furthermore, the pineapple, being the second fruit harvest of importance after bananas, contributes to over 20 per cent of the world production of tropical fruits.[110] This is of great advantage for my project, as this plant has already a place in the economy and social and agricultural status in the Philippines, making the Philippines the apt location for this research and future commercial possibilities.

Table 3.8 Pineapple production worldwide. FAO. (2012).



Summary and conclusion of 3.4

The pineapple plant has come a long way from its beginnings in the jungles of South America to becoming one of the most popular fruits in the world, providing not only fruit but also fibres that are used in the paper and textile industry.

[109] Py, C., Lacoeuilhe, J.J. and Teisson, C. (1987)

[110] On line available from http://www.fao.org/fileadmin/user_upload/inpho/docs/Post_Harvest_Compendium_-_Pineapple.pdf p.23 (Accessed August 2013)

3.5 The Pineapple in the Philippines

This section follows the pineapple plant from cultural, social and commercial viewpoints. Studies have been made to comprehend the plant's life cycle from plantation to fibre yield, methods of extraction, traditional and contemporary uses of the fibres and the possibilities of the remaining biomass to become another value-added income stream. The aim has been to understand in depth every stage of the growth and plant cycle to fully comprehend its potential, and to study the different stages to be able to assess how this project may become a commercial proposition, taking into account all aspects of its life cycle (See Fig 3.69, Piñatex intended life cycle).

Reflective practice

In the 18th century. the pineapple fruit became a status symbol in the great banquets and manors across Europe. In the Philippines, however, it was not the fruit that received that high esteem but the products made with the fibres coming from the discarded and valueless leaves…from these humble fibres a most magnificent and precious textile would be born, which by the 18th century had reached its pinnacle of craftsmanship and sophistication: the *piña* cloth. The women, with their *pañuelos*[111] …and exquisitely embroidered skirts and tops, and the men with their *barong tagalog,*[112] were the height of fashion and status, (Fig 3.28 & 3.51 c).

[111] Pañuelos: big hanky-like textile used as a shawl, Tagalog language

[112] Barong Tagalog: long shirt worn over trousers, Tagalog language

Fig 3.28 Piña pañuelo, Ayala Museum, Manila

To this day, the up-to-date but still very traditional garments made from *piña* cloth reign supreme in the greatest and highest gatherings in Filipino society, from political to social to bereavement rituals. It remains exclusive, still for the ones that can afford it, still made by hand. The treasure of *piña* lives on to this day. It is my hope that with Piñatex, the fibres may have the opportunity to be transformed into another industry for the benefit of all; from the manufacture of school bags for children, to shoes for everyone at an affordable price. To me this is a real turnaround and a full closure of the cycle of the pineapple plant: to develop products from the fibres that are affordable to all, across social and economic boundaries.

History of the pineapple in the context of Philippines history

Fig 3.29 Plate from Methamorphosis Insectorum, Surinamensium. Maria Sybilla Merian, 1705

As reported, the Philippines became a Spanish colony in the sixteenth century; the pineapple plant was introduced to the Philippines through contact with the Spanish .[113]

It quickly grew all over the Philippines, due to the country's fertile soil and suitable climate. The variety first cultivated in the Philippines was the Bromelia Pigna, better known as 'Red Spanish'. It is a tough plant, with leaves naturally adept in retaining water, making it easy to transport as a survival food. The fruits were brought along and eaten on long voyages to prevent scurvy. Crowns of these fruits were probably the first plants grown in the country. (Fig 3.30)

Fig 3.30 Mario Espeso, manager of Labo Coop with crowns of pineapple plants, 2013

In 1911, the smooth Cayenne pineapple from Hawaii was introduced to the Philippines by the Bureau of Agriculture. Today, its varieties, the Hawaiian variety (mainly used in the plantations of Del Monte Corporation and Dole Philippines in Mindanao in the south of the country) and the Formosa and Queen varieties (used amongst others by Labo Independent Cooperative (Labo Coop), our suppliers of PALF fibres), are the main varieties used for fruit production. The Red Spanish is still planted in many places because of its long leaves, which are sourced for fiber and is used in the weaving of the *piña cloth*[114].

[113] L.R. Montinola, *Piña,* Philippines: Amon Foundation, 1991, p. 83

[114] Conversation, FIDA meeting, March 2013 Manila

The pineapple plant, characteristics and yield

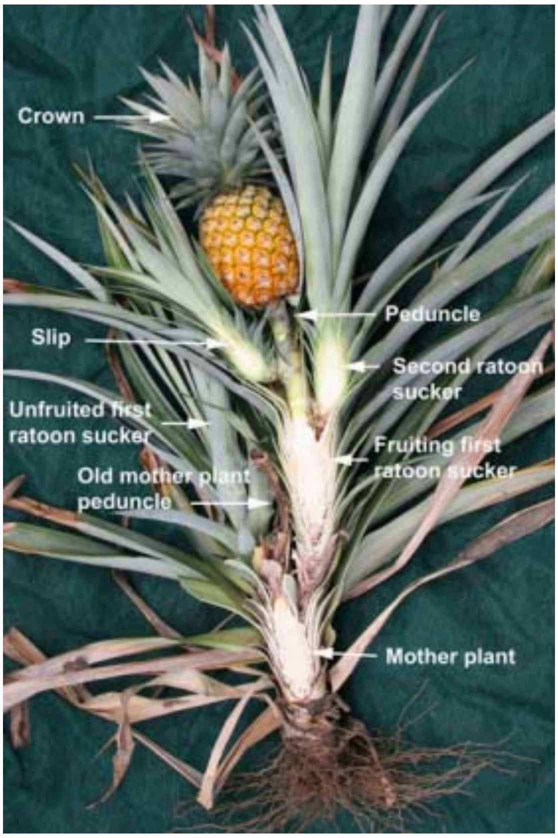


Fig 3.31 Structure of a pineapple. Garth M. Sanewski

Pineapples are grown on plants 60-120cm high and 90-120cm wide. As a tropical plant, it needs a lot of sunshine and usually grows best in moderately hot and humid climates, with moisture condensing on the leaves of the plants. The droplets run down to the root structure, making growth possible in the relatively dry season. However, the most important aspect of pineapple production is site location. Unproductive, low-nutrient soils such as pastures make the best locations for pineapple production because of their low soil organic matter, since all the nutrients needed for good growth are applied as foliar fertilizer.

In the Philippines, the high rainfall makes irrigation infrastructure unnecessary for small producers; however, the big plantations that are dependent on a much higher yield use irrigation as a way to control and guarantee a constant supply of fruit.[115]

[115] Conversation with Mario Espeso, manager, Labo Coop

Yield

According to the Fibre Industry Development Authority (FIDA), (2013 field trip)

- One acre of a pineapple plantation can sustain the produce of 20,000 fruits every 15 months, making it one of the most productive tropical fruits in the world. An acre can yield 20 tonnes of pineapples per 15 months
- There is one pineapple per shrub, weighing aprox. 1kg
- There are approximately 25 to 40 stiff, sword-like waxy leaves clustered tightly around a thick fleshy stem, varying in length from 80 to 130cm long
- 1000 plants would give approximately 30,000 leaves, wieghing about 1 tonne
- 1 Tonne of leaves typically gives 25 kg of fibre.(not in terms of a specific variety)[116]

This data gives

20,000 fruit every 15 months per acre

20,000 plants every 15 months per acre

This gives aproximately 600,000 leaves per acre every 15 months, which gives for 20,000 plants the equivalent to 20 tonne of leaves per acre. This represents 500kg of fibre per acre.

> The Philippines has 144,413 acres planted. (based on latests figures from the Food and Agricultural Organization of the United Nations (FAO), 2010.
>
> *Total of potential fibre production in the Philippines is 72,200 Tonnes of fibres per cycle.*
>
> (Theoretically, and based on this figures, the maximum Piñatex production in the Philippines, assuming all leaves are collected, would be 180 million square metres per 15 month/season).

[116] To obtain this yield, large amounts of chemical fertilizers are currently sprayed on a growing plantation every 10 days during the nine-month growing cycle, followed by an application of chemical hormone to force the plants to flower, Research: FIDA, Manila field trip, March 2103.

However, yield and strength vary from variety to variety as in table below.

Table 3.9 Pineapple plant variety and yield. FIDA. (2014)

Plant variety	Plants yield per Hectare (metric tonne)	Leaves in Plant (per season)	Leaves per Metric Tonn of PALF	Fibre extraction Per Kg/leaves	PALF wet	PALF dry
Formosa	22.68 MT leaves/Hectare	14 leaves/plant or 420,000 leaves /Hectare Once per season	1 MT PALF/ 1,453.000 leaves	78.43 kg of leaf per 1Kg of PALF	800Kg leaves= 35Kg of wet fibre 4.355% recovery	800Kg leaves 10Kg of dry fibre 1.24% recovery
Hawaiian	81.25 MT leaves/Hectare	30 leaves/plant or 900,000 leaves /Hectare thrice per seaso	1 MT PALF/ 852.000 leaves	66.66 kg of leaf per 1Kg of PALF	Recovery not known	Recovery not known

Current status of the pineapple industry

As already stated, the Philippines is one of the world's largest producers of pineapples.

The main production is held by two multinationals, Dole and Del Monte. It has been key to this research to understand the legal and logistic implications attached to this. The ownership of corporations in the Philippines must be 60 per cent owned by Filipinos and 40 per cent by foreigners in cases where there are foreign investors. This was reinstated at a meeting in FIDA's headquarters in Manila during my research and fact-finding trip to the Philippines in March 2013.

- Dole Food Company, Inc. (Dole) is the second largest global producer of fresh pineapples worldwide: in the Philippines Dole cultivates land that has been leased from private owners/farmers. The company also has member cooperatives who are planting pineapples, and the fruits produced are covered by marketing agreement with Dole as the buyer. *Dole has a say on what happens to the leaves because they own the planting materials.*

- Del Monte leases the land from private owners/farmers. The company owns the fruits and leaves of the pineapple.

The lands where the pineapple plants are grown belong to the farmers while the planting materials, specifically the pineapple variety, is provided by Dole/Del Monte. In return, the harvested fruits are directly bought from the farmers by Dole/Del Monte, covered by a marketing agreement. Since the planting materials are provided to the farmers, Dole/Del Monte have the rights to the disposal of the leaves.[117]

Plantation hectarage; main geographical areas and crop distribution in the Philippines

According to Dr Remedios Abgona, head reseacher from the Fibre Industry Development Authority (FIDA), more than 70 per cent of these areas are situated in the provinces of Northern and Southern Mindanao and are run by multinationals (Del Monte, Dole). These multinationals mainly export the fruits while the smaller cooperatives on Luzon and in the Visayas supply the domestic markets.

Major production areas of Northern Mindanao, Western Visayas and Bicol Region are shown in Fig 3.32.

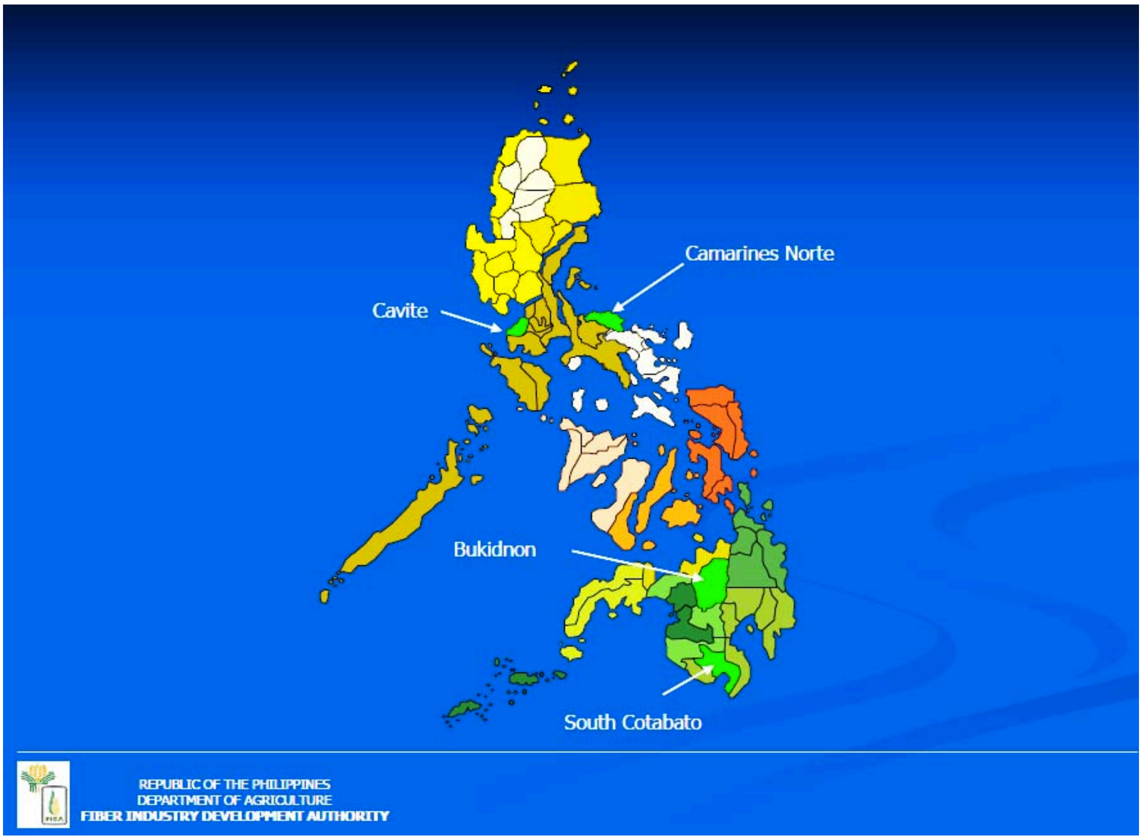


Fig 3.32 Main pineapple production areas in Philippines, FIDA 2013.

[117] Conversation with Engr. Mon Branzuela, Chief, PSD at Labo Coop, Philippines field trip, 2013.

Labos Coop is in the Bicol region, Camarines Norte . See table 3.10

Table 3.10 Fruit production by region in the Philippines. FIDA. (2013)

Pineapple in the Philippines

A. Fruit production – Hawaiian, Formosa/Queen Varieties

REGION/PROVINCE	AREAS PLANTED* (HECTARES)	%
SOCSARGEN (South Cotabato, Sarangani, North Cotabato, Sultan Kudarat)	**22,849**	**39.09**
NORTHERN MINDANAO (Bukidnon, Camiguin, Lanao del Norte, Misamis Oriental, Misamis Occidental)	**21,979**	**37.60**
CALABARZON (Batangas, Cavite, Laguna, Quezon, Rizal)	**3,869**	**6.61**
BICOL (Albay, Camarines Sur, Camarines Norte)	**3,084**	**5.27**
DAVAO REGION (Davao del Norte, Davao del Sur, Davao City, Compostela Valley)	**2,052**	**3.51**
OTHERS	**4,623**	**7.91**
TOTAL	**58,456**	

* Bureau of Agricultural Statistics, 2011

Varieties of Pineapples

In the Philippines the pineapple plant is grown for two different uses: fruit production, which is the biggest production and the one relevant for this research, and fibre production which is the variety used for the traditional craft of making the *piña* hand-woven textile. The pineapple varieties and their uses are summarized below and in Fig. 3.33.

Fruit production:

- Hawaiian variety (without spines on the leaf margin)
- Formosa/Queen variety (with spines on the leaf margin). This is the fruit variety I use for fibre extraction.
- Generally the leaves from fruit production are shorter and can be extracted by decortication methods

Fibre production:

- Red Spanish/Native Philippines Red, with spines on the leaf margin and longer leaves (140cm) which are extracted by the manual scraping method and used in the making of the traditional hand-woven textile *piña.*

a)

b)

c)

a) Hawaiian variety b) Formosa variety c) Red Spanish variety

Fig 3.33 (a, b, c) Pineapple varieties planted in the Philippines. FIDA presentation March, Manila, 2013

Currently, for the production of Piñatex, we are using the leaves of the Formosa variety, this being the variety planted by Labo Coop. According to Mr Tan, owner of Nonwoven Philippines, our collaborator, in the long run we should look into the leaves of the Queen variety as they have stronger fibres, but to date this has not been feasible.[118]

[118] Conversation with Mr Jimmy Tan, Manila March 2013

Pineapple-growing cycle and propagation

The pineapple plant is a perennial: it grows all year around. It has the capacity to live indefinitely. Once it does become adult and bear fruit, it develops little side shoots, leaving the original plant to die. The crown is the vegetative shoot on top of the fruit, and new plants take up to 24 months to produce fruit. Slips are side shoots from just below the fruit. Plants from slips take 20 months to produce fruit. Suckers are side shoots that develop from the main stem at ground level, and take 17 months to produce fruit, (See Fig 3.34).

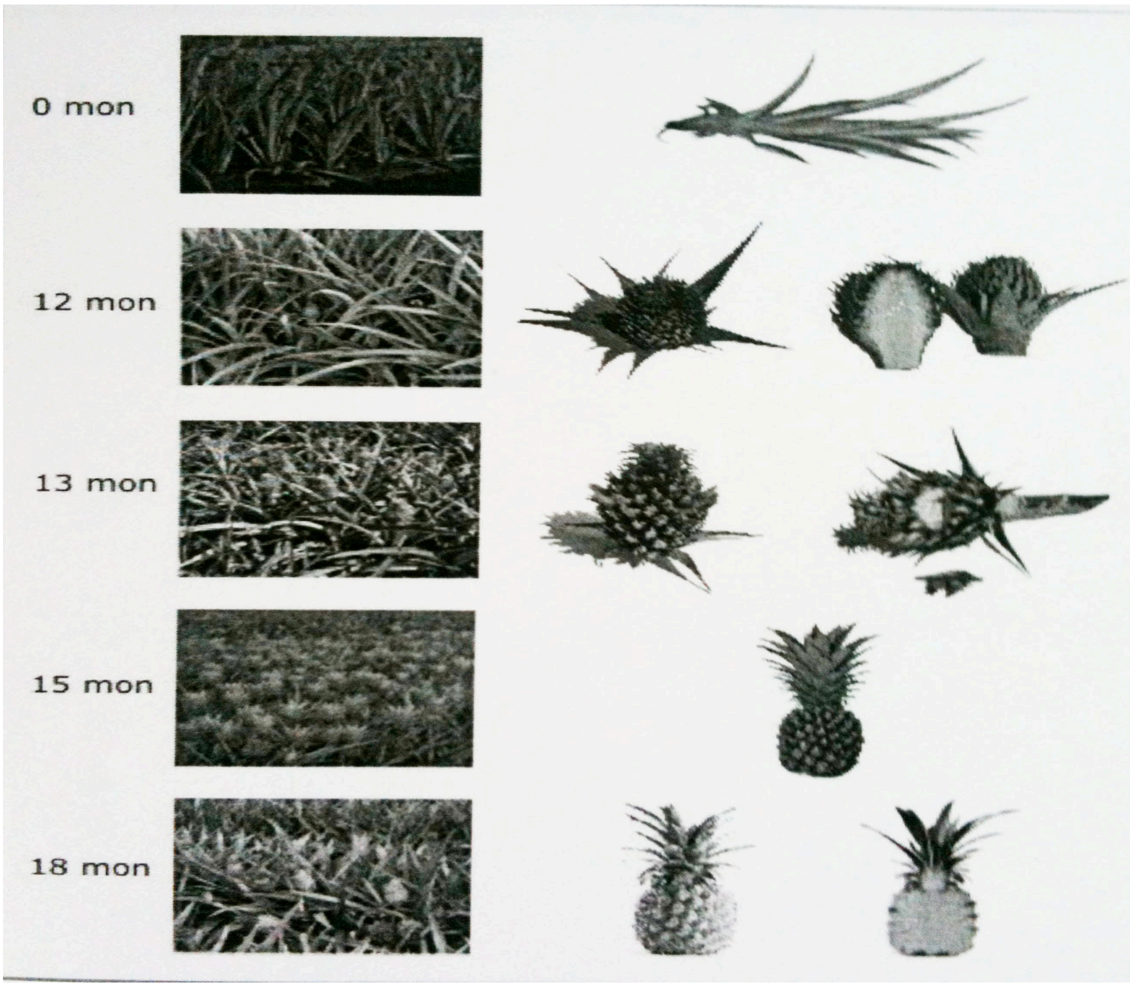


Fig 3.34 Growing cycle of the pineapple plant. FIDA, 2013

This kind of propagation using crowns, slips, suckers and even butts means that each plant is a clone (a genetically identical copy of its mother) (Fig 3.35). According to Beauman, these clones grow true to type and produce predictable and uniform crops.[119]

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[119] Beauman, 2005.

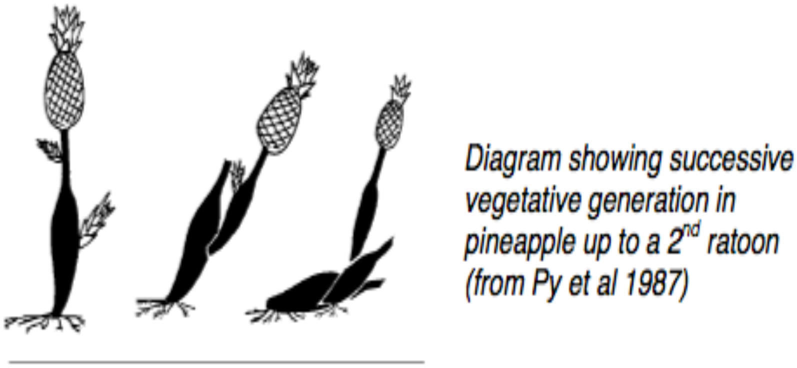
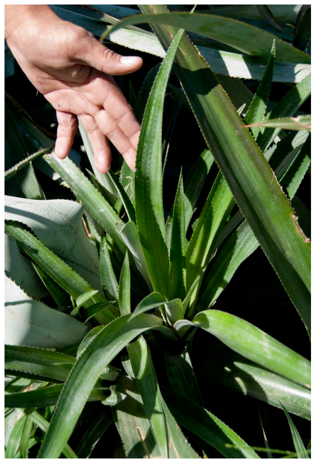


Fig 3.35, a) Propagation of the pineapple**.**

b) Crowns at Labos Coop ready for planting,



C) Suckers at Labo Coop, 2013

Each plant that is propagated produces one fruit at the top of its stem. This high-quality fruit is called the 'plant' crop. After the fruit is harvested, several suckers develop and one year later produces the 'ratoon' crop. The fruits are smaller and of lesser quality. A second ratoon crop can develop after the first crop is harvested. After that, the field is dug up and replanted.

This characteristic of the pineapple propagation has great advantages for the small to medium farming communities. They do not need to spend money on seedlings/new plants and be at the mercy and pressure of international suppliers to buy 'certified' seeds and plants, as with many other crops.[120]

Soil and climate requirements: seasons, cultivation and water usage

[120] Conversation with Engr. Mon Branzuela, Chief PSD at Labo Coop, March 2013

Below is the information given during my meeting with FIDA, based on their research and knowledge of soil, seasons and the cultivation of pineapple in the Philippines. This information has been touched on in section 3.4; however, the following charts give more specific details for pineapple growing in the Philippines.

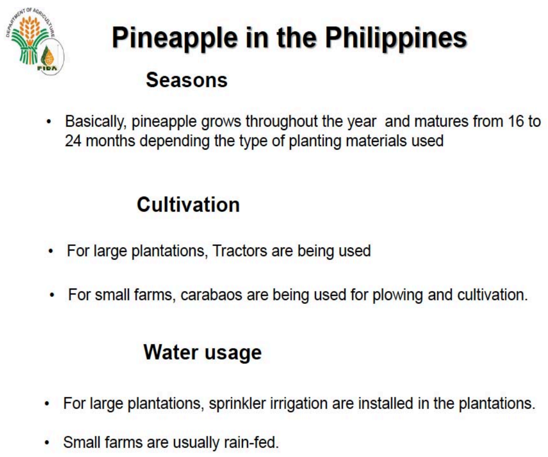


Fig 3. 36 Pineapple cultivation in the Philippines. (2013)

Social aspects of the pineapple harvest

Three-quarters of the pineapples found in European supermarkets come from Costa Rica. The reports the writer has read and sourced are mainly related to Honduran and Costa Rican pineapple plantations, but I consider that the data and my conclusions will also apply to a large extent to the corporations in the Philippines. The reports speak about poor working conditions, low wages and heavy use of toxic agrochemicals, which affect the health of workers as well as degrading the soil and polluting water supplies. Union membership frequently results in discrimination and lay-offs by the producing companies.[121]

Fig 3.37 shows all the actors in the pineapple supply chain, with retailers taking up to 41 per cent of the final value of a pineapple, compared with workers who receive approximately 4 per cent of the value (in the form of wages). These figures also correlate with the power that

[121] 'Cut Price Fruit', *Food Programme*, [radio broadcast], BBC Radio 4, broadcast Nov 14 2010

these actors have along the chain, with just a few major multinational traders and retailers controlling the market all the way from plantations to consumers.[122]

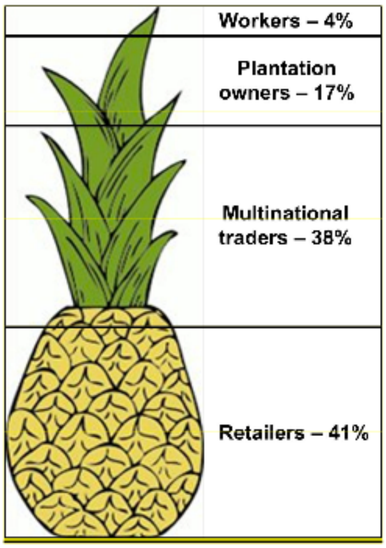


Fig 3.37 Social and commercial value of pineapples.
Food and Agriculture Organization of the United Nations, 2008

Previous research by Banana Link on the Costa Rican banana supply chain – which involves many of the same corporate actors as the pineapple supply chain – has illustrated how supermarkets use their buying power to push down prices to unsustainable levels, directly impacting on workers' wages, hours, health and safety, union repression and job security.[123]

The writer has found little information related to how the Philippines multinationals Dole and Del Monte work. Their plantations are based in the south of the country in Mindanao, which I have not visited, and it is difficult to get information from the the government bodies that I have been working with.

My work is being developed in collaboration with an independent cooperative, where farmers own the land and employ local people to work the land,[124] with the workers being part of the cooperative. The Philippines is unique in the use of the leaf fibres in the making of the traditional *piña* cloth, adding a significant value to the pineapple plant assets. Aside

[122] Consumers International, *Pineapple Case Studies* www.consumersinternational.org/pineapples (Accessed February 2013)

[123] Social and commercial value of pineapples. Food and Agriculture Organization of the United Nations, (2008) available from http://www.makefruitfair.org.uk/sites/default/files/ilrf_pineapplereport.pdf (Accessed August 2013)

[124] In conversation with Mario Espeso, manager of the Labo Coop, March 2013

from farmers, highly skilled workers and artisans such as scrapers, knotters and weavers are also involved in fibre and hand woven textile production.

Summary and conclusion of 3.5

I have considered the significance of the pineapple harvest, from the land ownership to the by-products in the Philippines and how the pineapple industry is organized.

It may seem that I have gone into considerable detail in section 3.5 on matters on which there is little published information. I have done this as conscientiously as I can, from the point of view that, in order to develop a product based on a closed loop cycle, we have to know what is currently happening, and be involved from the start of the cycle. Without a thorough understanding of local knowledge, how can we add to that knowledge and build upon it? I need to acquire an in-depth appreciation of the pineapple industry, its cycles, growth and varieties, as these have a direct influence on the way the value chain for Piñatex will be developed. Questions like – who owns the land? Who owns the by-product of the harvest? What is the cycle of growth? What benefits can Piñatex bring to the local communities?, These and similar questions have been one of the key findings of my field trip to Philippines in 2013.

It was after this trip that the full consequence and reality of the cycle was experienced, key questions answered and a road map for collaborative work started. I have considered in general the significance of the pineapple to the Philippines and how the pineapple industry is organized. It is now appropriate to study the life cycle in more detail and this is discussed in the next section, 3.6.

3.6 Production and uses of pineapple leaf fibres (PALF)

In this section I will go into detail on the present situation with PALF in the Philippines, from the current estate of production and yield to different methods of extraction and PALF's tradition and contemporary use in industry. In all the research carried out, the information for this section has been the most complex to gather due to the fact that PALF extraction and production is a nascent industry, going through all the ups and downs of trying to find markets, create a demand and consolidate all stakeholders.

Reflective Practice

During my work with the Design Centre Philippines, we used to travel and visit different weaving communities to work and co-develop textiles made from natural fibres, one of these being PALF. In one of our trips, we visited the weavers of Aklan, the birthplace of the hand-extracted pineapple fibres and of *piña* hand-woven textiles. India de la Cruz Legaspi, owner of one of the main weaving centres, showed me some of her heirloom clothing made with *piña* cloth – this was the first time I heard pineapple textiles called this way. Ms Legaspy made a comment: ' it was your ancestors the Spanish that showed us how to do it!'

This was said in such a way as if there were no space and time between the work of 'my ancestors', India's heirlooms and the work we were doing at that moment,(see Fig. 3.43).

I felt at once that this *piña* cloth was somehow the link between the past and the present, between the weavers in Aklan and my own professional life. Little did I know at that time that years later I would end up concentrating on this fibre for quite a different use – but somehow that first impression of beauty, fluidity and sheen characteristic of the *piña* cloth remained with me and started the thinking process to what was to become Piñatex a few years later.

Pineapple Fibres; production, extraction, methodology and yield

Pineapple leaf fibres (PALF) are extracted from the leaves of the plant *Ananas Comosus* of the family *Bromeliaceous*. Pineapple fibres are a by-product of the food industry, and thus a waste product of the pineapple fruit cultivation. As a by-product it is available in abundance for industrial purposes without any additional use of land, water, fertilizers and/or pesticides. However, producing fibre from the leaves requires space, water and energy, as I will show in this section.

a) b)

Fig 3.38 Labo Coop, a) Pineapple fields, b) PALF leaf from Formosa. Blanco B., 2013

Pineapple leaves are long, thin, waxy and pointed, with sharp spines on the edges, which curve towards the cross-section to maintain the stiffness of the leaf and act as a natural reservoir for capturing water (see Fig 3.26). The leaves vary from 140 cm long to 80cm. in length. PALF fibres are ivory white in colour, lustrous and silky to the touch. Its high cellulose content and fineness manifests in the characteristics of having a high tensile strength with excellent mechanical properties for a natural fibre (see Table 3.14). These qualities make PALF very suitable for making the nonwoven substrate, which forms the base of my product, Piñatex. Amongst other products made with PALF we have paper and paper yarn of remarkable thinness, smoothness and pliability that can be used in the making of textiles, furniture and accessories, (See Fig 3.52).

Piña fiber can be extracted by hand scraping, decortication or retting. However in the Philippines only the first two, hand scraping and decorticating, are generally used.

PALF production is divided into two different segments:

- Hand-extracted fibre, used in the local handicraft industry, which comes from pineapples specially grown for this purpose, the Red Spanish/Native Philippine Red (see Fig 3.39).

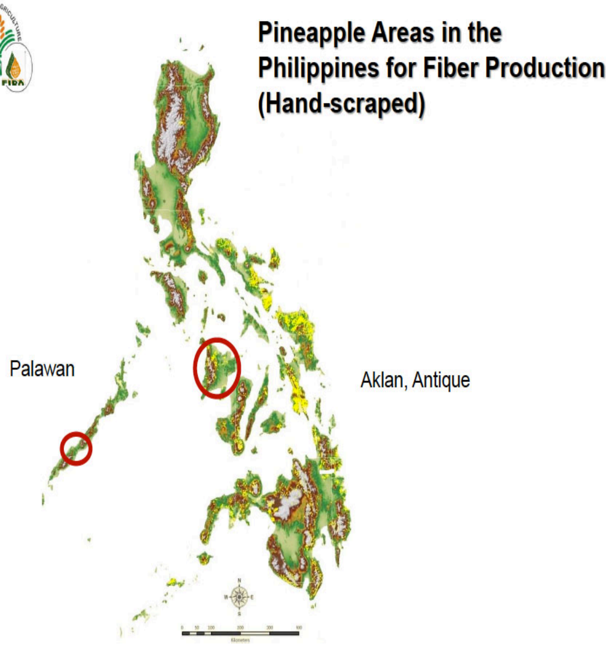
- Decorticated fibre, which comes from the commercially planted pineapples, the latter being the fibre and source I am using in the making of Piñatex (Fig 3.33).

Although not the fibre used in my research, the production of fibres from the Red Spanish/Native Philippine Red is worth mentioning, as it may suggest ways of enhancing the processes locally used, hence improving the viability of an existing craft important in terms of income generation to many weavers in the country.

Fig 3.39 Pineapple, Red Spanish variety. FIDA, 2013

As already stated, the Red Spanish/Native Philippine Red have longer leaves (140 cm) than the commercially fruit producing varieties; they have spines on the leaf margin and the fruits are smaller, but still edible.

There are two main areas of production, which coincide with the areas where *piña* cloth is still being woven: Aklan in the island of Panay and Palawan, the furthest archipelago to the west, close to Borneo. (See Fig 3.40).



a)

Pineapple in the Philippines

B. Mainly For Fiber production – Red Spanish/Native Philippine Red

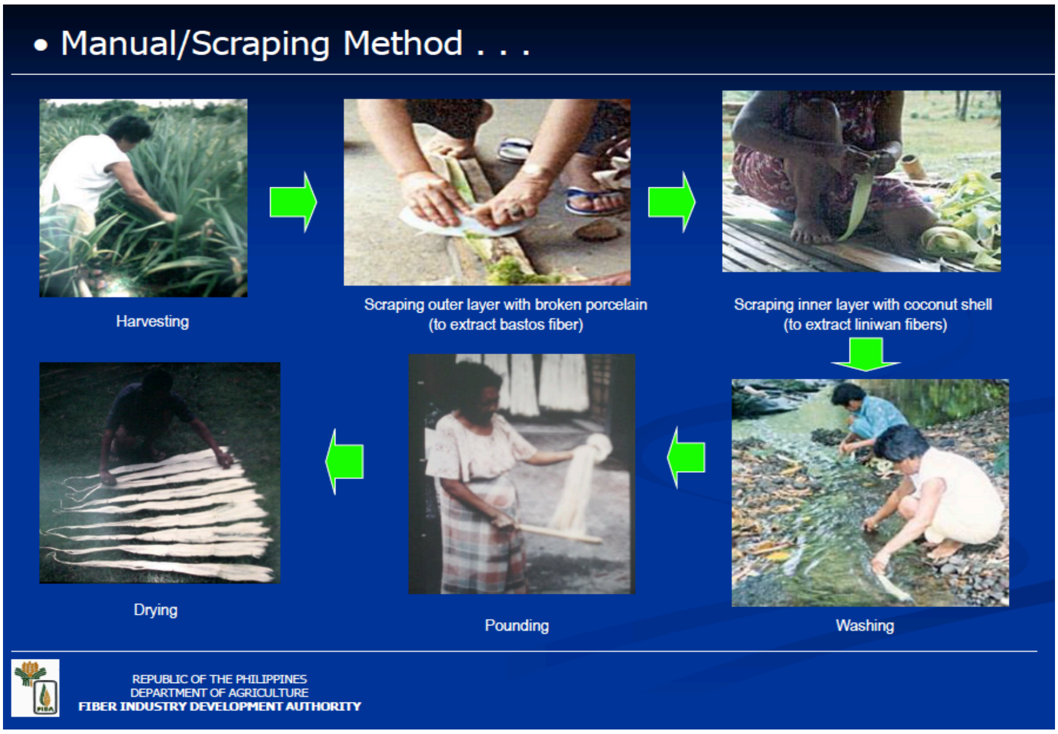
REGION/PROVINCE	AREA PLANTED* (HECTARES)	%
Western Visayas (Aklan, Antique)	**33.06**	**32.91**
Region IV-B (Palawan)	**67.40**	**67.09**
TOTAL	**100.46**	

* 2012 Data from the Fiber Industry Development Authority

Fig 3.40 a) Map of pineapple areas for hand-scraped fibre production,

b) Red Spanish pineapple cultivation in the Philippines. FIDA. (2013)

The traditional method of extraction is used. This process utilizes broken porcelain plates to extract the outer, *bastos* fibres from the leaves (see fig 3.41). Then the inner layer of the leaf is exposed to extract the *liniwan*, which are the inner fibres of the leaf. The fibres are then hand-washed to extract the lignin, pounded to soften the fibres and air dried before being sold in local markets directly to the weavers.



a)

b)

Fig 3.41 a) Hand extraction of PALF. **b)** detail. Courtesy of FIDA March 2013

Generally, women from the small farms that grow this variety of pineapples carry out this method of extraction, selling them to the local weaving communities, (Fig 3.42)

Fig. 3.42 Selling PALF fibres in Aklan, a centre for hand-woven pineapple textiles, 1999. Authors' archives

Traditional weaving process

After drying, the fibres are graded and aligned in preparation for knotting. During the knotting process, each fibre is extracted singly from the bunch and knotted end to end to form a long continuous strand; the fibre is then sent to warping and weaving, see fig 3.43 below.

a) b) c) d)

Fig 3.43 a) Knotting of fibres, **b)** Warping, **c)**Weaving, **d)** Piña dress (detail). Author's work

It is nearly impossible to comprehend, with our western minds, the skill and time it takes to extract PALF fibres by hand and to produce *piña* cloth. It takes a good weaver one day to weave from 50cm to 75cm lenght of cloth, such is the fineness and delicacy of it.

Moreover, because of the long process of hand-scraping, some scrapers and knotters find fiber extraction and knotting too tedious. A better method has not yet been found to make this manual extraction a more efficient and profitable one.

Decorticated *piña* fibre; production and methodology

a) b)
Fig. 3.44 a) FIDA decorticating machine, b) detail, decorticating machine in Labo Coop field., 2013

In the Philippines, PALF is industrially extracted using a decorticating machine.[125] (Fig. 3.44)

Production of decorticated *piña* fiber using mechanical methods and with a view to developing a pineapple fibre industry in the Philippines commenced only in 1999, when export started, but only in limited quantities, mainly used for paper-making.[126]

Aside from exports, decorticated pineapple fiber was also distributed to local processors, including a local textile mill, which started processing the fiber into yarns in 1999. The fibre was initially used for the trial run of polypiña fabric production (a blend of *piña* fibers and polyester at 20/80 ratio) as part of the project Development of Philippine Tropical Fabrics. In spite of the efforts from the government, the volume of production was minimal, being dependent on orders from buyers. Furthermore, some farmers/ plantation owners who tried producing decorticated piña fibre ceased to operate due to problems in production and marketing. Most of them claimed that fibre production was too costly, particularly on labour. Others demanded a higher price for their produce which the buyers found unacceptable. This fluctuation in demand is reflected in Table 3. 11.

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[125] The decorticating machine in Fig 3.44 is designed to extract different fibres, such as abaca, banana and pineapple. It comprises a rotating blunt fly wheel which separates the fibres from the biomass. FIDA has been advancing the technology by developing a decorticating machine that is safer than the previous machines used, giving more yield than the previous manner of fibre extraction; however, further work has still to be done to update the decorticating machine and the system used at present.

[126] The commercial production of decorticated piña fibre was launched in mid-1999 as part of the project 'Development of Philippine Tropical Fabrics'. In this project, FIDA with funding support from the Philippines Garment and Textile Export Board (GTEB) fabricated decorticating machines and distributed these to farmers in different areas for trial production. With the enactment and eventual implementation of the Republic Act No. 9242 entitled 'An Act Prescribing the Use of the Philippine Tropical Fabrics for Uniforms of Public Officials and Employees and for Other Purposes', more entrepreneurs will be encouraged to produce the fibre in order to sustain the requirements of the market.

Table 3.11 Fibre Production in the Philippines, (courtesy of Dr. Abgona, FIDA). (2013)

Year	*Pineapple fibre	*Abaca fibre	* Banana fibre	* Raw Silk
2006	4,400		1,200	
2007	3,600		15,700	
2008	4,700		65,000	1,130
2009	5.150			1,200
2010	200			565
2011	3,600	490,000	11,000	890
212	10,300	433,000		750

* In bales of 125kg.

The fibre used in the mechanical extraction method comes from the two main fruit varieties planted in the Philippines: the Formosa variety and Queen (Hawaiian) variety.

Piñatex fibres come from the Formosa variety leaves, as this is the pineapple planted by Labo Coop, the cooperative we are working with.[127]

Fig 3.45 Pineapple Formosa variety. Labo Coop, 2013

Apart from a few cooperatives scattered in the Philippines, the main production areas are the ones occupied by the multinational plantations, namely Dole and Del Monte which are in the southern provinces, (Fig. 3.32). They count for 80 per cent of total production output.

[127] Labo Coop's market is mainly Korea. This market prefers Formosa pineapples, which are not as sweet as the Hawaiian variety. In conversation with Mario Espeso, manager of Labo Coop, March 2013

Fig 3.46 Decorticating by machine. Courtesy of FIDA, 2013

Method

The leaves are hand picked from the pineapple plants once the fruit has been harvested, then piled evenly where the decorticating machine will be placed, which is usually at a strategic point in the pineapple fields. The leaves are chosen according to their length, (as even in length as possible) and their quality (they must not have cuts, be bent, bruised or misshapen). They are then fed to the decorticating machine, a bundle of 6/7 at a time, by two operators using the same machine. After being decorticated, the fibres they are brought to the nearby stream where they are washed and left to dry in the sun.[128] Once dried, the fibres are packed in polyurethane bags and store in the warehouse (Fig 3.47).

[128] At this point I do not have any reference as to the amount of water used, either as running water or as a closed tank and what happens to the water

a) b) c)

Fig 3.47 **a)** Decorticating PALF, **b)** PALF drying in the sun, **c)** stored PALF. Labo Coop., 2013

Constraints of the present method

Decorticating machines are presently placed strategically in the fields, but heavy rains and uneven terrain can make the gathering and extraction an unsafe and slow process.

There is a need to develop a designated decortication site, as this would mean that the site is dry and can be used all year around, incorporating a drying area for the fibres. This solution was discussed at the meeting with the Labo Coop, (Fig 3.48) and also at a meeting with the Fibre Industry Development Authority, but a steady demand needs to be achieved in order that this may happen. The lack of a continuous demand does not help the Coop to invest in better production methods.

Fig 3.48 Meeting at Labo Coop. Authors' Archives, 2013

Yield

The average PALF yield using a decorticating machine is 10.5 kg/day per two operators.

The waste of PALF at the washing stage is almost none.

Drying time in direct sun takes one day; inside it is more than a day, depending on the humidity of the surroundings.

For unbrushed fibres, they are bundled straight away; however, if they need to be brushed they are brushed first and then bundled and stored in plastic bags in the warehouse.

Pineapple fibre can stay in storage over a year when properly dried. However if not properly dried, it can get mouldy and discoloured, and may become brittle and lose its tensile strength.[129]

Organic waste

> 'The Dole Company, not Del Monte, requires the biomass to be put back into the soil as mulch. After every harvest the farmers are given enough time to collect the waste leaves and decorticate the fibres if they so wish. After a given time, the rest of the pineapple leaves left in the field will be knocked-down or returned back to soil to decompose using a bulldozer. This has been the practice of Dole in managing the pineapple plantations. They allow the farmers to decorticate the pineapple leaves in a given plot in the field at a given schedule. During the set schedule for bulldozing the lot, the farmers should leave the site and remove the decorticating machines in the area.'
>
> In conversation with_Engr. Mon Branzuela Chief, PSD at Labo Coop, March 2013

According to a 2011 article by Banik, Nag and Debnath,[130] organic waste in developing countries is often put to good use, as these economies dictate that resources and materials are used to their full potential and this propagates a culture of reuse, repair and recycling. From each pineapple plant, only 52 per cent is used; the remaining 48 per cent consists of fruit peel and leaves, forming the waste. Once the fibres have been extracted from the leaves, the

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[129] Information given by FIDA, 2013, and corroborated by my experience and laboratory tests carried out in PALF

[130] S. Banik, D. Nag, and S. Debnath, 'Utilization of pineapple leaf agro-waste for extraction of fibre and the residual biomass for vermicomposting, *Indian Journal of Fibre and Textile Research*, 36, June 2011, 172-177

remaining biomass can be used as a main constituent for compost, mixed with other waste, or used for vermicomposting. This adds a key element to the potential closed-loop cycle of PALF extraction. The fibre content in a leaf is only about 2.5 to 3.5 per cent of the total leaf biomass, and disposal of the biomass can become a problem.[131]

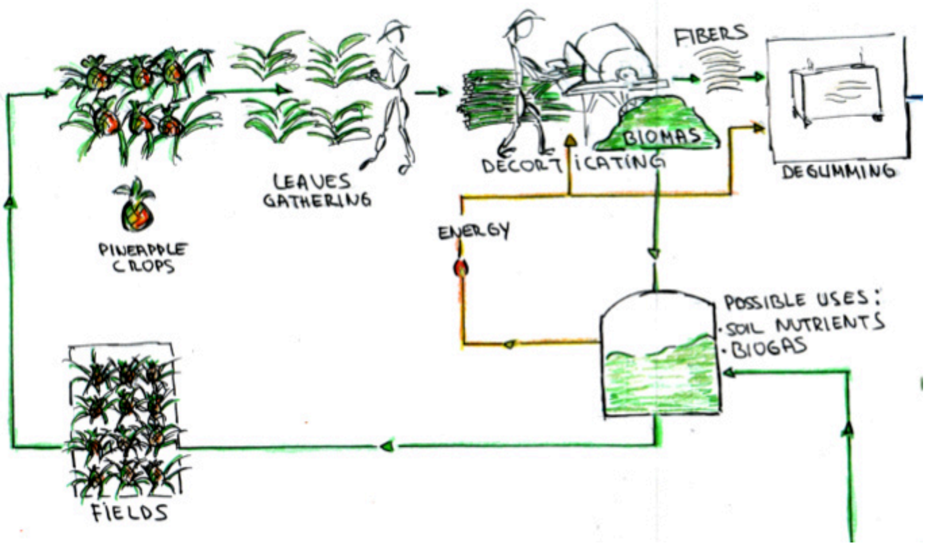

Fig 3.49 Piñatex intended cycle for biomass utilization. Hijosa C., 2013

This residual biomass can be utilized successfully for vermicomposting to make a total integrated package economically viable. Vermicomposting is a simple biotechnological process of composting using certain efficient species of earthworm gut.[132] Labo Cooperative has started a pilot plant implementing a vermicomposting facility using vermicomposting and the biomass left from PALF extraction. According to Mario, the Cooperative manager, 'the process is faster than common composting, and the resulting earthworm manure is rich in microbial activity, plant growth regulators and fortified with pest repellence attributes as well'.

[131] FIDA, 2013

[132] Banik, Nag, and Debnath.

a) b) c)

Fig 3.50 a) biomass from PALF extraction. b & c, stages of vermicomposting. Labo Coop., 2013

Though it is a new development for the Coop, the vermicompost is already in use at the first stages of the pineapple-growing cycle, saving them a considerable amount of money. However for the rest of the cycle they are still using commercial fertilizer with the aim of slowly phasing out the chemicals. They have experienced the consequence of using so many chemicals and the effect that this has in the infestation of the land, which is a major problem. Traditionally, the liquid of the biomass is being used for de-worming cattle, but this uses only a very small quantity.

According to Mario, ‘organic fertilizers would help in avoiding a major present issue they have and that is of the land being infested by the use of a great quantity of inorganic fertilizers’.[133]

Another potential scope for PALF biomass is its conversion into biogas, which, in the future I would hope we can look into as part of the closed-loop cycle intended for Piñatex production.

Producers of PALF

As we can see from the table below, the cooperatives that have been engaging in PALF extraction is not significant. The market is not yet mature enough to sustain the expenses and manpower needed. My project is very fortunate to be working with Labo Coop. Labo is one of the oldest cooperatives, well organized and reliable. The fact that the Coop benefits greatly from other revenue streams from the pineapple plant, makes it possible for them to

[133] Conversation with Mario Espeso, general manager, Labo Progressive Multipurpose Cooperative March, 2013, in Camarines Norte

sustain PALF extraction as a sideline for the farmers, in the hope that one day this extra revenue will become a steady income to the cooperative and its members.

Table 3.12 Producers of decorticated PALF fibres. FIDA presentation, Manila. (2013)

Producers of Pineapple Decorticated Fibers

Association/Cooperative	Contact Person	Contact Number	Production as of 2012, kg
Labo Progressive MPC Brgy. Malasigui, Labo, Camarines Norte	Mr. Mario Espeso Gen. Manager	(054)585-2455 585-2230 447-6565	9,189.5
Batas Multipurpose Coop Silang, Cavite	Ms. Leticia Racela FIDA- NCR	913-2789-90	200
Pililia, Rizal			18
T'boli Farm Growers MPC Edwards, T'boli, South Cotabato	Mr. Adolfo D. Tanco Jr. Manager	(083)237-1104 09089896044	900

Traditional and contemporary applications of PALF

Piña[134] as the name suggests, is associated with the coming of the Spaniards, in the sixteenth century, when the Philippines become a Spanish colony. During the Spanish regime, only one variety of pineapple was known in the country. This variety was then called *Bromelia Pigna*, but is now known as the Red Spanish variety.

The beginning of pineapple cultivation in the Philippines marked the start of the craft of *piña* cloth weaving in the country. The decree of the Franciscan order of 1580, which urged the teaching of crafts and trades, further helped promote *piña* cloth weaving. The Spanish missionary nuns taught the young girls not only religion, but also other crafts such as embroidery, that honed the native people's skills and talents.[135] According to Lourdes Montinola, the only scholar to write a detailed book on this textile, *piña* production reached

[134] Spanish for pineapple

[135] Montinola.

its peak in terms of 'perfection' in the late eighteenth and the first half of the nineteenth century.

I have visited the National Museum in Manila on many occasions and, as a textile designer, ponder how the weavers of the period reached such perfection and craftsmanship using hand-woven techniques and natural fibres.

Hand-woven, intricately embroidered *piña* cloth was greatly prized then and believed to have matched, or even surpassed, the most intricate lace or other luxurious handiwork in vogue in Spain and France at the time. *Piña* cloth was such an important novel cloth that in 1571 it was used to pay royal tribute, or poll tax imposed on the inhabitants of the Philippines.

a) b) c)

Fig 3.51 a) *Piña mantilla*, b) detail, c) *Barong Tagalogue,* traditional men's shirt

The emergence of cheaper and imported machine-woven fabrics, the foreign influence on Filipino fashion and the introduction of sugar production and other lucrative endeavours resulted in the decline of the *piña* cloth industry. By the closing decades of the twentieth century, *piña* production had declined so much that it had to be systematically revived and sponsored.[136]

Today, thanks to continuous government support,[137] the *piña* textile, while still a luxury, has been revived and is being used in the making of wedding and christening gowns, vestments, high fashion evening wear, and *Barong Tagalogue,* (Fig 3.51).

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[136] M. Roces,'Dress, Status, and Identity in the Philippines: Pineapple Fibre Cloth and *Illustrado* Fashion', *Fashion Theory*, 17 (3), 2013, 341-372

[137] The implementation of the project 'Pilot Production of Piña Fiber and Cloth in Aklan' in 1989 with the partnership of both the government and the private sectors, however, helped in the revival of the industry. The joint efforts of the Fiber Industry Development Authority (FIDA), together with the National Agricultural and Fishery Council (NAFC), Aklan Agricultural College (now Aklan State University) and Patrones Casa de Manila, a non-government organization, made this project a success. Relative to this is the establishment of the Piña Weaving Demonstration and Training Center in Balete, Aklan, where a series of training workshops on skills development and strengthening were conducted by FIDA.

Contemporary use of PALF

The result of a series of experiments conducted by the Philippine Textile Research Institute (PTRI)[138], under the project entitled 'Development of Philippine Tropical Fabrics',[139] proved that decorticated pineapple fibre from the commercial pineapple plantations is a suitable material for textile production. This new textile, called *polypiña*, is made from a blend of polyester and PALF, and used in the making of government officers' and school students' uniforms. This project kick-started a new way of using commercially produced PALF fibres in the Philippines.

More recently, PALF is also gaining popularity as fibre reinforcement in polymer composites because it is low in cost, low in density, high in specific properties, biodegradable and non-abrasive to processing machinery.[140]

In Thailand, a company called Yothaka[141] is using a PALF paper yarn combined with resins in the making of contemporary furniture with very attractive results.

Fig 3.52 PALF paper yarn made furniture by Yothaka

Part of this contemporary trend includes Piñatex, the new textile developed in this PhD. Piñatex is unique in that for its' manufacturing uses industrial processes from the nonwoven textile industry. This uniqueness of process and resulting product is what has brought about its patent (PCT/GB 2011/000802), now at the national phase (see Appendix 3). The author hopes that the new industry being developed will become as successful as the making of

[138] The goal of PTRI is to support the Philippine textile and similar industries to achieve global competitiveness through consumption of aboriginal resources and progress of technical competence in textile production and quality assurance.

[139] From 1997 the government launched a project, 'Development of Philippines Tropical Fibre' to help commercialize indigenous fibres and textiles. The Philippines Textile Research Institute (PTRI) has developed a blended textile using 20% PALF with 80% polyester to produce what it is called a 'polypiña cloth'. This is used as textile material for office and school uniforms. This textile was launched as one of the tropical fabrics along with banana and abaca fabrics in the 1st International Manila FAME Market Week in 1997. Source http://www.ptri.dost.gov.ph

[140] Conversation with Jimmy Tan, owner of NonWoven Fabric Philippines, Manila 2012

[141] Yothaka International Co., Ltd. http://www.yothaka.com

piña cloth has been in the eighteenth and nineteenth centuries in the Philippines, bringing hope and a better life to all involved, from the farm to the factory and beyond.

Summary and conclusion of 3.6

In this section, I have documented the research carried out as a result of a field trip, visits, meetings and interviews with relevant bodies and organisations in the Philippines mainly in 2013. Researched was carried out on the production and extraction processes of PALF, plant varieties used, methods, yield and the potential, present and future, of the usage of the remaining biomass after fibre extraction. I have looked into the uses of PALF both in the traditional hand-woven textiles and in the making of contemporary products.

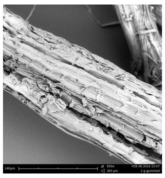
On the basis of this exploration and work, I can make certain conclusions:

- The industrial extraction of PALF, in spite of the present government efforts to commercialize decorticated *piña* fibres, is not yet sufficiently developed.

- There is not yet enough demand for the fibres to make this new industry stable and viable to the pineapple-farming communities in the Philippines.

The deeper significance of this is that my project will need a lot of help and advice to make the first and most important stage of its development, which is the procurement and extraction of PALF fibres, a sustainable and viable proposition for all involved.

3.7 Scientific research into PALF and consequent nonwoven substrate



In this section I will be showing the results of the research carried out onto the technical characteristics and properties of PALF and its comparison with other cellulosic fibres. I will be discussing the development of various degumming solutions, this being the primary key stage in the making of the nonwoven substrate. Furthermore, the resulting nonwoven substrate was studied and analysed through Scanning Electron Microscope (SEM) images, with tests being carried out on tear and tensile strength, together with UV light and soil composting for biodegradability. Latex impregnation was carried out, as well as the impregnation with other resins and polymers. On the basis of this work, various coatings and surface finishes were experimented with, to arrive at the final product, Piñatex. Finally, technical performance tests such as tear strength, tensile strength, Martindale tests have been carried on in the final product, Piñatex. These tests have been based on specification matrix given by market players in the fields of shoes, accessories, interiors and the car industry. This will be dealt with in detail in section 3.9.

This experimental work has been possible with the help and collaboration of various research centres, institutes and universities (see table 3.13).

Table 3.13 Collaborating partners in the R&D of PALF and Piñatex. Hijosa C. (2014)

- Fibre Industry Development Authority (FIDA) Philippines (2012 -)
- Ananas Anam, (2012 -)
- Leitat Technological Centre, Barcelona (2012-2013)
- The Institute for Creative Leather Technologies, Northampton University (2013-2014)
- Institute of Materials, Minerals and Mining, (IoM3), London (2013 -)

- Bangor University, Bio-Composite Centre (2014 -)
- Bonditex S.L. Barcelona (2014-)
- Professor Rees Rawlings, my tutor (2013 -2014)

Reflective practice

The RCA is not a science-based college. As this PhD progressed, I became aware of the need to understand the characteristics of PALF fibres and subsequent substrate, this being the building block of Piñatex. I had started this research from the design point of view, not the scientific point of view, driven by a question: 'Can I make a material that can be used as an alternative to leather?'. However, by the end of year one it became clear that there was a need to understand characteristics and properties of the fibres, these being the basic building blocks onto which I could develop a first substrate and then the final product, Piñatex. Thus the scientific world became involved as a guiding and driving tool in understanding and developing Piñatex. In order to achieve this, I tried first to have links with Leeds University through the RCA, but after a few months of waiting it didn't materialize. Eventually I decided to look for funding and then worked with an independent textile laboratory in Barcelona, Spain (Leitat Technological Centre). It was with the collaboration of Leitat that the patent for Piñatex was achieved. As part of the research carried out we also developed an enzyme degumming process for PALF (included in the patent). My experimental work in RCA with colour, texture and finishes led the research through aesthetics. However, at the end of the working on the patent in collaboration with Leitat, it become apparent that the aesthetics were not being developed to the standards and quality I was hoping for. As a textile-based designer, I am very aware of the importance of good handling, feel and surface qualities in textiles, and I was getting increasingly frustrated about not achieving what I was looking for. Furthermore, as the research moved on, the qualities of Piñatex changed and metamorphosed, bringing about the realization that this was a *new material per se*, and not just a substitute for leather as was my initial thinking. Consequently, I started to comprehend the importance of looking into the intrinsic qualities of PALF as the foundation to understand how I could develop a material instilled with its own characteristics and aesthetics, which would at the same time include the technical specifications needed to bring it into the marketplace.

Looking for alternative ways to develop a material that would encapsulate the above realization, I visited the Leather Technology Centre at Northampton University. They agreed to help in achieving a better handling and finish while working on the technical specifications. This stage of the research was a breakthrough in terms of what I was looking for. At present (Spring 2014) I am starting to work with a textile finishing company, Bonditex S.L. (Barcelona), to bring the laboratory samples and knowledge acquired from all previous R&D into the first commercially viable prototypes with the aim to enter into the first production phase using roll-to-roll textile manufacturing technology.

It is now apparent that the development of this new material which I called Piñatex is a balancing act between different industries, knowledge transfers, skills and ideologies, and it is working at the interface of these: the textile world, the leather industry, nonwovens, natural fibres, agriculture and the scientific world, that will determine the future and viability of Piñatex, with collaboration and knowledge-sharing being the key aspect of all the work.

3.7.1 Pineapple raw fibre (PALF)

The investigation into the properties of PALF has been carried out using the fibres from the leaves of the Formosa variety pineapple, as this is the fibre being used throughout the research and product development being carried out (Fig 3.53).

a)

b)

Fig 3.53 a) Non-treated (gummed PALF fibres, **b)** detail of fibres showing gum (Magnification 500 μm)

The first stage of the investigation of PALF looked into the raw fibre using a Scanning Electron Microscope (SEM) and transmitted light microscope, then into the physical and mechanical properties and finally into the chemical constituents of PALF. These measured properties of PALF have been compared to those of other fibres from the Philippines, namely abaca, and banana fibres.

Experimental procedure of PALF

The tensile strength, Young's modulus and elongation at break[142] were obtained from tensile tests carried out on a bundle of several fibres of nominal length of 10 cm. A schematic stress and strain curve is shown in fig 3.54 with these parameters defined.

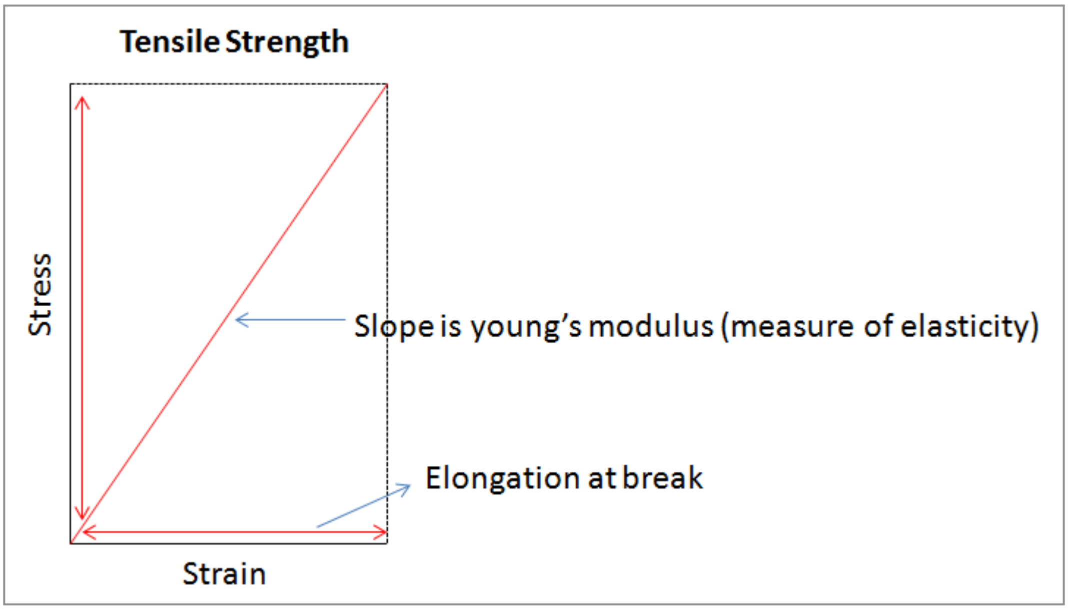


Fig 3.54 Schematic stress and strain curve (Prof Rees Rawlings, June 2014

The chemical constituents study was determined on 4 batches of fibres, which were designated 1,2,3 and 4.

Microscopic examination of PALF has been carried out throughout the R&D at key points in the research to corroborate the findings.

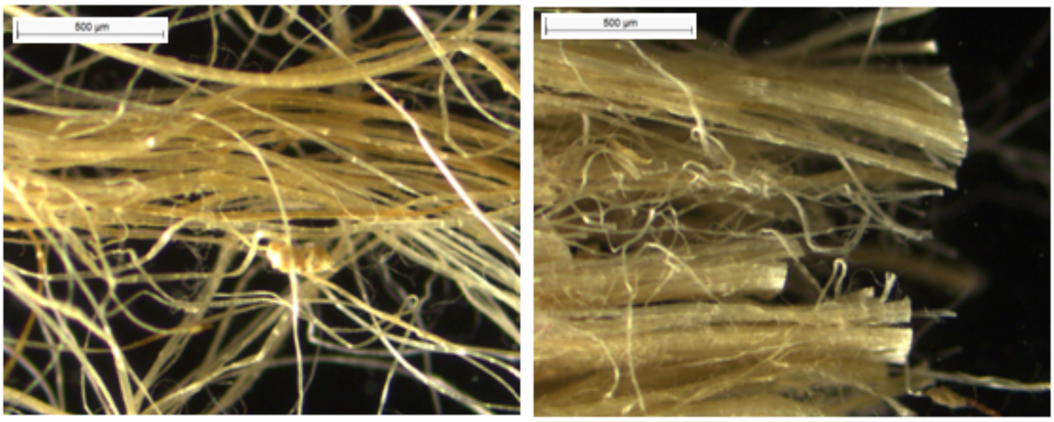
Fibre fineness has been determined extracting the shortest fibres from the sample, examining them with a microscope with transmitted light (ZEISS Axioplan) and recording the image. Fineness of the fibres was determined on about 150 fibres[143] using the analysis programme DeltaPix 300.

[142] Elongation at break is the strain up to the point the fibre fails as shown in Fig 3.54; in conversation with Prof Rees Rawlings, my tutor, July 2014

[143] Leitat Technological Centre, 2012

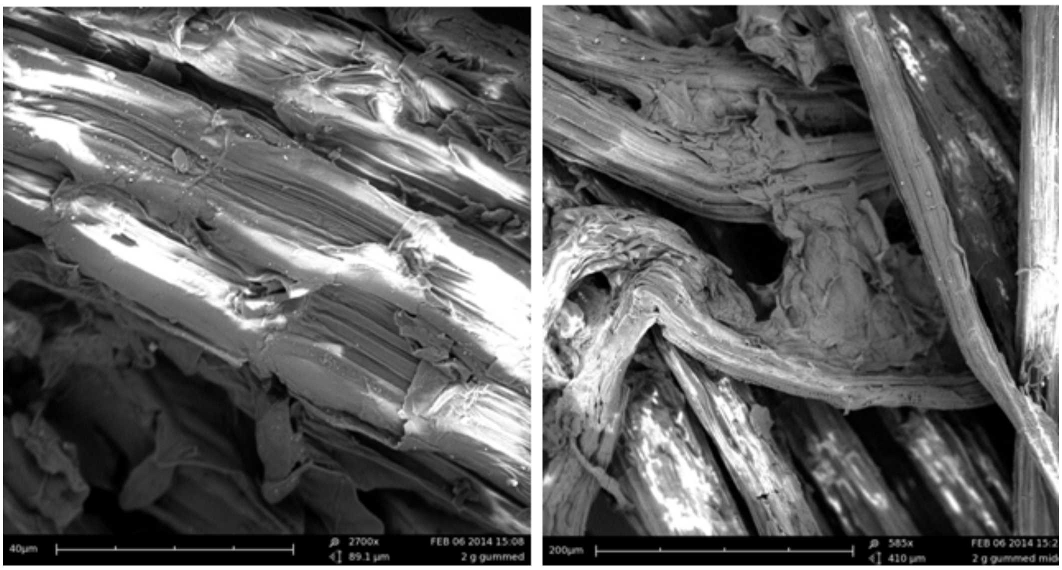
Results and discussion of PALF

PALF fibres have a ribbon-like structure that can be clearly seen in the Scanning Electron Microscope (SEM) images, in Fig 3.55 (a) and (b). Furthermore, we can clearly observe the presence of fibrils detached from the main fibres. The fibres are bonded together by means of gum, which is principally made of lignin and pectin.[144] Pectin forming the union between the fibres is shown in Figure 3.55 (c) and (d), taken by transmitted light microscope.



(a) (b)

Fig 3.55 (a & b) SEM images of gummed PALF fibres showing fibrils detached from the main fibres



(c) (d)

Figure 3.55 (c & d) SEM images of gummed PALF fibres showing bonding by gum. (Bio-composite Centre Bangor University, 2014

The physical and mechanical properties are presented in Table 3.14. The average fineness of the fibres was 75 µm. The results are from Leitat Technological Centre, 2012.

[144] Leitat Technological Centre, 2012

Table 3.14 Physical and mechanical properties of PALF, (Leitat Technological Center, 2012)

Properties	**Value**	**Properties**	**Value**
Density (g/cm^3)	1.526	Specific Modulus (MPa/g/cm)	4070
Softening Point (°C)	104	Elongation at Break (%)	3
Tensile Strength (MPa)	400-1600	Moisture regain (%)	12
Young's Modulus (MPa)	6260 62.60(GPa)	Average fineness (μm)	75

If we compare this data to the data on jute, sisal and ramie in Table 3.4 (Comparative properties of natural fibres and conventional synthetic fibres, p-65), we can observe that the density of PALF, jute, sisal and ramie is comparatively similar. There is considerable variability in the data for PALF tensile strength (400-1600 MPa), which is not unusual when testing fibres, as may be seen from the figures quoted for various fibres in table 3.4. Unfortunately we do not know the mean (strength value for PALF), but it is likely to be greater than the values quoted for sisal and jute and ramie, judging from the data of table 3.4. Looking at the results for Young's Modulus of PALF and comparing it with values from Table Fig 3.4 we can observe that my modulus of PALF is lower than ramie but higher than of jute and sisal. This means that PALF extends elastically a greater amount than these other fibres for a given stress.

Table 3.15 Chemical constituents (percentage) of 4 batches of PALF fibres, according to Leitat Technological Centre. (2012)

α-cellulose	**Hemicellulose**	**Lignin**	**Pectin**	**Ash**	**Wax**
78.11 %	9.45 %	4.78 %	-	-	-
69.5–71.5%	17.0–17.8%	4.4-4.7%	1-1.2%	0.71-0.87%	3-3.3%
70-82%	18%	5-12%	-	0.7-0.9%	-
68.5%	22.2%	4.0%	-	0.6%	2.5%

(Batches 1,2,3,4 from top to bottom of table)

Based on the results from the table above, we can say that PALF fibres are mainly constituted of cellulose with small amounts of lignin and pectin; this is consistent with the values given in table 3.16 for the most representative fibres from the Philippines.

As shown in the table, the cellulose content of PALF is higher than that for abaca and banana fibres, with least concentration of lignin, greater cell length and minimum cell diameter. The high percent of cellulose content confers on PALF a good tensile strength. It is due to this tensile strength that PALF fibres have already been used to reinforce polymers in composites[145] and show its potential in the making of a nonwoven substrate.

Table 3.16 Properties of selected natural fibres from the Philippines. Philippines Textile Research Institute, (PTRI), 2013

Physical and Mechanical Properties of PINEAPPLE/ABACA/BANANA

PROPERTIES	PINEAPPLE		ABACA		BANANA	
	RAW	TREATED	RAW	TREATED	RAW	TREATED
1.Tensile strength kg/gm/m	24.97	16.33	40.80	31.58	20.90	25.71
2.Fineness (Denier)	21.54	17.45	98.50	22.70	48.80	43.05
3.Residual Gum,%	35.04	7.69	28.70	6.40	41.90	10.29
4.Moisture Content,%	9.31	7.86	10.80	8.24	9.70	9.79
5.Hot Water Extractives	5.52	3.64	2.86	1.02	16.45	11.49
6.Cold Water Extractives	5.36	0.65	1.45	0.47	14.21	8.27
7.Alcol-Ben Extractives,%	1.95	1.33	1.70	0.35	1.70	1.40
8.Total cellulose,%	75.44	95.97	68.50	86.11	56.44	89.98
9.Alpha Cellulose,%	56.09	87.33	54.50	63.27	49.53	54.23
10.Lignin,%	4.31	2.50	8.70	3.23	13.22	3.86
11.Ultimate Celll Length(mm)	5.00	-	3.00	-	3.50	-
12.Ultimate Cell Diameter(mm-3)	8.00	-	20.00	-	25.00	-

(Denier: Mass of yarn for length of 9000 metres)

145 Leitat Technological Centre, 2012

Conclusion of PALF

We can conclude that one of the main characteristic of PALF is its fineness, a key property in the making of a nonwoven mesh, with high cellulose content and least amount of lignin amongst the most commercially available natural fibres in the Philippines. PALF also has good elasticity and tensile strength, which makes this fibre the most optimal solution in the making of the nonwoven textile being developed.

The mechanical properties are perfectly acceptable, with a density comparable to selected natural fibres, namely jute, sisal and ramie; a tensile strength much greater than jute and sisal and higher than ramie, Specific Modulus being greater than jute and sisal and comparable to ramie. Consequently there is no reason why we should not continue using PALF for the product being developed. All the tests done so far prove that PALF is the most appropriate fibre.

3.7.2 Degummed PALF fibres

The next stage in the process is the degumming of PALF; before fibres can be made into a substrate they have to be degummed, which means the removal of all gum from the fibre. It is important to determine an effective degumming agent, to understand the effects of such process and determine the structure and properties of the consequent degummed fibres.

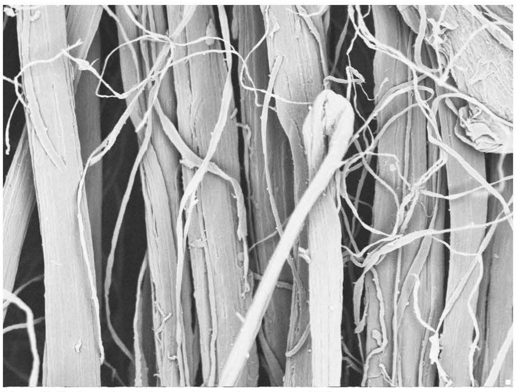
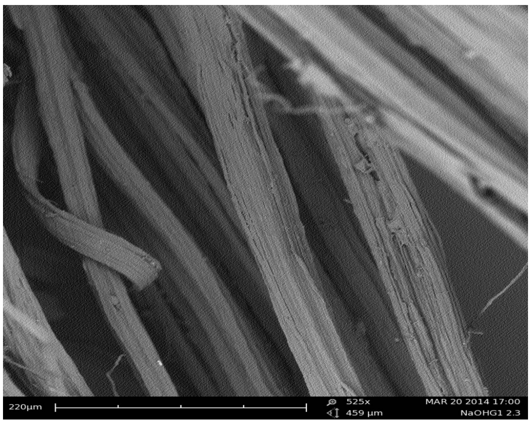


Figure 8. Back-scattered electron image of sample 2. x500.

a)

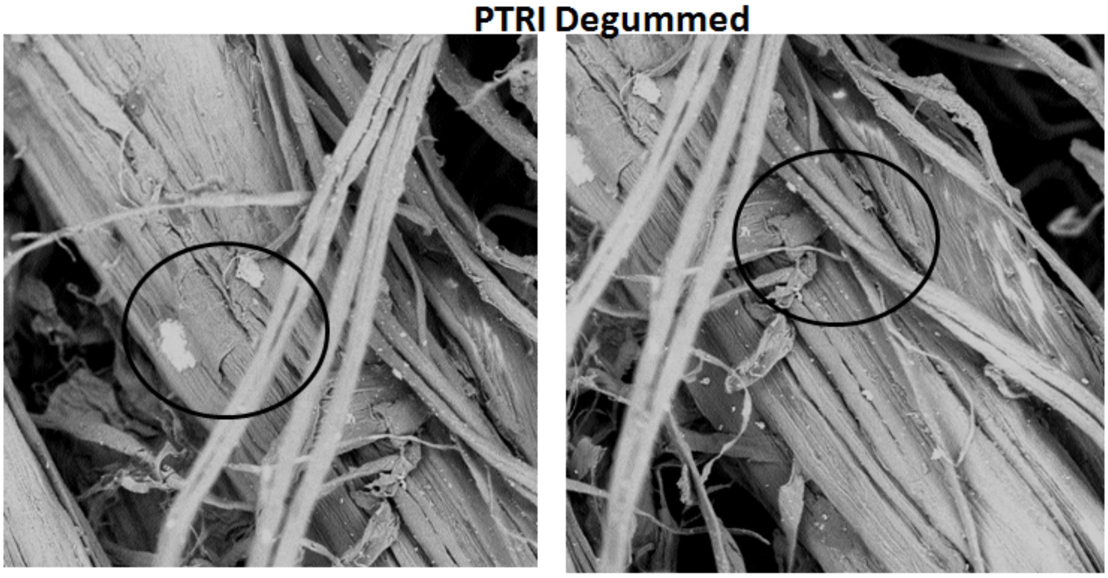


b)

Fig 3.56 a) Gummed PALF image, back-scattered electron image; b) Degummed PALF fibres, (NaOH), 2014

The focus of this research segment was to develop a sustainable formulation for degumming PALF. Enzymes are used to improve fibre separation, as may be seen from Fig 3.58 c), and enzyme degumming was performed in collaboration with Leitat Technological Centre in 2012. However, the company we are working with in the Philippines does not have the facilities to use this technology and have been using a sodium hydroxide formulation, (NaOH), (Fig 3.58, b) in collaboration with the Philippines Textile Research Institute in

Manila. Consequently, it was decided that we would develop an optimum standard sodium hydroxide degumming formulation to be used until our colleagues in the Philippines are in a position to put into practice the enzyme degumming processes developed. Furthermore, the degumming using standard formulation, (NaOH) was investigated and compared with sodium carbonate and sodium bicarbonate for optimum performance, as the manufacturer of the nonwoven substrate in the Philippines was having problems with 'dust' at the production



stage.[146]

Fig. 3.57 PALF fibres degummed by the Philippine Textile research Institute, Manila. Images courtesy of the Bio-composite Centre, Bangor University, 2014

(The solid white particulate (encircled) are present in the fibres degummed at the Textile Research Institute, Manila, using standard formulation NaOH)

[146] Conversation with the plant owner, Spring 2014. He reported what he called 'a white dust' that was blocking his machines in the manufacturing process.

Experimental procedures of Degummed PALF

Several degumming procedures were performed on PALF fibres. See table 3.17 for details.

Table 3.17 Chronological R&D degumming of PALF

Degumming process	**Collaborators**	**Methodology**	**Results**	**Date**
Enzyme degumming	Leitat Technological Centre, Barcelona	Four enzyme types have been used in order to determine the best degumming formulation	5 enzyme formulations developed	2012
Sodium Hydroxide (NaOH) Sodium Bicarbonate ($NaHCO_3$) Sodium Carbonate (Na_2CO_3)	Leitat Technological Centre, Barcelona; Bangor University Bio- composite Centre with Dr Kritika Kumar (Ananas Anam)	Traditional method using Sodium Hydroxide (three concentrations) Sodium bicarbonate Sodium carbonate	Optimum degumming formulation presently used in the making of Piñatex	2012 (Leitat) 2024 (Bangor)

Experimental procedures were carried out using standard enzyme solutions and sodium hydroxide (NaOH). Furthermore, sodium bicarbonate ($NaHCO_3$) and sodium carbonate (Na_2CO_3) were tried at various concentrations as a benchmark for establishing the optimum formulation for PALF degumming.

Microscopic inspection has been carried out on longitudinal sections of each PALF from both degumming methods, using transmitted light with a ZEISS Axioplan Microscope, the program DeltaPix 300 and an image magnification of x 12.5[147].

The fineness of the degummed fibres was measured as defined previously for PALF fibres in Fig 3.53.

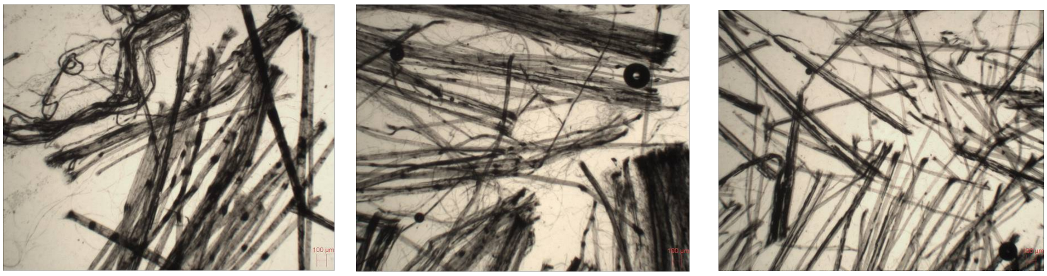
[147] Leitat Technological Centre, 2012

Tensile strength of the samples was carried out by means of INSTRON 5544 equipment, according to standard UNE EN ISO 5079:1996. The temperature and the humidity conditions for fibre preparation were 20.9ºC and 63 per cent, respectively[148].

Results and discussion of Degummed PALF

From the study carried out in Leitat using enzymes and sodium hydroxide, we can observe, (Fig 3.58, a) the presence of fibrils detached from the non-treated fibres, b) the highest quantity of detached fibrils in the NaOH treated, and c) the least amount of fibrils are detached in the enzyme-treated fibres.

The following images have been taken of each sample:



a) b) c)

Fig 3.58 Microscopic inspection of PALF, **a)** Non treated PALF, **b)** NaOH treatment, **c)** Enzyme treatment B11, Leitat Technological Center, 2012

In the enzyme degumming we observe only a small quantity of fibrils detached from the fibres. During the microscopic examination, it was observed that the main difference between the samples is the damage represented by the presence of filament (fibrils) detached from the fibres, with conventional sample showing the most quantity of fibrils.

Looking at Fig 3.59, a clear distinction can be made visually between the treated and untreated fibres, with colour change, texture and softness being noticeable to the naked eye.

[148] Leitat Technological Centre, 2012

Fig 3.59 Detail of PALF treated and untreated.
Left to right: untreated fibres, conventionally treated fibres, enzyme treated fibres.
From top to bottom: unbrushed fibres and brushed fibres. Leitat Technological Centre, 2012

As we can see on the images, non-treated and conventional samples have a yellowish colour. Enzymatic treatment improved the aspect of the fibres, giving them a whiter colour. All fibres (conventional and enzymatic process) present a rough touch after treatment, as the treatments eliminate the waxes and other components on the surface of the fibres, which provide them a soft touch. After the opening (brushing) process however, the fibres become softer than before, without using any softening agent.

Table 3.17 shows the obtained fineness of the fibres before and after degumming. We can observe a high coefficient of variation in the values, which is due to irregularities in the fineness of the fibres.

Conventional samples present the best results, i.e. the finest results and the lowest coefficient of variation. These results show that conventional process is more efficient in separating the fibres although it also damages them as was seen in Fig 3.59, middle image top.

Table 3.17 PALF fineness measurements. Leitat. (2012)

Sample	Average fineness (µm)	Minimum fineness (µm)	Maximum fineness (µm)	CV (%)	Average fibre title (dTex)
Not treated	**75**	21	393	59.8	**68 =61D**
B11	**80**	29	597	84.6	**78=70D**
Conventional	**60**	28	150	33.3	**43=38.7D**

Note: B11: Enzyme degumming; Conventional: Sodium Hydroxide (NaOH)
dTex, linear density: mass of yarn in gms per 10,000 metres length.
Conversion of dTex to denier is: 68 dTex = 61 D; 78 dTex =70D; 43 dTex =38.7D

Observation:

If we compare this data with the data of Table 3.16, it can be seen that my non-treated and treated finest values are greater than those quoted for pineapple. This could be because I do not know the variety of pineapple plant used in the previous work and fineness may depend on plant species.

The results of the tensile strength tests carried out are presented in the table below.

Table 3.18 PALF tensile strength and elongation at break. Leitat Technological Center. (2012)

	Strength (cN)	CV of strength (%)	Extension at break (%)	CV of extension at break (%)	Tensile strength (cN/Tex)
Not treated	111.56	44.72	3.62	51.44	16.41
Conventional	154.76	21.82	4.21	36.09	35.99
Enzyme B11	127.39	32.24	3.45	21.52	16.33

Notes: Tex= mass of yarn in gm/metre length
cN/Tex =centi Newton/Tex
cN/Tex= tenacity= 1000xbreaking Force (N) divided by linear density (dTex)

We can observe that conventional samples present the best results, followed by non- treated and B11 samples. These strength values are in units of force and if converted to units of stress the following values are attained:

- Non-treated PALF 252.4 MPa
- Enzyme B11 233.3MPa
- Conventional 546.9MPa[149]

i.e. Converting to stress values has emphasised the better performance of conventionally treated fibres.

Non-treated samples should have the highest tensile strength, as any added chemicals are likely to weaken the fibre. However, conventional samples gave better results than non-treated samples. This may be due to the presence of fibrils which may adhere to the fibres, increasing the coefficient of friction and thus adding more strength to the fibre (as we saw in microscopic inspection, fibrils are present in a greater quantity in this sample). Furthermore, the tensile strength of conventional samples may also be increased by the presence of NaOH, (during the mercerisation process of cotton, the addition of more than 23% of NaOH can increase the tensile strength of the fibre.[150]

Conclusion of Degummed PALF

The aim of degumming is to remove natural impurities and the lignin component of the fibre, so that it becomes flexible and clean. In the making of the product Piñatex, degumming is needed to make sure that the fibre can withstand the severe needle punching process and bending needed to develop a nonwoven mesh.

It has been the aim of this research to look for the most environmentally-friendly practices available to use throughout the life cycle of Piñatex. For this reason an enzyme degumming process specifically for PALF was developed. However this degumming formulation has been developed at laboratory stage and it will only be up scaled when Ananas Anam and our collaborators in the Philippines are in a position to do so, and if it proves to be the optimum solution for use in the industrial processes.

The examination and study of PALF degumming has demonstrated that:

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[149] Calculations given to me by Rees Rawlings, July 2014

[150] Conversation with researchers at Leitat Technological Centre, 2013

Conventional treatment increases the number of fibrils, which may contribute to the increased tensile strength.

The enzymatic results vary depending on specific formulations for different fibre applications and requirements. We can have a) high length of fibres, suitable for yarns, or b) fineness and tensile strength, the latter being the qualities we are looking for in the making of a non-woven substrate.

On the basis of this exploration and practical work carried out, the following assumptions can be made:

If the fibres are not well cleaned from their impurities, the nonwoven machine gets clogged up and production needs to be interrupted to clean the machine.

For this purpose a new formulation using NaOH has been developed at laboratory stage (2014), which shows no solid impurities when looked under the SEM microscope, with fibres being cleaner than the results achieved using sodium bicarbonate and sodium carbonate.

The research also showed that the white dust particles shown in Figure 3.56 could be caused by the use of a high percentage of NaOH and a lack of thorough washing after degumming. The use of 1% acetic acid solution in the last rinse during the research carried out seemed to have cleared up this problem.

3.7.3 Nonwoven PALF substrate

PALF nonwoven substrate is the result of a mechanical action carried out at nonwoven industrial level. For reasons of IP, the full results of this research will not be presented.

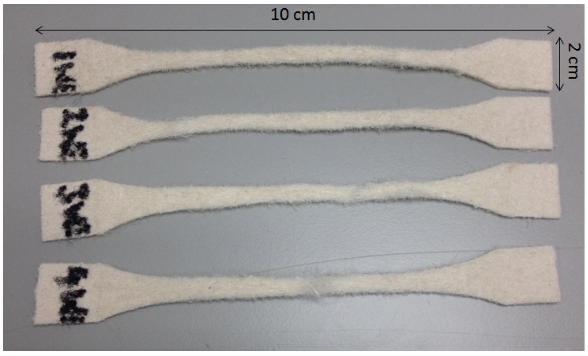
In the development of Piñatex various substrate compositions were developed and studied in an attempt to arrive at an optimum density, strength and weight, using from 100% PALF to a mix of PALF and man-made fibres from petroleum to organic sources. This research has been concentrated on two substrates, namely NW01 and NW04, using the same weight and density of mesh but different compositions.

Experimental procedure of nonwoven PALF substrate

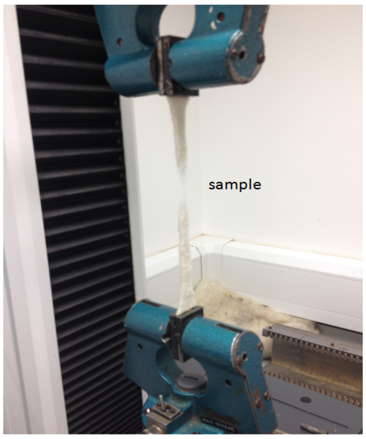
Systematic microscopic examination of PALF substrate has been performed to fully understand the physical layout of the fibres in the substrate. This is key to understanding the production processes and the mechanical performance in order to adapt the substrate not only to the market requirements but also to the present available manufacturing processes. Extensive SEM studies were undertaken to understand the direction and evenness of the fibres. Part of these research was carried out in co-operation with the Northampton University Leather Technology Centre (2013).

Tensile and tear strength tests were carried out at different stages and for different substrates to determine the optimum formulation for the final product, Piñatex. Tensile tests were carried out on two kinds of substrate, namely NW01 and NW04, (presently being used in the making of Piñatex) and a comparison was made between the two.

The samples for testing were cut into a dog-bone shape from both the warp and the weft direction of the substrate (Fig 3.60). The tensile tests were carried on four samples each, warp & weft from both NW01 & NW04. Therefore, in total 16 samples were tested. Figure 3.60 a) shows the photographs of the prepared samples left overnight to condition at 20^{o}C & 65 per cent humidity. The machine used for tensile testing of the specimen was a Universal testing machine, shown below.



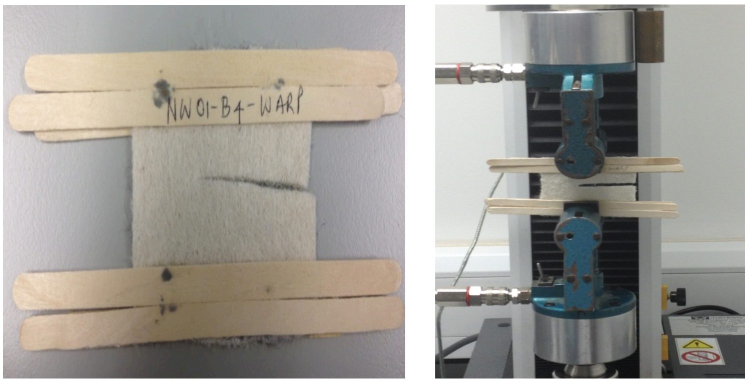
a)



b)

Fig. 3.60 a) Photograph of the sample prepared for tensile testing:
b) Universal testing machine in operation for tensile tests.

Tear strength measurement is one of the most crucial tests for investigating the performance of any material. Figure 3.61 a) shows the prepared samples for tear strength left overnight to condition at 20C & 65 per cent humidity. The samples for tear testing were 7cm x 4 cm. The substrate was cut warp & weft, using four samples each from both the directions in NW 01 & NW 04, with a total of 16 samples used for testing.



a) b)

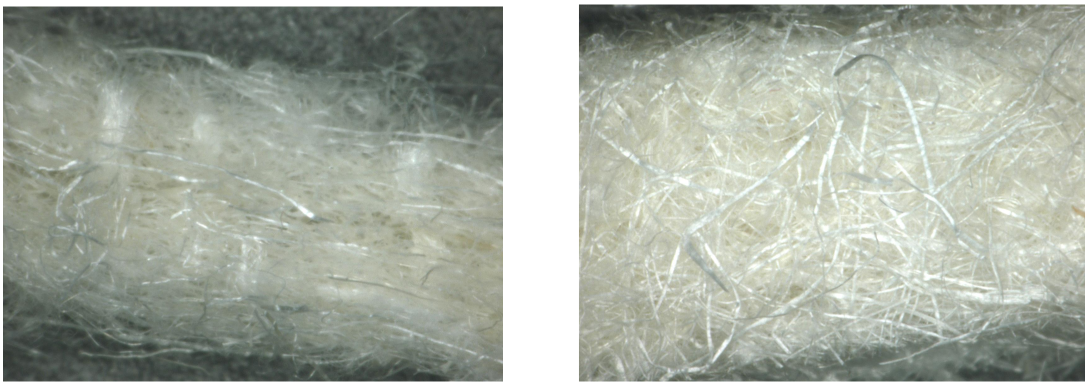
Fig. 3.61 a) Substrate sample prepared for tear testing **b)** Universal testing machine in operation for tear tests.

Finally, composting and UV degradations tests were carried out to assess the life expectancy of the material (in section 3.7.4).

This research was carried out in the Biochemistry Department, Bangor University (Spring 2014).

Results and discussions of nonwoven PALF substrate

SEM studies were carried out on the substrate, both from the cross-section (lateral view) and the top section (dorsal view). From the former view we can observe that the substrate is composed of layers of fibres. The dorsal view shows the variation of fibre width, with the thick ones, more solid, being inclined to be in one direction, while the fibrils seem to be in more than one direction (see Fig 3.62 b). This mix brings about a more multidirectional layout, with the thicker fibres being laid less randomly than the thin/fibrils, which take a more prominent and important role, this being needed to develop a strong mesh. The right mix may be that, for a good and solid non-woven mesh we will need the right amount of fibrils for entanglement and the right amount of thicker fibres for strength.



a) Cross lateral view b) Dorsal top view

Fig 3.62 a & b PALF substrate detail cross and dorsal, 2013

The load-extension curves below show the results of tensile tests performed in the two substrates, NW 01 and NW 02, in sets of four in both warp and weft directions.

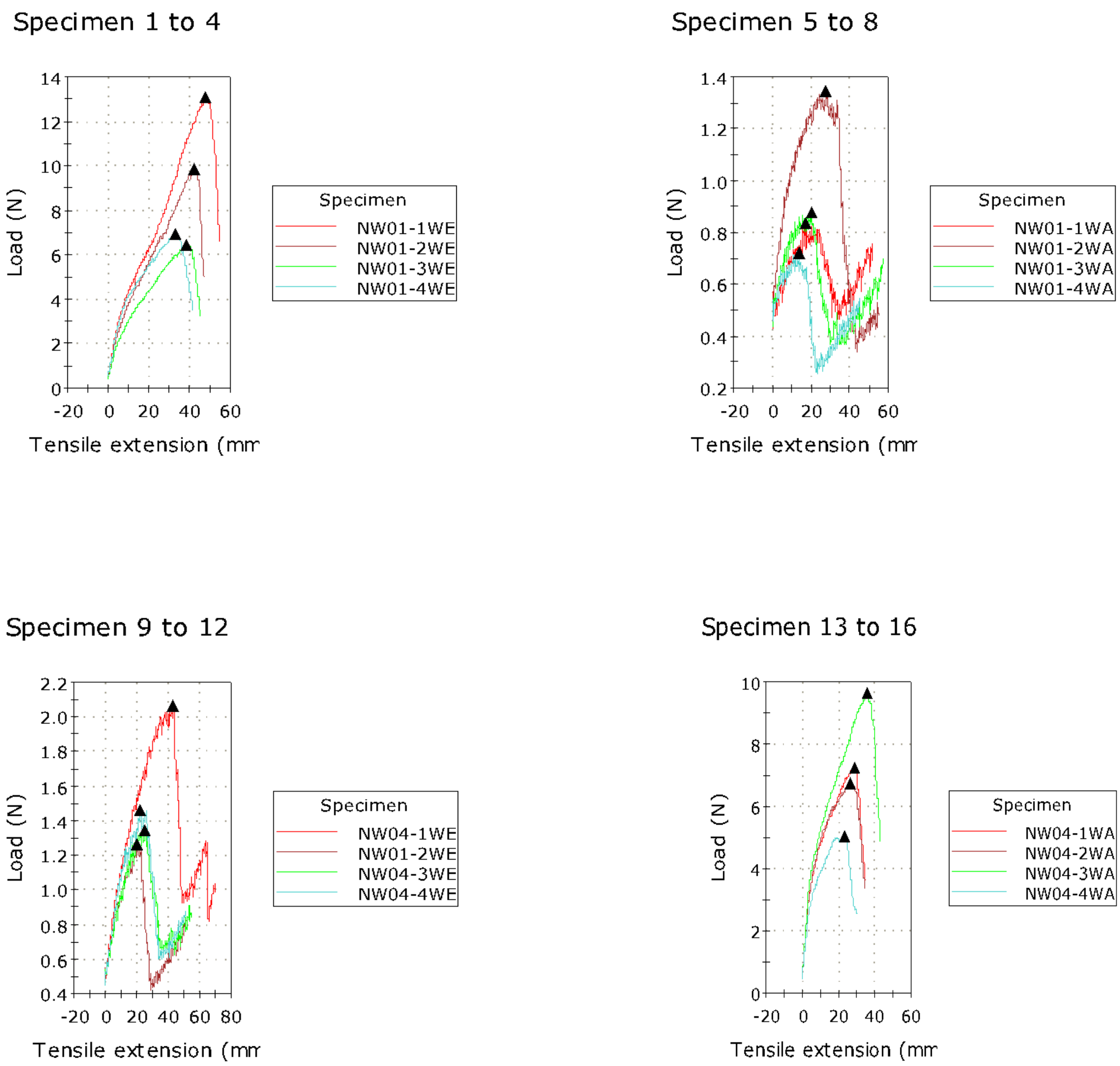


Fig 3.63 Load extension curves NW01 and NW04. Bangor University Bio-Composite Centre, 2014

WE=weft and WA= warp

The load-extension curves for samples NW01 in the warp direction exhibits a maximum, the load then fell before rising slightly at higher extensions. The same samples in the weft direction did not show a rise in stress after the fall from the maximum load.

The load-extension curves for samples NW04 were the opposite, i.e those for the weft direction had a small rise in load after the fall from the maximum, where the curves for the warp direction shows a single maximum.

The data from the plots is tabulated below and the average values calculated from the four readings. (Explanation based on discussions with Rees Rawlings, July 2014)

Table 3.19 Tensile strength of nonwoven substrates NW01 and NW04 warp & weft. Bangor University Bio Composite Center, 2014

Specimen label	Average value of Maximum Load (N)	Average Extension at Maximum Load (mm)	Average Area (cm^2)	Average Tensile stress at Maximum Load (MPa)	Average Tensile strain at Maximum Load(mm/mm)
NW 01 warp	9.08	42.38	0.23	0.38	0.56
NW 01 weft	0.94	27.25	0.23	0.04	0.25
NW 04 warp	7.18	30.49	0.23	0.31	0.40

(Note: NW 04 weft value not available at this point of the research)

Tear strength measurement is one of the most crucial tests for investigating the performance of any material. Below is the final table of the results of tear strength carried out on substrates NW01 and NW04.

Table 3.20 Tear strength of nonwoven substrate NW01 & NW04. Bangor University Bio Composite Center, 2014

Product Code	**Tear Strength**	
	Newtons (N) **Warp - Weft**	**Kilogram force (Kgf)**
NW01 substrate	69.17 - 40	7.05
NW04 Substrate	118 - 33	12.064

If we compare these results, with the results given in table 3.21, which is the tensile strength needed for textile uppers (the body of shoe, not including the sole) from the shoe industry, we can see that even before we start processing the nonwoven substrate we have achieved a very good tear strength, particularly for NW04, which is the substrate presently used in the making of Piñatex.

Table 3.21 Upper fabric requirements (market tests) provided by the shoe industry, 2014

Property	Test No.	High Risk	Commercial Risk	Satisfactory
Tear strength	132	Any result below 17.65 N	Two or more results: 17.65 – 33.32 N	All results =>33.32 N OR: one result: 17.65-33.32 N

Based on these findings we can conclude that the mix and weight of PALF substrate is the optimum for the final product, Piñatex, and that the layering of the fibres in multidimensional way achieves the required properties. However the weft is the weakest link and needs to be looked at in more depth.

Conclusion of nonwoven PALF substrate

On the basis of the exploration and research carried out in the PALF substrate I can conclude that NW01, and particularly NW04, has achieved the desired tensile strength, density and weight needed to make it the optimum base for Piñatex, based on the technical specifications given by the market for textile upper (shoes).

The tear strength results of table 3.20 show that both NW 01 and NW 04 are anisotropic with NW01 being less anisotropic. Table 3.19 is incomplete (weft value) so I cannot assess anisotropy readily. However looking at the load extension curves I would estimate that the tensile strength values will show both to be anisotropic, but this time NW04 to be less anisotropic. So as far as anisotropy is concerned, the results show both substrates are anisotropic and it is not possible to say one substrate is more anisotropic than the other as it depends on the parameter being measured.

Furthermore, the tear strength and the tensile strength data clearly demonstrates both substrates to be anisotropic.[151]

3.7.4 Soil composting of PALF substrate and Piñatex

This investigation has been carried out at Bangor University Bio-Composite Centre, as a follow-up investigation of the previous tests carried out, based on an interest from all parties involved in this research into the possible deterioration of Piñatex to light and its final disposal as a compostable material.

Soil composting and UV-degradation tests were performed on both the nonwoven substrate and some of the Piñatex finished samples. Furthermore, UV light tests were carried out in Piñatex and PALF substrate on a number of samples to determine its level of resistance to light.

Experimental procedure of PALF substrate and Piñatex

<u>Soil Composting Test</u>: A number of Piñatex finished samples (shown in figure 3.64-a) were selected for soil composting. These were cut to have a minimum of 8cm in length and no less than 1cm in width.

a) b)

Fig. 3.64 a) Nonwoven and Piñatex samples selected for soil testing; **b)** Soil box holding the samples. Bangor University Bio-Composite Centre, 2014

[151] Exhibiting properties with different values when measured in different directions

The soil boxes were filled using John Innes No 2, potting-on compost. The fabrics were weighed (in an air-dried state) and placed into 2 soil boxes, (Fig 3.64-b). The weights of the assembled boxes were recorded at the start of the test. During the full process, the boxes were weighed twice a week, and if it indicated a loss of weight, water was added to return to the initial set weight; this controls the soil moisture content throughout the test.

After 12 weeks, the soil was removed and the fabric samples were revealed (Fig. 3.65 a) and b).

a)

b)

Fig 3.65 a) & b). Soil boxes after 12 weeks. Bangor University Bio-Composite Centre, 2014

Each sample was weighed and placed into a 50°C oven to dry overnight. Prior to removing any remaining soil off the samples, the samples were weighed. The remaining soil was then removed and reweighed.

UV-degradation tests were performed on both the nonwoven substrate and the Piñatex finished samples.

Samples were exposed to UV-irradiation for 20 hours and 40 hours in total. This used method BS EN ISO 105-B02, where a fixed period of irradiance under xenon lamp is permitted. The colour change was measured relative to the colour of the sample prior to weathering. In both cases colour change was negligible.

Results and discussions of PALF substrate and Piñatex

PALF non-woven fabrics can be degraded during a soil bed test. Several samples lost sufficient mass to indicate that some biodegradation occurred.

PALF non-woven impregnated with latex showed physical changes, which indicate microbial activity; however, indicative weight data were contradictory.

It should be taken into consideration that this experiment was run as a demonstration not as a fully controlled experiment. Further testing using a more robust sampling strategy would be required to confirm action on the fibre or on the latex component.

Samples of dyed and finished Piñatex also showed signs of microbial action; however, there was little sign of colour change. This indicates good dye or print stability within the product. Some samples left coloured patches in the soil bed, indicating that despite no colour change being seen in the sample, some pigment had been leached.

The results were encouraging, as all samples had considerable integrity and strength at the end of the 12-week exposure test. A longer exposure period could be considered for future test studies.

Table below demonstrates that there are negligible changes over the time period of the experiment.

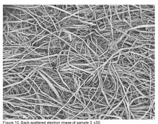
Standard Name	**Standard CIE L**
NW 01	85.74
NW 01-20 hours	85.25
NW 01-40 hours	85.92
NW 04	87.07
NW 01-20 hours	87.41
NW 01-40 hours	87.78
Standard Name	**Standard CIE L**

Two finished Piñatex samples were also exposed to the UV light for 20 hour and 40 hour period. The colour change in this case was also negligible.

Conclusion of 3.7

These preliminary tests have demonstrated that the nonwoven substrate and finished Piñatex was unaffected after being exposed to UV light for 40 hours, and showed negligible biodegradation after a 12 week exposure test; however, a longer exposure period would be advisable. Based on the above, we can conclude that both the substrate and the final product have an acceptable resistance to both soil and UV light.

3.8 The textile world of nonwovens

 [152]

In this section I will be looking into the general characteristics of the nonwoven industry: the products that are made using this textile process and the technologies used.

Reflective Practice

The first time I heard about nonwovens was when I was working with the Design Centre Philippines in Manila. As I delved further into indigenous fibres of the Philippines, I become aware of the fineness and strength of PALF. With the idea already mentioned in Chapter 3.1, *Would it be possible to make a mesh with these pineapple fibres to develop a material to use as an alternative to leather?,* I went to see the owner of Nonwoven Fabrics Philippines Inc., a nonwoven company based in Manila, and posed the question to him. He said my idea was appropriate for development using nonwoven technology and that he would help me out. Little did I know that this simple question and this first meeting opened the door into a new direction for my work: from being involved with woven textiles and in particularly hand-woven textiles, I slowly shifted into the world of natural nonwovens.

The nonwoven factory fascinated me, this was no workshop with handlooms as I was used to working and seeing in the Philippines. This was a cavernous place with huge clunking machines, the biggest I had ever seen. They were not making any nonwovens with natural fibres; the factory makes polyester and polypropylene nonwovens, mainly for the car industry. However, the owner took my idea seriously and we started to develop a mesh using pineapple leaf fibres.

From this simple question and humble beginnings eight years ago, Nonwoven Fabrics Philippines has been behind my ideas all along. Together we started to develop the nonwoven substrate; in our first trials we made a substrate, which was too loose and difficult to work with, with not much body and substance. Slowly we got it more even, stronger and

[152] PALF nonwoven substrate, top view, showing the multidirectional layering of PALF.
Photo courtesy of the Institute of Materials Minerals and Metals (IoM3), (2013)

more dense, going from a mixture of PALF to a mix of man-made and organic fibres which has produced a substrate with good strength and evenness, using different weights of constituents.

There is significant work involved in the development of PALF substrate. In order to do this work the factory needs to stop its standard production, clean the machines and adapt and adjust the processes to using pineapple fibres. At the end, the new material comes out of what looks like an endless tunnel, transformed into what to us is a beautiful piece of work, 'our' substrate material.

It is my hope that my simple primary question and our shared vision in the Philippines, will materialize in the near future into a new industry, bringing jobs and an income both to the farming and the industrial community.

What is a nonwoven fabric?

A nonwoven is a fabric made directly from a web of fibre without the yarn preparation for knitting or weaving. In a nonwoven the assembly of textile fibres is held together 1) by mechanically interlocking a web or mat; 2) by fusing of the fibres as thermoplastic fibres or 3) by bonding with a medium such as bio-resin or synthetic resin, latex, starch, casein.[153] The fibres may be oriented in one direction or may be deposited in a random manner. This web is then bonded together by one of the methods describes above.[154]

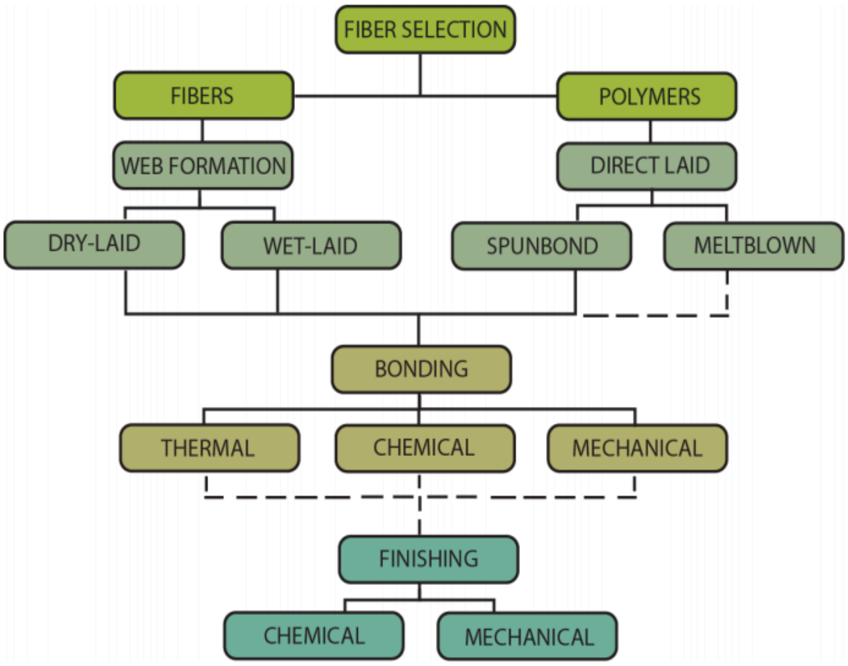
The basic steps to a nonwoven material are:

- Raw material (fibre or raw polymer) selection and preparation
- Web formation
- Web consolidation and bonding
- Finishing

[153] A protein found in milk and milk products

[154] Association of the Nonwoven Fabrics Industry, (INDA), 2010 available from http://www.inda.org/about-nonwovens/ (accessed February 2014)

Table 3.22 Typical non woven manufacturing process. The Nonwovens Institute. (2010)



Furthermore, nonwovens are engineered fabrics manufactured by high-speed, lower cost processes than traditional processes in the woven textile world.

The nonwoven industry is quite new, starting in the USA in the 1950s and 1960s, its products initially being used in the manufacturing of single-use, disposable products such as wipes and nappies. Today nonwovens are highly engineered, and are made up of a variety of materials including fibres, powders, adhesives, films and other materials that provide specific solutions to a multitude of functionalities such as interlinings, geotextiles, carpet backing, automotive parts, filters and wipes (See Fig 3.66).

Fig 3.66 Selection of nonwoven products. The Nonwovens Institute, 2010

Market segments, product applications and demand

The world of nonwovens is a fast-expanding market. According to a study by Smithers Apex,[155] a global business market research company, the global nonwoven market is projected to reach $40.1 billion by 2015, with a CAGR[156] of 8.5 per cent from a $26.7 billion 2010 base. Driving this figure is the high-growth Asian market.

According to Smithers, disposable nonwovens lead the way in market share with a value of 38.8 per cent of the total market value, with polypropylene polymer being by far the largest single raw material used in nonwovens, accounting for 37.3 per cent of all raw materials for nonwovens.

We can observe that the use of natural fibres in the nonwoven industry is still minimal, according to the chart in Fig 3.67.

[155] *The Future of Nonwovens to 2015: Global Market Forecasts*, IntertechPIRA, 2010

[156] Compound annual growth rate

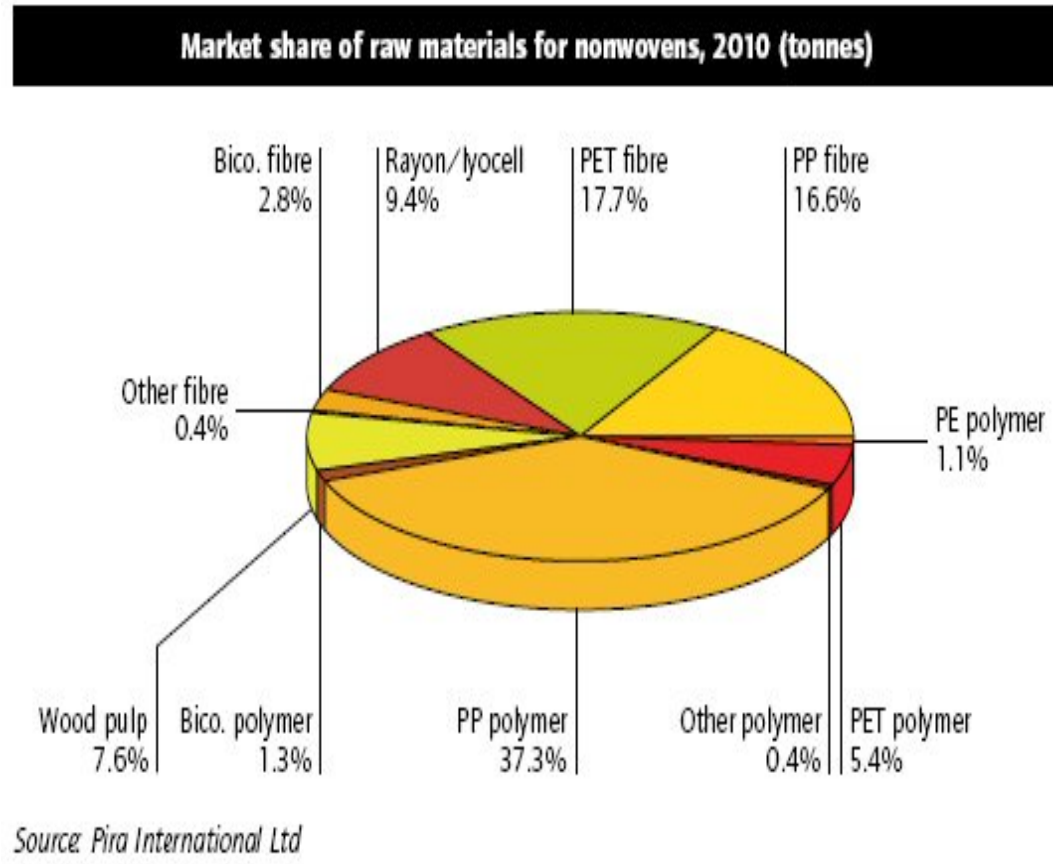


Fig 3.67 Market share of raw materials used in nonwovens. Sustainable Nonwovens, 2014

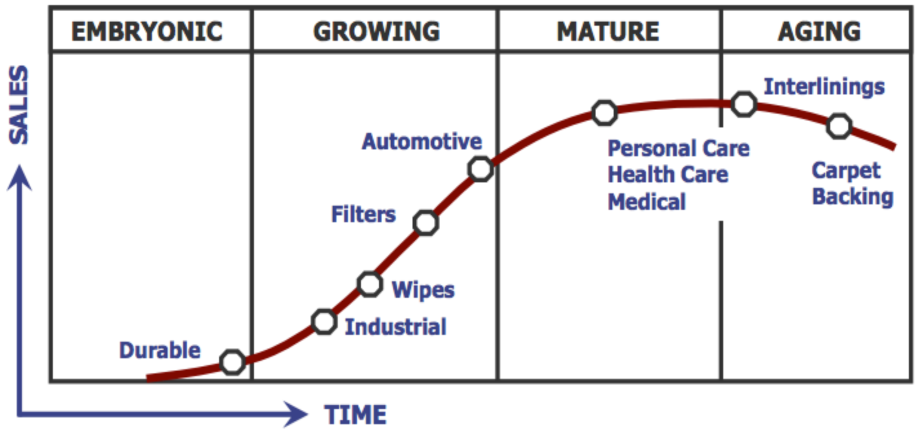
Product applications

Demand for nonwovens is forecast to continue to rise, with disposable markets continuing to grow, representing 68 per cent of nonwoven demand by 2016 (Table 3.23 - a). It is worth noting that according to Corinne Gangloff ,[157] the use of nonwovens for high-performance applications is a growing area and one with high returns, with niche markets such as aircraft seating becoming increasingly important due to the weight-saving advantages, this being an intrinsic quality of this versatile material.

[157] Corinne Gangloff, US Nonwovens Fabric Demand, *Indian Technical Textile Association Journal*, 7 1March 2013, p.8 Available from http://www.ittaindia.org/control/include/subject_pdf/9536-March%20E-Bulletin.pdf

(accessed August 2013)

Table 3. 23 (a) Nonwoven product applications. The Nonwovens Institute, 2010



Furthermore, according to the Nonwoven Fabric Industry (INDA), durable nonwoven markets such as geotextiles and the construction and automobile industries are growing at a rate of 4.5 per cent annually and will outpace the disposable market segment by 2016 (INDA 2011). In the chart below I have included Piñatex and its substrate Piñafelt as added products in the nonwoven world. For example it is envisaged that both Piñatex and Piñafelt would have applications in the automotive field, fashion and possibly medical textiles, amongst other fields. See Table 3.23 (b).

Table 3.23 (b) Nonwoven product applications and potential Piñatex niches in the nonwoven world

Automotive	Fashion	Construction	Medical	Personal and house hygiene
Interlining Laminates Composites **Piñatex** ***Piñafelt**	Interlinings Insoles Reinforcing Backing **Piñatex**	Roofing Insulation Soundproof	Surgical gowns Masks Drapes and covers Packaging Plasters, etc **Piñafelt, PALF yarn** (future research)	Diapers Adult incontinence Personal Wipes Household wipes

Insulation	Geotextiles	Interiors	Filters
Thermal Acoustic **Piñatex**	Soil stabilizers Erosion control Drainage systems Frost protection Agriculture mulch Water barrier Foundation stabilizers	Upholstery Padding Wall covering Panelling Carpet backing and carpets **Piñatex**	Gasoline Oil Air Vacuum bags Water Coffee and tea Bags Mineral processing **Piñafelt**

∗Piñafelt is the name given to the first stage of Piñatex as a nonwoven substrate.

Summary and conclusions of 3.8

We can see that the nonwoven field is a fast-growing industry, with great potential extended over several different markets. Extensive R&D is being carried out to further this potential, especially in some key markets such as the automotive industry, medical and health care. We can observe that most of the nonwovens in industry are not used by themselves but as components, usually in hidden form (e.g. linings inside jackets).

Furthermore, on the basis of this exploration and research into nonwovens I can conclude that the materials developed in this research, Piñatex and Piñafelt, have a place in some of the markets studied, being used as nonwoven textile material in their own right, and not as a component, with potential for growth into several markets, some of them as yet untapped, as per Table 3.23 b).

3.9 Piñatex Production

> I seem to remember that you wanted to position this material against leather, which I would oppose. Leather is a good, albeit misunderstood material and talking leather down will prove to be a mistake. However, leather will be increasingly scarce and expensive, so there will be a need for additional materials. At the moment these are mostly coming from fossil fuels via plastics.
>
> So if I were you, I would be promoting your material on its own merits and trying to find routes for both its utility and its emotional qualities[158].

This section is the culmination of all the research work carried out in this PhD, which results in Piñatex™ as a newly developed nonwoven textile. However, its development will be dealt in a general manner for IP reasons, which now belong to my company Ananas Anam. I will be explaining the production processes from the agricultural section to the industrial manufacturing and the final product. Key attributes and applications will be looked at, and finally the development of a collection of first samples, which are being used to launch Piñatex in the marketplace (April 2014).

Reflective practice

Piñatex was born out of teamwork, sensorial experiences, human experiences and a close and deep respect for nature. Nature is the common denominator in all. The inspiration is rooted in nature, 'steeled' so to speak by science and C2C design inspiration. It is then interwoven into a rich tapestry, which includes people, places, and experiences.

[158] Conversation with Dr Mike Redwood, leather technology expert, RCA, Feb 2013

The creative side of Piñatex, key to this project, is another story, which presently has very little space to grow and expand (mid 2014). As this project has become a start-up company (Ananas Anam UK Ltd) there is not much time left for thinking creatively at present. To me, a lot of things come about when I allow space for thinking creatively, or rather 'not-thinking', not allowing the outside world to push my boundaries and take possession of my mind. A great luxury to have and make this space, particularly at this moment of Piñatex's development.

This creative space/not-thinking may not materialize into anything 'real' but it does bring me into a place where 'things' real or otherwise have a safe haven to become and be born. I do hope that both processes, team work effort and the more personal creative effort, may one day find a balance to feed into each other and grow more steadily.

The product

Piñatex™ is a natural and versatile material which can be used as a textile or as a leather alternative in the fashion, accessory and upholstery markets; it can be mass-produced, which makes it a cost-effective textile proposition.

Piñatex is produced from the fibres of pineapple leaves. The leaves are a by-product of the pineapple harvest. Piñatex™ uses a patented technology which protects both the process and the finished material.

The production

The production of Piñatex starts at the farm with the gathering of the leaves, which is carried out by designated farming cooperatives. All aspects of the pineapple harvest are already geared to the food crop; the leaves are the by-product of the fruit harvest and therefore require no additional land, water, fertilizers or pesticides.

The substrate production goes from decortication of PALF fibres to the nonwoven manufacturing. The by-product of decortication is bio-mass, which could be further converted into organic fertilizers and/or bio-gas. This is followed by the degumming of PALF and the consequent making of a nonwoven mesh or substrate (with grammage and composition varying depending on the final product specifications and market demands), to finally being made into a versatile material, using specific coatings to meet the market requirements (Fig 3.68).

Fig 3.68 Piñatex manufacturing processes, from the field to the final product. Ananas Anam, 2014

The Cradle to Cradle approach

The development of Piñatex is inspired by the Cradle-to-Cradle design principles, (See Chapter Two, 2.2&2.3) which support ecological, intelligent and innovative design within today's economic environment. Designs that evolve as a result of the interdependence between their elements and the natural world, recognizing and taking into account the consequential effects of such designs.[159] These principles are being used as inspiration throughout the production processes and the product design and development, with the intention to be put into practice as the project develops and becomes commercially viable.

The evolution of Piñatex thus is the result of the interdependence of several resources and processes along its life cycle (see Fig 3.68), from the farm to the products made, to the final disposal of these products. Such processes are thought through and designed taking into account their consequential effects in the natural world and society.

[159] McDonough and Braungart, 2002

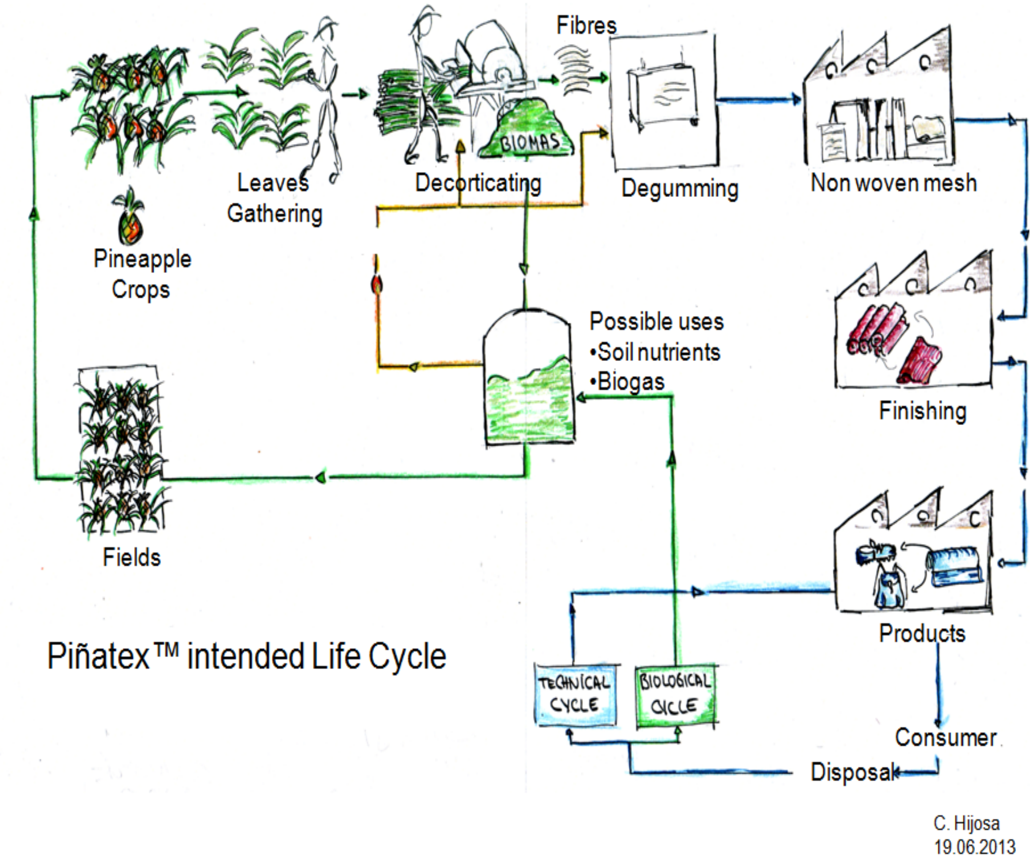


Fig 3.69 Piñatex intended life cycle. Hijosa C., 2013

Key attributes and applications

Piñatex™ *is a compelling new material, branded, natural, stylish and innovative, combining environmental and social principles along with providing good value for money to its users* (Ananas Anam 2014). The key attributes of Piñatex are summarised in the table 3.24.

Table 3.24 Piñatex key attributes. Ananas Anam. Courtesy of Bruno de Penanster. (2014)

Key attributes

Outstanding performance	• Piñatex characteristics: breathable and soft, light and flexible, mouldable and easily dyed, can be printed on and laser cut • Fully tested for clients specifications. (e.g. tear strength, etc.)
Natural and sustainable	• Fibre requiring no extra water for its growing • Inspired by *Cradle-to-Cradle principles®
Versatile and mass-produced	• Various thicknesses, finishes, and applications • Roll-to-roll production on widely available machinery 
Cost effective and flexible offer	• Produced at a fraction of the leather manufacturing cost • Comprehensive range of commercial products (fibre, mesh, off-the-shelf finished product, tailor-made solutions)
Patented	• Process and finished product patented • Geographies: EU, USA, Japan, China, India, the Philippines

www.pinatex.com *Cradle to Cradle® is a trademark of McDonough Braungart Design Chemistry, LLC. piñatex

Furthermore, Piñatex has been tested according to market standards for shoes, bags and furnishing, as represented in the table below.

Table 3.25 Piñatex technical data. Ananas Anam, 2014

Piñatex technical data

Technical Spec.	Thickness (mm)	Weight (gpsm)	Tear Strength* (N)		Tensile* Strength (N)		Seam Rupture* (N)		Light Fastness**	Abrasion *** (rubs/ cycles)
			warp	weft	warp	weft	warp	weft		
Piñatex	1.2-3.0	200-600	132.7	108.3	629.5	290.3	513.4	194.4	Negligible change in colour after 40 hrs UV light exposure	Slight wear/ colour contrast after 25,600 revs.

Piñatex technical data for 1st lab sample from **Bonditex-Bagahe 01-tungug (refer catalogue)**

* tests conducted at Bonditex S.L., Barcelona (2014)

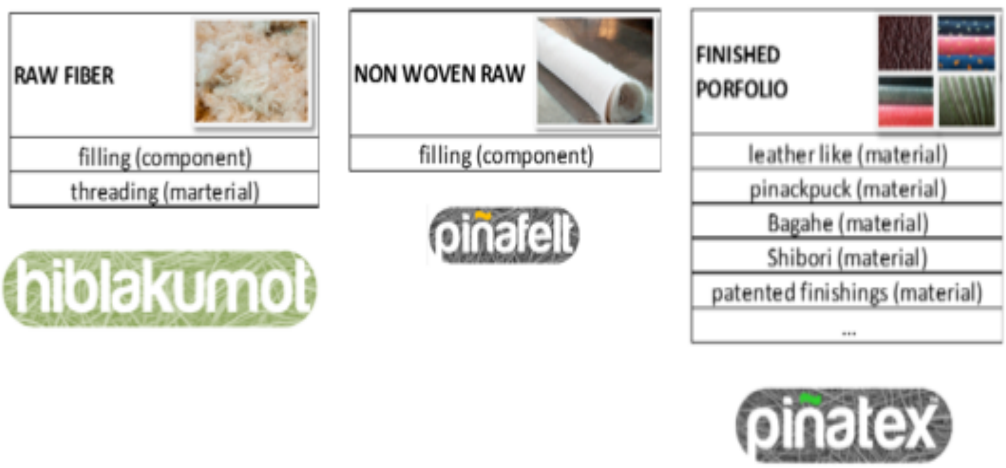
**test conducted-fabric's resistance to fading when exposed to UV light (AATCC 16A Option 1 or 3, Class 4 minimum at 40 hours) at The Bio Composite Centre, Bangor University, 2014

*** test conducted-martindale abrasion (DIN EN 13520) at Intertek Testing Services, Centre Court, Meridian Business Park, Leicester, LE19 1WD, UK

Product applications

Technical and market research have shown the scope of pineapple fibres, first as a yarn in itself or blended with other fibres, second as a nonwoven substrate and finally as a finished product. The different stages of the product development have been presented to different market segments with some of them showing interest in using it and collaborating with its further development. The table below shows the three segments.

Table 3.26 PALF product development scope and market segments. Ananas Anam, 2014



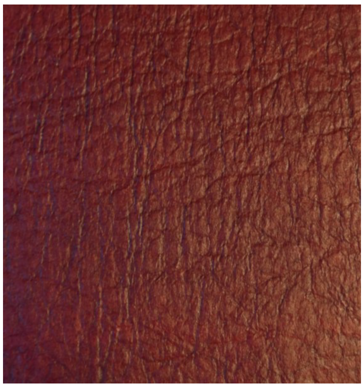
The Piñatex collection

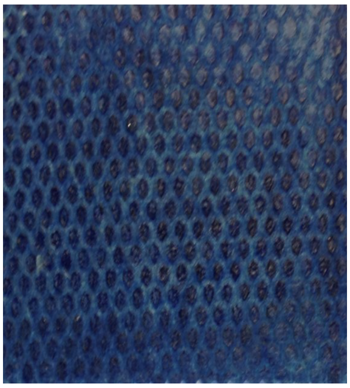
I have divided the research of Piñatex into collections, based on the physical properties and particularly on the aesthetics attributes achieved. At present (April 2014) three collections have been made.

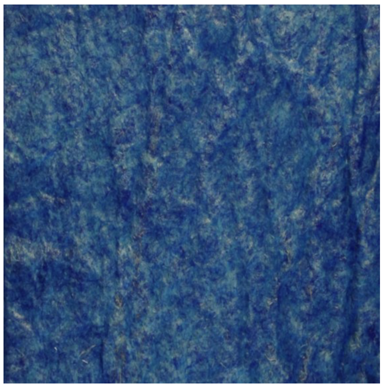
Bagahe Collection

The Bagahe Collection[160] was the first collection (2012-2013), when the creation of a leather alternative finish was the aim. It shows the experimental work with different textures and finishes, based on achieving a strong and durable finish. These are laboratory tests, some of them finished with my own techniques to achieve the desired qualities, others in collaboration with Bonditex S.L. and Leitat Technological Centre in Spain.

[160] Bagahe means travel goods in Tagalog, language of the Philippines.







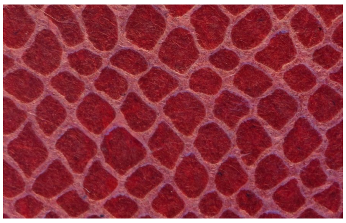
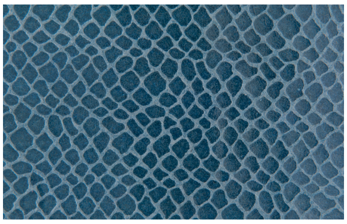
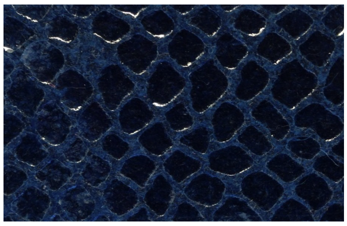
Bagahe 01 Bagahe 03 Bagahe 04

Bagahe 05 Bagahe 06

Fig 3.70 Piñatex first collection.
Bagahe 01, developed by the author in collaboration with Bonditex, 2009;
Bagahe 03 in collaboration with Leitat, 2012;
Bagahe 04, 05, 06 in collaboration with Leitat, 2012-2013)

Bagahe Collection: Transfers

The Bagahe Collection came about while doing research with the Northampton Leather Technology Centre, and experimenting with transfers used in the leather industry, Fig 3.71.

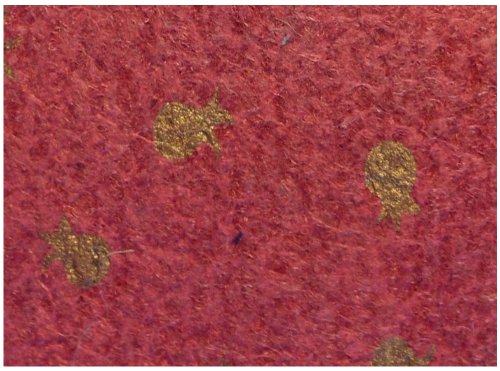
  

Bagahe 08 Bagahe 09 Bagahe 10

Fig 3.71 Bagahe Collection. Hijosa C., Stuart Booth, 2013

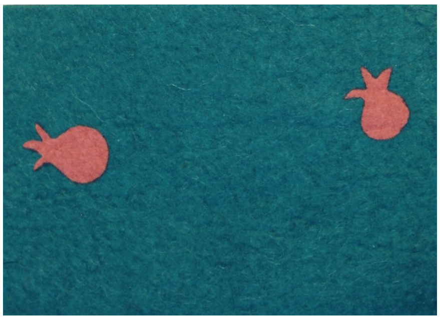
Pinackpuck Collection

The Pinackpuck Collection[161] incorporates the pineapple symbol as a pattern, using a traditional printed format. I have developed this collection using the print and dye textile department at RCA, experimenting with printed technology and wax finishes.

Pinackpuck 01 Pinackpuck 04

[161] Pinackpuck means beaten cloth in Tagalog. This is in reference to the traditional technique employed in the Philippines to soften and make the hand-woven cloth more pliable by beating it with wooden mallets.

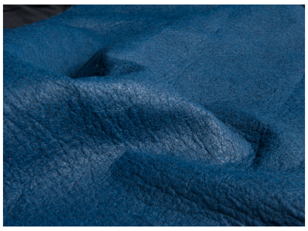


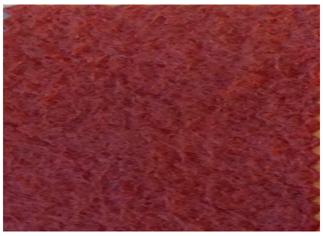
Pinackpuck 02 Pinackpuck 03

Fig 3.72 Pinackpuck Collection, Hijosa C. RCA, 2013

Gamussa Collection

The Gamussa Collection[162] has a flat finish and it is soft and pliable. It came about from experiments done with colour and texture at the RCA, with the final finishing carried out at the Northampton Leather Technology Centre.





Gamussa 01 Gamussa 02 Gamussa 03

Fig. 3.73 Gamussa Collection, developed by the author in the Textile Dept, RCA and Stuart Booth at the Northampton Leather Technology Centre, 2013

[162] Gamussa in Tagalog means very soft leather cloth such as chamois or suede

Piñatex technical information

Extensive testing has been performed on Piñatex and the substrate to understand the material and its comparison to the market needs, as already stated in Section 3.7.

The results shown in Table 3.24, which corresponds to laboratory samples, developed using formulations and technology specifically for the roll-to-roll textile processing, indicates that industrial scale manufacturing is feasible. At the time of writing, (June 2014), the first stage of the roll-to-roll manufacturing processes have been successfully completed. The results from tests performed on first production samples are shown in Table 3.27.

The data of Tables 3.25 and 3.27 are in good general agreement.

Table 3.27 Piñatex technical data for Bagahe Natural/NW04/08/14/Tumbled. Ananas Anam, 2014

Technical data for Bagahe Natural/ NW04/08/14/Tumbled

Sample / Technical Spec.		Bagahe Natural/NW04/08/14 
Thickness (mm)		2.5
Weight (gpsm)		400
Tear Strength* (N)	Warp	128.76
	Weft	72.37
Tensile Strength* (N)	Warp	386.77
	Weft	192.21
Seam Rupture* (N)	Warp	432.66
	Weft	182.01

* Tests conducted at Bonditex S.L., Barcelona, 2014

piñatex non-woven textiles

ananas anam™ new material for a new world

Summary and Conclusion of 3.9

In this section I have shown the versatility that the new material, Piñatex, is able to achieve using various technologies from the leather and textile industry and experimenting in a creative and explorative manner, while using tried and tested machine processes, as well as manual processes.

On the basis of this exploration and work and the experience gained, I can draw certain conclusions. As already mentioned, the development and potential of Piñatex sits at the interface of several technologies and industrial methodologies, and it is through their use and exploration, alongside different aesthetics, that a product with market potential has been achieved. This was clarified further by the market reaction received when the samples were presented to several key market players.

Considering this I can conclude that Piñatex has a potential place in certain market segments as a new textile, and can be used in a range of market applications such as shoes, bags and upholstery.

3.10 Ananas Anam – the company

'Sustainability does not need to come at the sacrifice of economic prosperity. Through projects that balance conservation, community, culture, and commerce, I hope to encourage a new model for sustainable development: one that shows how working toward ecosphere safety can be commercially viable. I am convinced that if revenues generated by the success of these inclusive, holistic approaches are poured back into the Whole—the holistic system involving the entire sum of its parts—they can help to safeguard natural resources, enhance the livelihoods of communities, and promote sustainable economic development.[163]

'A restorative economy will have as its hallmark a business community that co-evolves with the natural and human communities it serves'[164]

This section is about the company Ananas Anam, funded as a consequence of the work carried out in this PhD.

Piñatex is being launched into the market through Ananas Anam Ltd. (www.ananas-anam.com), a start-up company I founded in 2010 as the result of the research work carried out in this PhD. Ananas Anam is part of InnovationRCA,[165] (2013-2014) which is supported by the James Dyson Foundation.

Ananas Anam's vision is to develop textiles and related products using processes that enhance the wellbeing of the earth and its people through the entire life cycle of the products. Our inspiration is the Cradle-to-Cradle approach, which supports ecological, intelligent and innovative design policies within today's economic environment. In this light, Ananas Anam is a for-profit company with strong social responsibility and low environmental impact.

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[163] Jochen Zeitz, CEO, PUMA, *The Zeitz Foundation for Intercultural Ecosphere Safety*, 2010, p 2. Available from http://www.thelongrun.com/files/media-kit/TheZeitzFoundationBrochure.pdf (accessed Sept 2013)

[164] Hawken, 1993

[165] InnovationRCA is the Royal College of Art's centre for incubation and business support, helping students and graduates transform compelling ideas into successful businesses. Their mission is to strengthen the culture of design innovation and entrepreneurialism at the Royal College of Art

Ananas Anam mission statement

The mission statement of Ananas Anam is the result of my experience of working in the Philippines, where I first became aware of my responsibility as a designer, with design becoming a connecting tool between people, technology and the raw natural materials I was working with. Out of these experiences, Ananas Anam vision came about, and with it the wish to develop a business proposition that would encompass people, economy and the land.

Below is the resulting mission statement:

> *Ananas Anam is a company oriented to an ethical, human responsible and environmentally smart business growth.*
>
> *Ananas Anam aims to meet the challenges of our times by developing products in which commercial success is integrated with, and promotes, social and cultural development.*

Social and sustainable objectives

Through its business and products, Ananas Anam is committed to promoting a more sustainable lifestyle, improving the usage of nature-based resources and creating a positive impact on communities, (see Table 3.28).

Table 3.28 Ananas Anam business proposition. Bruno de Penanster, CFO, 2014

Objectives	**Comments**
To promote more sustainable materials for home and fashion	• We believe passionately that Piñatex's success will broaden the appeal for natural and sustainable materials among our end-users and will inspire retailers and manufacturers to look for more sustainable production solutions
To offer a more healthy and natural alternative to consumers	• Ananas Anam intends to use natural materials such as natural dyes & bio-resins which are hypoallergenic and non-toxic for the production of Piñatex. Research is under way for this purpose.
Good value for money and affordable for all	• While a performing and versatile textile, Piñatex remains cost-effective due to its origin and manufacturing process. The price of this textile can remain low and is not affected by oil price or other scarce resources
To reduce waste via a better end-of-life design	• Piñatex is intended to become compostable once the product is disposed of. Research is under way for this purpose.

A better use of resources

Objectives	Comments
Upcycling of a natural agricultural waste	• Piñatex is made of natural fibres extracted from the waste leaves of pineapple plants
Reduction of water and fertilizer usage	• It requires no additional land, water and fertilizer for its growth and harvest
Natural dyes and coating solutions	• Piñatex does not require heavy metals or polluting chemicals for its manufacturing process
Natural fertilizer and renewable energy	• The biomass left over after fibre extraction can be further processed to produce respectively natural fertilizers and/or biogas

Market positioning and markets

With leather becoming more scarce and expensive, there is an enormous opening in the market for alternative materials, which to date has been partially filled by plastics and technical textiles. The arrival of a suitable material of natural origin with supportable environmental credentials such as Piñatex's is likely to be a welcome addition in this growing market segment.

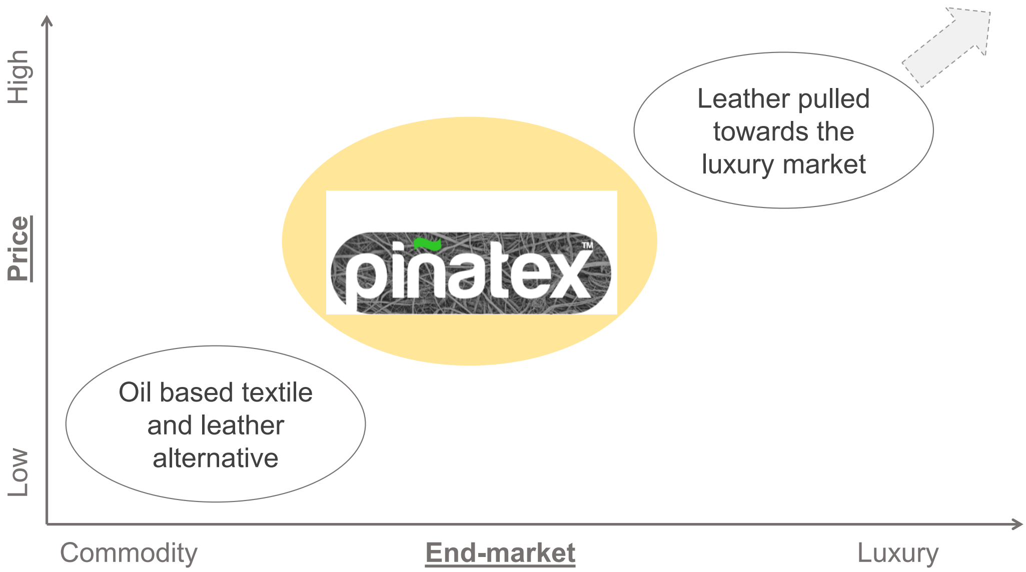

Fig 3.74 Piñatex: market position. Ananas Anam, courtesy of Bruno de Penanster, 2014

Markets

Piñatex can be produced in a variety of colours, finishes and thicknesses, which will fit a wide variety of applications. Below are the key market segments studied, with the aim to introduce Piñatex first into the footwear and accessory markets, followed by the upholstery market. The car and aircraft industries will also be looked at, at a later stage (Fig 3.75).

Fig 3.75 Piñatex market segment. Ananas Anam, 2014

Ananas Anam was founded as a logical step forward from this PhD. It has gone through its first two years as a start-up company, (part of InnovationRCA) and is now entering into the first manufacturing production run (mid 2014).

I can conclude by saying that Ananas Anam has given this research project by practice the possibility to make my vision a reality. The extensive research carried out and acquired knowledge, is the foundation upon which Ananas Anam is being built.

3.11 Summary and conclusions of chapter three

In this chapter I have firstly studied the leather industry in the context of its sustainable credentials and my previous work. From these experiences and my work in the Philippines with natural fibres, a new material, which I called Piñatex, has been created. Alongside this new material, its life cycle, from the agricultural sphere to the manufacturing processes, (that is to say from fibre to the final product) has been studied and put into practical use. Furthermore, thorough research has been carried out on the fibres, consequent substrate and final product, which has proven that this new material's technical attributes are comparable to similar materials in specific market segments. These markets have been studied and researched, and assumptions for Piñatex based on the mentioned market have been established. Finally, the first manufacturing processes have already taken place, safeguarded by collaborative agreements with the various stakeholders in the Piñatex life cycle.

Based on the work carried out I can conclude that I have developed a new material which is pleasing to the touch and eye and that the comprehensive range of laboratory tests carried out have shown that this material has properties applicable to a wide range of industrial applications. I can thus state that I have successfully developed a material that satisfies the criteria set at the beginning of this PhD.

CHAPTER FOUR: Mapping the Way to Sustainable Design – How the Concept of *Upstream* and *Downstream* can help designers link the materiality of making to the immateriality of concept and values.

> 'Designers would do well to remember that they are not in the artifact business. They are in the consequence business. And for design to truly be a force for positive change we must always ask what consequences design creates – from materials and energy use to toxicity, pollution, and social inequality.'[166]

> 'Research is about understanding the world. It is about giving people knowledge to understand the world of material better'[167]

In Chapter Four I will be looking at the conceptual model *Upstream* and *Downstream* applied to understanding my own practice from a sustainable design perspective, using the mapping system developed in Chapter Two. In addition, the contribution and influence that the three case studies have in my own practice will be assessed. Furthermore, Chapters Two and Three are brought to bear on guidelines for other material designers engaged in sustainable practice.

Throughout this project, the design thinking has been focused on the processes as well as the product development. This part hinges on 1) how my design model relates to the conceptual model 'The Designer's Role in Facilitating Sustainable Solutions',[168] which I am using throughout my thesis as an analytical tool, and 2) how I interpret and learn from the three case studies to encapsulate the aforementioned theory, and how the above can be incorporated with my own experience acquired during the processes. The aim is to understand, link and map design in relation to materials, artifacts, patterns of production and consumption (the *Downstream* end of the design process), to the immaterial concepts, value systems, world views, aspirations, being reflected in the *Upstream,* the immaterial dimension of design.

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[166] Alan Cochino

[167] Dr Yanki Lee, 2012 (in conversation)

[168] Wahl and Baxter,

4.1 Piñatex framework in the Upstream and Downstream model

As already mentioned, in the development of a framework for my project I have used the conceptual model *Upstream* and *Downstream* as an analytical tool to understand and analyze how this concept relates to my own practice.

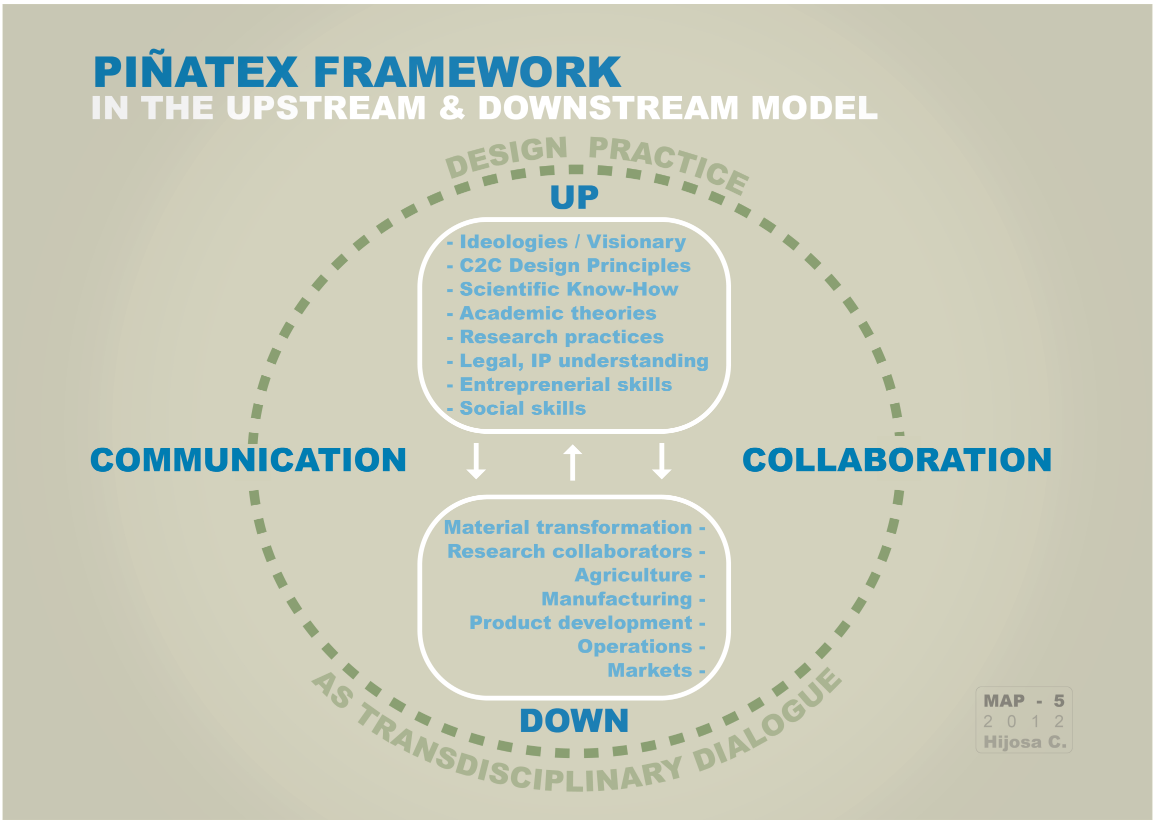

Fig 4.1 MAP 5, Piñatex Framework, C. Hijosa, 2014

The map above (Fig 4.1) shows the different layers being developed, and how the sharing of knowledge as transdisciplinary dialogue, has become the stepping stones upon which this project is built.

In the *Upstream* I have interacted with academics, scientists, researchers, chemists, visionary leaders and business mentors. These experiences and encounters have broadened my vision to encompass a varied sets of values, concepts and new knowledge such as scientific expertise on how to treat and process natural fibres, legal knowledge on how to understand and protect one's work, understand and write patents and the importance of collaborative agreements amongst the different stakeholders. In addition I have learnt business entrepreneurial skills from business mentors and institutions,[169] which enables a realistic business proposal and a route to market to come about. Finally, Cradle to Cradle design principles bring about practical tools, which help link the economic side of the project to the social and ecological responsibilities.

In the *Downstream* I have interacted with farmers and farming cooperatives, whose sense of what it means to grow and take care of nature is clearly evidenced. I have also encountered fibre processors, makers and manufacturers, with whom I share the common language of making and material knowledge, through which the logistics of the value chain from fibre to product become clear and real. Then there are potential clients in this business-to-business model who bring the product to the people in a final validation of it. The interface between these participants and the value of the shared knowledge form the structure for the *Upstream* and the *Downstream* model.

The knowledge I have acquired through these contacts, experiences and knowledge transfer, is the kernel I am building on as an *evolving designer*, which I then transfer into the world through my work.

Mapping of Piñatex in the Upstream and Downstream model

By comparing and tapping into existing arguments, I identify where I am as a starting point in the map, (Fig 4.2). I am a designer with years of experience working with materials, leather and natural fibres. According to this model I am a *downstream* designer (1).

[169] Imperial College Business School (2012) and InnovationRCA (2013 -)

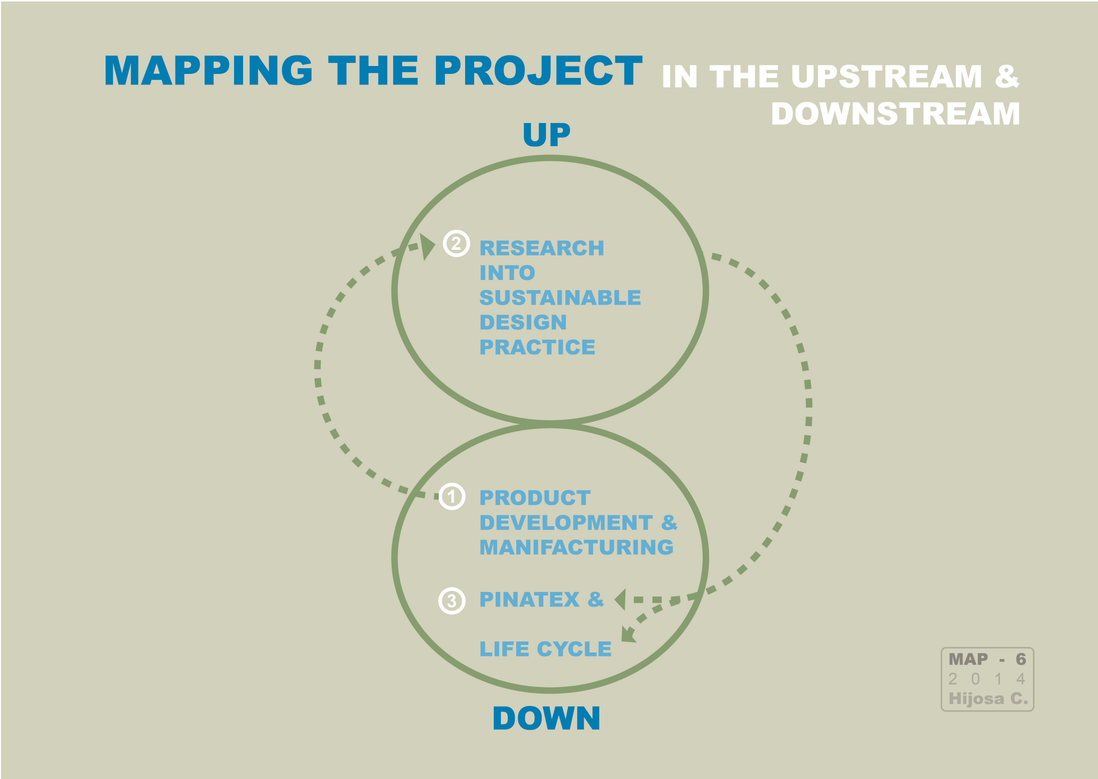

Fig 4.2 MAP 6, Piñatex in the *Upstream & Downstream*, C. Hijosa, 2014

Then I analyse my role: even though I have been doing this for many years, there was a turning point in my work (going to the Philippines, meeting and working with weavers, (real people), and finding out and experimenting with alternative materials, (natural fibres). Consequently, I started to realize how materials are directly linked to people and the influence that this has in their lives, local communities and the environment. So I wish to move *upstream* and learn how to incorporate people and sustainability into my work[170] (2) in order to bring the knowledge acquired into society through design and design practices (3) which is the *downstream*. So this model is not a conceptual model any more because I am using it, but a practical tool to understand design.

[170] This is the reason for entering this PhD

4.2 Relationship between the development of Piñatex and the three case studies

The development of Piñatex has come about from my work experience (Fig 4.1) and the influence and inspiration from the three case studies.

- From SEKEM I learnt that agriculture, particularly biodynamic agriculture, care for the land and utilization of the resulting by-products, needs to be considered as an intrinsic part of the whole value chain, alongside all stakeholders being involved. Social and ecological responsibilities being an intrinsic part of any product development.

- The C2C philosophy has been influential in bringing to the fore the importance of developing a product through thorough research, based on awareness of the product's processes and components, which need to be integrated as part of the whole closed-loop cycle from the start, thus linking and following from SEKEM's aspirations.

- Gawad Kalinga has been an inspiration and is a potential partner to bring the lessons learnt into the Philippines, and how, in spite of the huge undertaking that this entails, together we can and will bring changes to some of the most disadvantaged segments of society in the Philippines.

4.3 How the concept of *Upstream and Downstream* can help designers link the materiality of making to the immateriality of concept and values

Based on the scholarly research carried out (the *Upstream* and *Downstream* model) and my experience of developing Piñatex, a new mapping approach has come about. This is a practical, fluid model, not academic, which can be used as a working tool in design, firstly to visually understand where we as designers are coming from based on our values and aspirations, and secondly, to find the middle ground – where things can and are allowed to happen. Here, ideas, people and processes move from the '*Upstream* and *Downstream'* to the '*In-flow* and *Out-flow'* zone, creating myriad pathways of creative and interdisciplinary dialogue (Fig 4.3, Map 7).

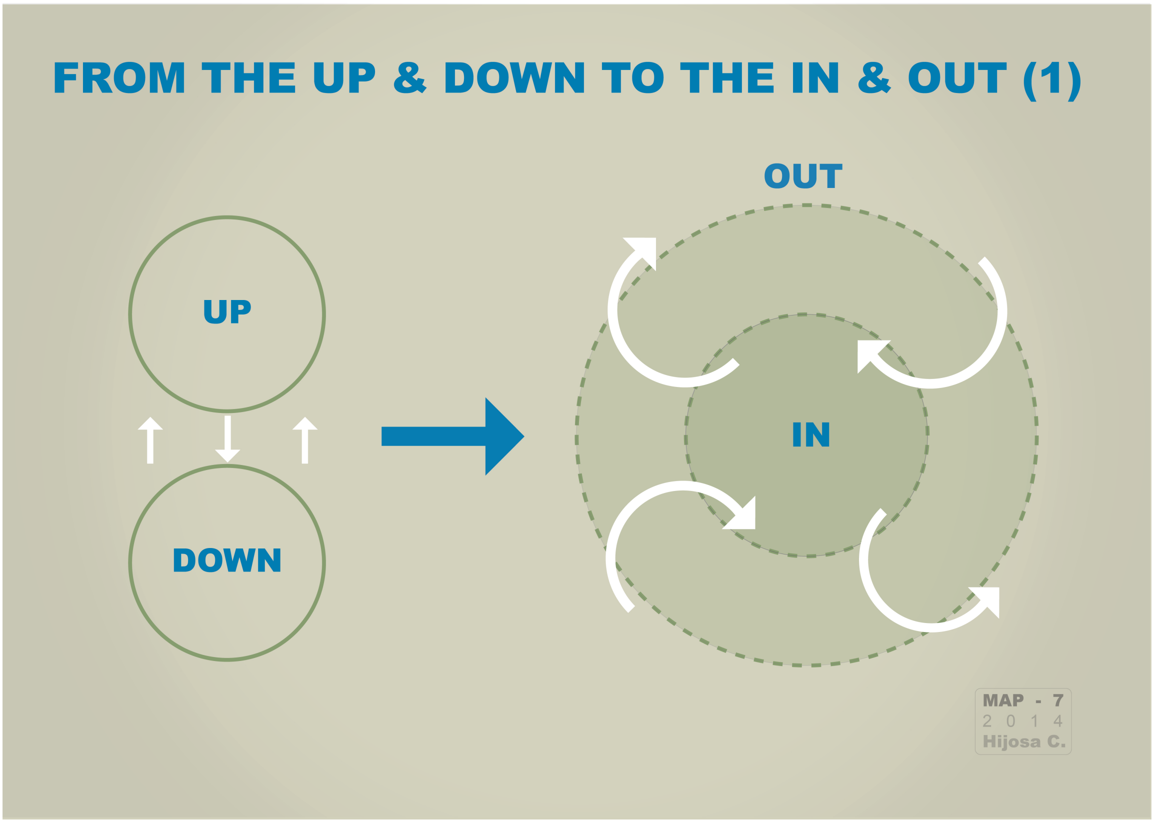

Fig 4.3 MAP 7. From the *Upstream & Downstream* to the *In-flow & Out-flow*. Hijosa C., 2014

This kind of framework, when applied to design, can help us to conceptualize how different value systems and different assumptions change our experience of reality, and the way we approach the intentionality behind design. This change in '*why* we design things and processes in turn affects *what* and *how* we design'.[171]

Mapping the concept: from the *Upstream and Downstream* to the *In-flow* and *Out-flow*

As already mentioned, from the point of view of material designers, the academic-based mapping moves from the *Upstream & Downstream*, (no 1, in (Fig 4.4) into the *In-flow & Out-flow*, (no 2), which then becomes a fluid mapping system based on real world issues and how we act upon them, No 3 (Fig 4.4).

[171] Wahl and Baxter.

Based on the aforementioned experiences, a new model has come about (Fig 4.5).

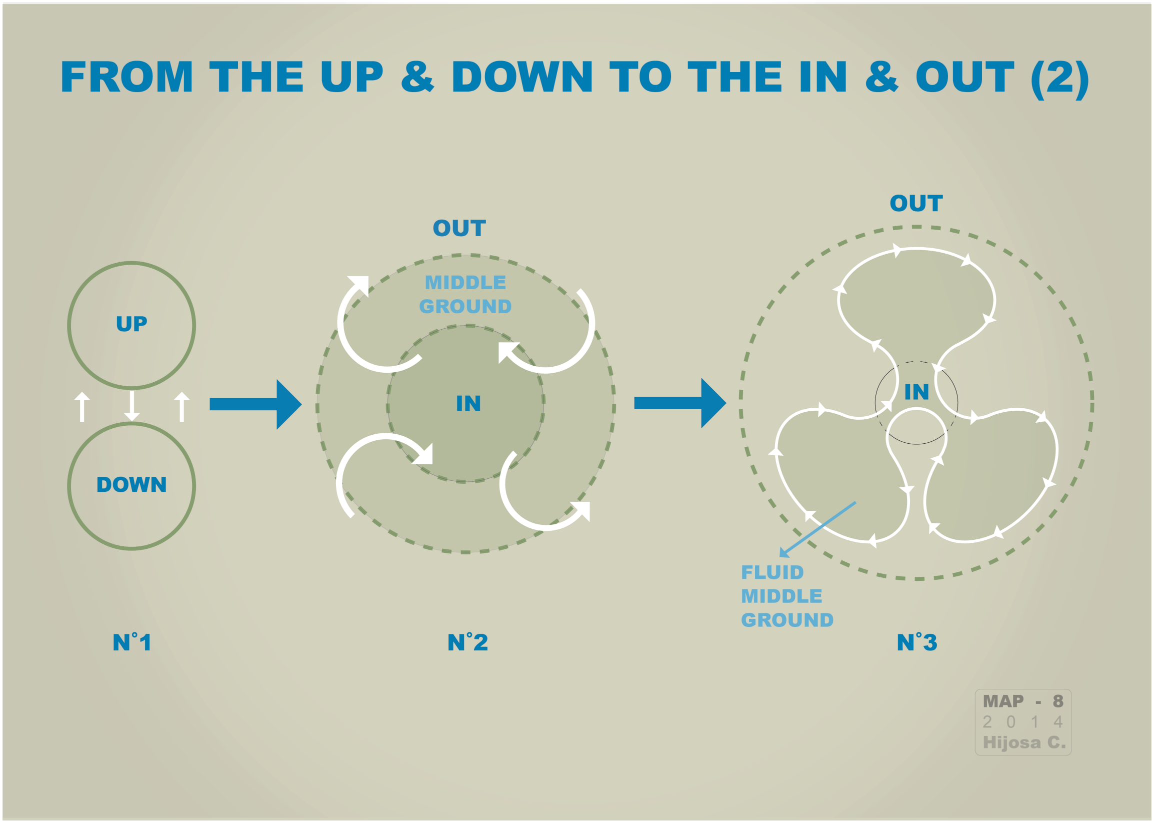

Fig 4.4 MAP 8. Transformation in mapping from the *Upstream & Downstream* to the *In-flow & Out-flow.* Hijosa C., 2014

This kind of framework, when applied to design, can help us to conceptualize how different value systems and different assumptions change our experience of reality, and the way we approach the intentionality behind design.

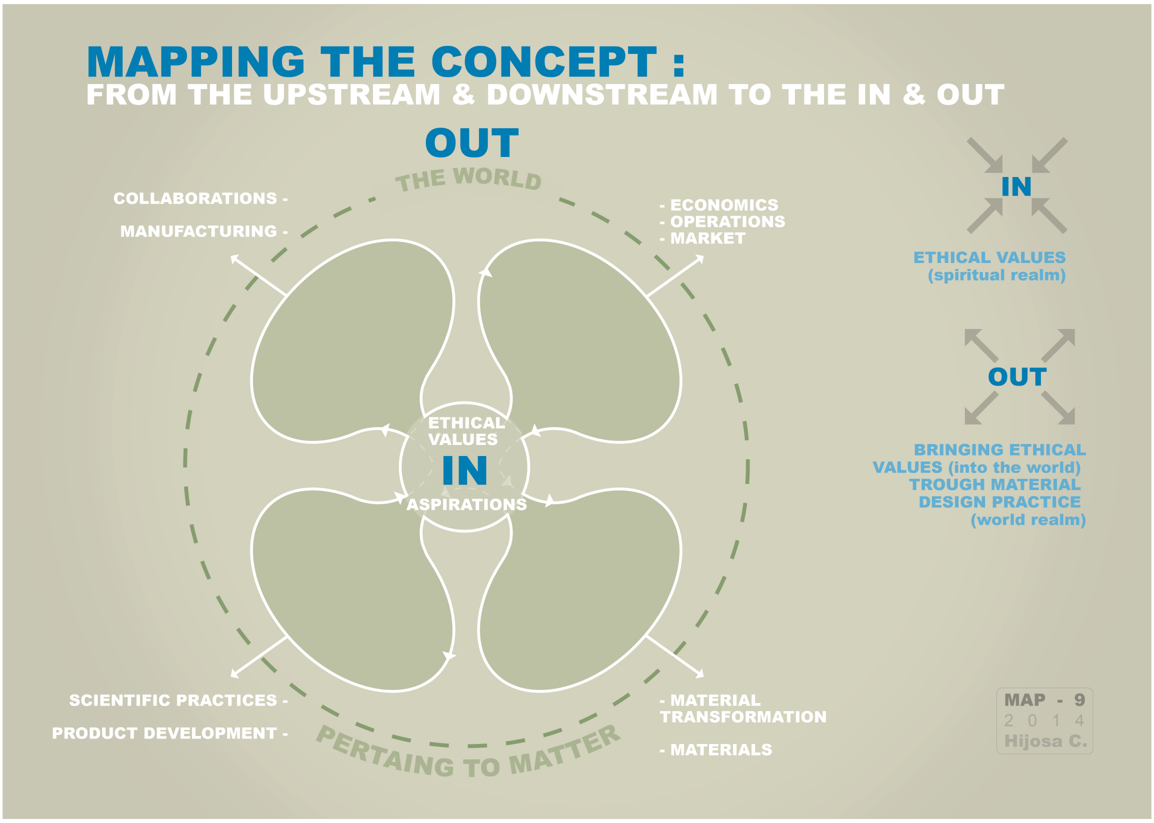

Fig 4.5, MAP 9. From the *Upstream & Downstream* to the *In-flow & Out-flow*. Hijosa C., 2014

Through our ideals and vision of the world, the *In-flow*, (Fig 4.5) we move into the world as material designers, the *Out-flow*. Through our design practice we confront issues based on world realities such as manufacturing issues, IP, legal agreements, etc., and respond to this based on our principles and acquired knowledge and how we interpret these subjects.

Such a viewpoint has repercussions on how we view design, which must be open to contributions from diverse disciplines and perspectives if we are to bring changes and a transformation towards a more sustainable design practice, which, based on Map no. 9, must be also rooted on our own uprightness and personal convictions.

This system developed is not a universally applicable blueprint bringing about sustainable solutions as a top-down model, but as an integrative process in which all stakeholders participate in the complex system of *In-flow* and *Out-flow*.

According to Fisher and Giaccardi,[172] 'rather than believing that we can design universally applicable blueprints, it may be more useful and appropriate to think of the outcome as an emerging and dynamic system.'

So this mapping system is not a conceptual model, it is an *analytical tool* to understand our role and position as designers – I go from concept to tool and at the end I want to develop a full cycle from materials to a product which includes everyone in its life cycle.

4.4 Summary and conclusion of Chapter 4

Chapter four has dealt with the development of a series of maps to support the paradigm shift required by materials designers to face the challenges and adversities of developing a product or system, taking into account our own and acquired values, looking into our practice from an all-encompassing point of view. This emergent design setting can serve designers to position themselves in a more central and active role in the strategic development of products, processes and design practices.

By understanding from which position/point of view and values we stand, we can move out into the world with the conviction that we are key and need to take our place as responsible human beings in the transformation of materials into products.

Such a view has enormous consequences for the way we view design, which must be open to contributions from diverse disciplines and perspectives if we are to bring changes and a transformation towards a more sustainable design practice.

The question I have started this dissertation with, 'How can a design practice link elements of materiality (artifacts) with the immaterial elements (value systems) in order to improve sustainable, social and economic development?' has come full circle in this mapping system.

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[172] Fischer, G. & Giaccardi, E. 'Meta-Design: A Framework for the Future of End User Development"'in H. Lieberman, F. Paternò, & V. Wulf (Eds.), *End User Development,* Dordrecht, Netherlands: Kluwer Academic Publishers, 2006 pp. 427-457. (online) http://l3d.cs.colorado.edu/~gerhard/papers/EUD-meta-design-online.pdf.

CHAPTER FIVE: Final reflections and projections into the future

* "Caminante no hay Camino,
Se hace Camino al andar"
Antonio Machado, 1912[173]

Chapter Five rounds up this dissertation with some thoughts, reflections and hopes for the future.

Reflective practice

What sort of questions do I mumble to myself when I am rambling?

With what sense am I rambling?

Is it my mind and thoughts?

My eyes?

Ears?

Sense of touch?

Emotions?

and

Where do these ramblings bring me?

Questions bring more questions and the whole picture of my project is not an easy one.

[173] Machado, A. ***Trans:** 'Traveller there is no path (way), the path (way) is made by walking" Full poem: "Caminante, son tus huellas el camino, y nada más; caminante, no hay camino, se hace camino al andar. Al andar se hace camino, y al volver la vista atrás se ve la senda que nunca se ha de volver a pisar. Caminante, no hay camino, sino estelas en la mar."

Do we think broad?

Far, near?

Business only?

Or people and the earth?

How do we link all these?

What is the golden thread that keeps the highs and lows joined together and makes a good composition?

I see it as a colourful thread full of light. Light is its main ingredient, and energy. Light, keeping our vision somehow from clouding, energy keeping us going.

What and who constitute this thread?

It is not one person, one energy, one moment. It is the whole, all of us, made up of different blends, like a really good performance yarn.

In other words, it is team spirit that keeps the core of this yarn/thread very clear and strong, blended by the conviction of our joined vision.

(Re: Written 2012.06, just after finishing a business plan for a joint project with Imperial College Business School, London, which awarded us (the team I was working with in the Business school and myself) the prize for the Entrepreneurship & Design Business Plan in 2012).

What are the next challenges

It has been a long and arduous journey, from a thought to a product and a process, and as the quotation in this chapter from the poet Antonio Machado, the journey already travelled is only the footsteps left behind – the future *camino*/way, will become a reality as we journey into the future.

The challenges are continuous and demanding; no less would be expected from a project that is now a start-up company.

The most pressing challenge is to fine-tune the development of Piñatex as a fully tested mass-produced textile (in progress, October 2014). Alongside this, the other challenge is to develop Ananas Anam as the conduit to bring to reality the full life cycle of Piñatex in a manner that benefits all involved.

As I am writing these words (August 2014), Ananas Anam, which has been part of InnovationRCA for nearly two years, is coming to the end of its cash injection and time allocated to bring the product to market. However, Piñatex is not quite ready yet, as it takes immeasurable time to fine-tune a new product and its processes.

How to balance the financial needs with the needs of the market and the needs of fine-tuning a product is really that – a delicate, and difficult balancing act. This balancing act represents a big challenge for Ananas Anam.

The other main challenge is to raise the necessary funds to keep the whole project going and running as a for-profit company with high social and low environmental impact.

Alongside the above, there is the need to get on board the right multidisciplinary team, (from agriculture to manufacturing, research, finance, design, markets) to make this company a successful reality[174].

[174] The company already has a base team in London and Spain, with collaborators in the Philippines and Spain

The balance of all these challenges will dictate the future and success of my PhD project and, as a result, Ananas Anam becoming a real force in the world.

Future plans

The potential of this project is linked with the success of overcoming the issues stated in 5.2 and into further and continuous research.

There are different stages in the development of Piñatex to achieve the project's full potential.

Short term:

- Piñatex technical characteristics and production processes ready for the market (in progress, October 2014)
- More sustainable chemical formulations developed
- Manufacturing processes and supply chain secured
- Partnership agreements throughout the full cycle in place
- Develop a market demand and supply for Piñatex

Mid term

- Develop better fibre extraction and decortication processes; upscale these, as well as the present degumming processes
- Look into more efficient fibre-drying processes using sustainable energy
- Fine-tune the present nonwoven mechanical processes
- Explore the possibilities of using other natural bonding chemicals in the finishing for Piñatex
- Look into the possibility to bring about organic pineapple-growing methods.
- Expansion of the Piñatex range

- Exploration of achieving fire-retardant properties using blends of cellulose and protein fibres
- Yarn development using PALF and selected blends from other fibres
- Research into other commercially available varieties of pineapple plants and other available tropical fibres such as banana fibre, abaca, kapok, etc.

Long term

- Look into exploring other markets for PALF fibres, such as medical and hygiene, based on PALF's antibacterial and hypoallergenic properties
- Industrial uses of PALF such as sound proofing, dust and UV protection

Finally, I envisage the full project as a blueprint to bring the knowledge developed to any other pineapple-growing country in the world such as India, Costa Rica, China, etc. This being done in accordance to the vision and mission of Ananas Anam.

Contribution to knowledge

As stated in Chapter One, Section 1.3.2, the contribution to knowledge of this PhD is:

- A product that aims to sustain the environment and the people throughout its intended closed-loop cycle through fair economics

- A transferable technology based on the findings above

- A design methodology (through mapping) which is inclusive of ethical, ecological and economic practices as an integrated model for material designers

Final reflection

As a material designer, I believe we must endeavor to open ourselves to humanity with the inner trust and conviction that what we do for the world has vast consequences in the world and in ourselves. The transformation we seek to better a particular world reality has also the potential to better ourselves.

Let us find our own voices from within and then, with inner clarity and strength, move out into the world.

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Appendices

Attached to this thesis as a separate document with a separate Table of Contents