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Comparative Study of Conventional and “Smart” Plant Protection Systems in Vineyards in Terms of Economic Analysis

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Περίληψη

Στις μέρες μας, οι ανησυχίες για την ανθρώπινη υγεία, την υποβάθμιση του περιβάλλοντος και τους διάφορους κινδύνους που πουν προκύπτουν από τέτοια ζητήματα έχουν καθιερώσει την εφαρμογή της Ατζέντας 2030 για τη Βιώσιμη Ανάπτυξη των Ηνωμένων Εθνών (ΟΗΕ) μια αναπόφευκτη υποχρέωση για τις επιχειρήσεις και τους υπεύθυνους χάραξης πολιτικής. Ωστόσο, τόσο οι πολιτικοί παράγοντες, όσο και οι οικονομολόγοι, οι επενδυτές, οι επιχειρηματίες αλλά και η κοινωνία στο σύνολό της αποθαρρύνονται από δυσκολίες διεξαγωγής τέτοιον καθηκόντων. Σήμερα, περισσότερο από ποτέ, οι συζητήσεις σχετικά με τις επιχειρήσεις και το περιβάλλον έχουν πολλαπλασιαστεί, μετατοπίζοντας την εστίαση στη δημιουργία αξίας σχετικά με τα 3P, συγκεκριμένα, τον πλανήτη, τους ανθρώπους και το κέρδος (People, Planet, Profit). Στην ίδια κατεύθυνση, υπάρχει μια τάση μείωσης των εκπομπών αερίων του θερμοκηπίου στη γεωργία, αλλά κάθε πρακτική προς αυτή την κατεύθυνση αμφισβητείται ώστε να μην επηρεάσει αρνητικά την παραγωγικότητα και την οικονομία των αγροκτημάτων, διότι αυτό θα περιόριζε την εφαρμογή της, λόγω της υψηλής παγκόσμιας ζήτησης τροφίμων και του ανταγωνιστικού περιβάλλοντος.

Οι πρακτικές Γεωργίας Ακριβείας (PA) που χρησιμοποιούν εξοπλισμό υψηλής τεχνολογίας περιγράφονται στον ακαδημαϊκό κόσμο ότι έχουν την ικανότητα να μειώνουν τις γεωργικές εισροές από συγκεκριμένες εφαρμογές, καθώς στοχεύουν καλύτερα τις εισροές σε χωρικές και χρονικές ανάγκες. Επιπλέον, υποστηρίζεται ότι η Γεωργία Ακριβείας μπορεί να επηρεάσει θετικά την παραγωγικότητα των αγροκτημάτων και την ποιότητα των τροφίμων με τις πρακτικές Ολοκληρωμένης Διαχείρισης Παρασίτων (IPM) που τίθενται στο επίκεντρο. Αυτή η εργασία επιδιώκει να ρίξει φως στο πεδίο των πρακτικών Γεωργίας Ακριβείας διενεργώντας μια ανάλυση κοστολόγησης κύκλου ζωής (LCC) προκειμένου να συγκρίνει έξι διαφορετικές ρυθμίσεις αναφοράς της παραγωγής αμπελώνων, για να αξιολογήσει τόσο την αποτελεσματικότητα όσο και το κόστος σε σχέση με τις έξι διαφορετικές παραλλαγές [από μερική έως πλήρη εφαρμογή] των Πρακτικών Ολοκληρωμένης Διαχείρισης Παρασίτων, για την καταπολέμηση του περονόσπορου. Η συγκριτική ανάλυση αποκάλυψε ότι, για τη δεδομένη χρονική στιγμή, η εφαρμογή του IPM είναι περιορισμένη λόγω της δυσκολίας μιας τέτοιας επένδυσης σε σύγκριση με τις υπάρχουσες εναλλακτικές λύσεις. Για παράδειγμα, οι κεφαλαιουχικές δαπάνες που σχετίζονται με την απόκτηση και τη λειτουργία του προτεινόμενου IPM έχουν ως αποτέλεσμα χαμηλότερη Καθαρή Παρούσα Αξία (ΚΠΑ) από το συνολικό κόστος που σχετίζεται με τις υπάρχουσες εναλλακτικές λύσεις, θέτοντας το IPM ως τη λιγότερο ελκυστική επένδυση. Ωστόσο, η ανάλυση σεναρίων δείχνει ότι κάτω από διαφορετικές οικονομικές συνθήκες η προτεινόμενη IPM μπορεί να είναι μια ελκυστική επένδυση και, επομένως, θα μπορούσε να εφαρμοστεί ευρέως.

Λέξεις κλειδιά: *Γεωργία Ακριβείας, Ολοκληρωμένη Διαχείριση Παρασίτων, Ανάλυση Κύκλου Κόστους Ζωής, Αμπελώνες*

Abstract

Nowadays, concerns about human health, environmental degradation, and its various hazards have established the implementation of the Agenda 2030 for Sustainable development of the United Nations (UN), an inevitable obligation for business and policymakers. Yet political actors, economists, investors, entrepreneurs, and civil society are daunted by the task at hand. Today more than ever before, discussions concerning business and the environment have proliferated, shifting the focus on creating value regarding the 3Ps, namely, Planet, People, and Profit, nonetheless. In the same direction, there is a trend of agricultural greenhouse gas emissions reduction. Still, any practice in this direction is challenged to not negatively *affect farm productivity* and *economics* because this would limit its implementation due to the high *global food demand* and the competitive environment in this sector.

Precision Agriculture practices using high-tech equipment are described in academia as having the ability to reduce agricultural inputs by site-specific applications, as they better target inputs to spatial and temporal needs. Furthermore, Precision Agriculture is argued to positively impact *farm productivity* and *food quality* with Integrated Pest Management (IPM) practices put in the spotlight. By undertaking this investigation, the author seeks to shed light in the field of Precision Agricultural practices (PA) by conducting a Life Cycle Costing (LCC) analysis in order to compare six different reference settings of vineyard grapes production, to assess both the effectiveness and the costs with regards to the six different variations [from partial to full implementation] of Integrated Pest Management Practices, in combat to downy mildew. The comparative analysis has revealed that, for the time being, the implementation of IPM is limited due to the intractability of such an investment compared to the existing alternatives. To exemplify, capital expenditure related to the acquisition and operation of the proposed IPM results in a lower NPV than the total cost associated with the current alternatives, setting the IPM as the least attractive investment. However, scenario analysis has pointed out that the proposed IPM can be an attractive investment and thus could be widely implemented.

Keywords: *Precision Agriculture (PA), Integrated Pest Management (IPM), Life Cycle Costing (LCC), Vineyards*

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1. Introduction

This first chapter of the study will introduce the concept of sustainability in general and its importance in Agriculture, in particular. Then the problem background of the research, as well as the research problem, are presented together with the purpose of the study.

In an effort to meet "the needs of the present without compromising the ability of future generations to meet their own needs" (Our Common Future, 1987), multiple concepts, tools, and methods, focusing on different challenges have been developed for both companies and business practitioners to implement. In such conditions, management should ensure not only the survival and development of entities but also to contribute to the sustainable development of wider society through the company's business. The low resilience of ecosystems imposes sustainable management of natural resources through more rational uses, land protection, energy-saving, and low carbon production technologies. Environmental and economic sustainability assessment relating to a product, or a process is a severe concern for many stakeholders, e.g., public deciders, farmers, entrepreneurs, and consumers (Gaillard &. Nemecek, 2009).

Agriculture and food production is considered as one of the principals responsible for environmental impacts and natural resources overexploitation, and thus, the agricultural sector has a great responsibility in managing these resources that are the principal inputs of its processes. To this extent, it is viewed as preferable to carry out farm management that combines carbon capture and emission reduction considering several farming phases (Khan & Hanjra, 2009). At the same time, alongside environmental protection, production systems shall pay attention to economic viability to support both private and public decision-making and meet consumers' requirements for high quality and low impact products.

In search of *how the degree of sustainability of agricultural engineering techniques can be holistically* assessed, a new conceptual model, so-called Life Cycle Managements (LCM), has risen. LCM has been increased from the necessity to deepen the knowledge with regards to all impacts (environmental, economic, and social) that occur during every stage of the life cycle of goods/ services production and consumption, from planning to disposal, or from "cradle-to-grave" (Guinee, 2002). Recently, LCM has gained remarkable consensus as a methodological framework and is deemed helpful to decrease footprints as well as add value to products or supply chains and improve the sustainability performance of a business or organization (Strano et al., 2013). Life Cycle Costing (LCC) is a widely accepted economic tool used in rational and systematic management in the primary sector (Sgroi et al., 2015; Kambanou, 2020), and government planners often request it for decision-making (Andrieu et al., 2017).

1.1 Problem Background

By examining the latest scientific literature on sustainability discourses, it has become apparent that Agricultural Sustainability is the most representative discipline-focus issue that also provides the most numerous links with other fields within the overall landscape of Sustainability research (Kajikawa et al., 2014). The exponentially growing population, considering resource scarcity and environmental externalities, is perhaps one of the most challenging issues of the Anthropocene. This challenge can be divided into two components: *food security* and *food safety*. Simply put, food security regards food free of pathogenic microorganisms and food security related to adequate food provision for all. In this line, Food security generally concerns only the developing countries, while both developed and developing countries may face food safety issues to deal with the demanding food requirements without compromising human health and Environmental degradation matters.

Food security has been ensured in developed countries by relying on extensive crop breeding and use of synthetic Plant Protection Products (PPPs) for Plant Disease Control, synthetic fertilizers and irrigation for crop growth, and heavy mechanization to assist sustainable productivity yield. Therefore, it is a common belief for both farmers and crop advisors to follow conventional farming strategies that were established during the Green Revolution (1950-1960), maintaining significant use of non-sustainable inputs (PPPs, fertilizers, fossil fuels, etc.) despite the multiple negative impacts that have been identified as a result to their extensive application.

On the one hand, as the global population will have approached 9 billion by 2050, there will be increased agricultural demand by 60% (for outputs) in comparison to the annual average for the years 2005-2007, representing an increase of approximately 1% per annum (UN FAO, 2015). Besides its importance in ensuring food security of society (SDG 2), accountability is even greater as in most countries agriculture represents a large percentage of total manufacturing benefit, providing large employers, and has significant importance for the Gross Domestic Product (GDP) (Tsangas et al., 2020). Therefore, it is implied that the agricultural sector is considered one of the most vital sectors for economic expansion globally.

However, agriculture simultaneously represents an essential source of emissions that degrades the environment and impairs the quality of life (Savic et al., 2019). In such a way, the agricultural sector is facing augmenting challenges that are mostly related to social issues (e.g., food security control, rising demand of food, commercial margins), as well as to environmental issues (e.g., climate change, environmental protection, and legislation) (Bonneau et al., 2017).

Agriculture is, therefore, under frequent scrutiny because of its fundamental importance and its high environmental and social impact. Thus, there is a strong demand for a system that is contemporary, profitable, sustainable, and attuned to diverse needs. As such, multiple competing systems have evolved. Each has a respective suite of strengths and weaknesses at the whole farm and aggregate level. Therefore, it is considered as one of the most exciting domains to be viewed in-depth under the spectrum of sustainable development.

With respect to the current situation of sanitary crisis, while the ongoing COVID-19 pandemic has no connection to food safety in the EU, such a crisis can place both food security and livelihoods at risk. In this sense, the COVID-19 pandemic has underlined the importance of a robust and resilient food system even more in the direction that functions in all circumstances and can ensure access to a sufficient supply of affordable food for citizens. Furthermore, it has also made people acutely aware of the interrelations between our health, ecosystems, supply chains, consumption patterns, and planetary boundaries in the *cycle of life*.

As the General Secretary stated:

> "The pandemic has taught us our choices matter. As we look to the future, let us make sure we choose wisely".
>
> Antonio Guterres
>
> (United Nations Secretary-General, 22 September 2020)

Today more than ever before, it has become clear that we all need to do much more to keep ourselves and the planet healthy. The current pandemic is just one example of the plenty of catastrophes that humanity has and will be faced with. The increasing recurrence of droughts, floods, forest fires, and new pests is a constant reminder that our food system is under threat and must become more sustainable and resilient (EE, From Farm to Fork, 2020). A shift to a sustainable food system can bring environmental, health, and social benefits, offer economic gains, and ensure that the recovery from the crisis (aftermath of the COVID-19) puts us on a sustainable path.

The transition to sustainable food systems is perceived as both challenging and promising. Due to the undergoing evolution of markets with citizens' expectations evolving on a daily basis driving significant change in the food market, such a transition can be an opportunity for farmers, fishers, and aquaculture producers, as well as food processors and food services. This transition will allow them to utilize sustainability as their trademark and to guarantee the future of the EU food chain before their competitors outside the EU do so. Finally, the transition to sustainability presents a 'first mover' opportunity for all actors in the EU food chain (Farm to Fork, 2020).

One of the components of shifting agricultural production systems to more sustainable paths would be the reduction of synthetic (chemical) Plant Protection Products (PPPs) use that, even if it has significantly assisted on higher yields, simultaneously has negatively impacted environmental assets. Doing so seems very difficult for farmers, as there is a fear of yield reduction with a severe effect on farm economics. Therefore, technological advancements on both PPP types (introducing biological PPPs) and application methods could be a winning combination if yields remain at current levels (or even increase) and farmers' income is not affected.

Such interventions in conventional farm practices seem of more interest regarding farms occupied with specialty crops that produce high added value agricultural products that: on the one hand, require regular treatment with PPPs to protect them from numerous pests and diseases. On the other hand, they produce medium to high income for their owners so that they can invest in novel technologies and solutions. One of the crop types that follow these criteria and has a wide application in most European countries is vines for both fresh grape consumption and wine production.

Between the interventions that could be applied in vineyards, Integrated Pest Management (IPM) is a modern method of keeping a record of all chemical products used in farming practices. When IPM is combined with bio-PPPs either entirely or partially substituting conventional synthetic PPPs, the environmental impact is reduced significantly. If the application of both synthetic and biological PPPs is conducted using precision techniques, then it is expected that the final PPP quantities spread in the vineyards are reduced without jeopardizing yield decrease.

1.2 Purpose of the Study

The purpose of this study is the evaluation of the cost performance related to the application of PPPs through spraying in a vineyard (table grapes) in Piemonte, Italy, with regards to six different farming systems and practices to ensure comparable results. This holistic assessment can be carried out through the implementation of Life Cycle Costing (LCC) based on capital budgeting (Roselli et al., 2020). LCC concerns the analysis of investment opportunities involving long-term assets, which are expected to produce benefits for several years (Peterson & Fabozzi, 2002).

By undertaking the current investigation, the researcher seeks;

⇒ to contribute to the transition to Sustainable development by assessing the economic impact/ burden that is caused through the adoption of different Pest Management Practices in general and Integrated Pest Management Systems, in particular.

⇒ To contribute to the research gap characterized in the literature as quantitative evidence on the potential of IPM to increase economic Sustainability relative to non-IPM strategies under region and crop-specific growing conditions, and even more within the European context (Lefebvre et al., 2014).

Therefore, for fulfilling this purpose, the author considers a farmer who wants to invest in a new Integrated Pest Management System (IPM), and thus they wish to realize whether such an initiative will be profitable in the long run. The scope of the LCC is to identify the impact of different PPPs types and application techniques for fungicides related to downy mildew in the Italian vineyard throughout one year. The vineyard under examination is assumed to be at full production, in which vine growth is complete and production is stable so that revenues and costs are constant (Roselli et al., 2020). Only grape production is considered (vineyard planting phase, growing phase, and end-of-life are excluded from the assessment), and the only agricultural operations considered are pest management practices to combat downy mildew in vineyards, always in conjunction with the overall cost of the complete vineyard operations.

2 Theoretical Framework

This chapter presents and reviews the theories that create the base for this study. Firstly, the main theories in the field of Smart Agriculture are presented, having as a starting point its origins and as an ending the latest typology of agricultural practices employed. Afterward, representative literature on how the profitability of such practices can be assessed is reviewed, justifying the selection of Life Cycle Costing that is engaged in the next chapter on the materiality analysis.

2.1 Agriculture

Agriculture is a crucial production sector that ensures food as well as a series of materials and is characterized as one of the most conventional sectors of the economy. It has been facing various challenges in recent years, such as competition in the world market due to high production costs and lack of irrigation water. In addition, agricultural production influences the environment by different means of pollution and the overuse of natural resources because of the large inputs of raw materials and energy requirements to increase crop yields (Mygdakos et al., 2004). Therefore, nowadays, to survive competition on an international level, producers face challenges that regard high quality and low price of produce, using environmentally friendly methods.

The scientific community is once again called upon to find solutions to these problems. At this stage, efforts are being made in two directions: *biotechnology* and *new technological improvements*. On the one hand, advances in biotechnology have led to the emergence of new, more productive crop varieties with more excellent resistance to enemies and changes in climate, reducing in this way the use of chemical and physical inputs. On the other hand, advances in electronics and computers are giving rise to new techniques for maximizing farmer profits and protecting the environment (Markinos et al., 2004), giving rise to what is called Smart Farming or Precision Agriculture (PA). New applications of technology and electronics seem to have great potential to address the above-mentioned challenges. Specifically, Information Technology (IT) has created new dynamic tools, including Geographic Information Systems (GIS), Experienced Systems, Global Navigation Satellite Systems (GNSS), and Satellite Remote Sensing, while Agricultural Engineering and other related Engineering disciplines processes sensors for monitoring cultivation parameters and autonomous agricultural machines (Karydas and Sillaios, 2000).

2.1.1 Factors affecting agricultural production

A good understanding of the dynamics involved in food production is considered a good starting point to ensure food security by achieving higher crop yields. Crop yields are influenced by several factors, and those can be grouped into three basic categories, namely, technological (agricultural practices, managerial decision, etc.), biological (diseases, insects, pests, weeds), and environmental (climatic condition, soil fertility, topography, water quality, etc.) (Metclfe and Elkins, 1980).

To this end, technological progress has always been a critical potential disruption for the dynamics of the economic and sectoral systems (Tilman et al., 2001). In addition, Agricultural Productivity has seen a significant increase since the mid-twentieth century due to the existence of new technologies in agriculture. In fact, the mechanization of agricultural production has contributed significantly over time to improve the parameters of the cultivation process, alongside optimized crop varieties, intense mechanization, irrigation, and crop nutrition through rigorous fertilization, they are believed to have increased agricultural production yields remarkably (70% in Europe and 100% in the USA) (Lamichhane et al., 2016).

2.1.2 Dependence on Plant Protection Products

According to FAO, pests and diseases are two of the main factors that are responsible for 20% yield loss before harvest in fruits and vegetables globally, according to FAO (Dias et al., 2016). Plant protection products (PPPs) or pesticides are terms used interchangeably to describe formulations intended to protect plants and plant products from harmful organisms during production and storage. PPPs include herbicides, fungicides, and insecticides. It is worth noting that the use of PPPs has doubled since 1980, as the increased use of PPPs was one of the main drivers of the "Green Revolution," contributing to the 2.5-fold increase of crop yields in developed countries (Keulemans, Bylemans and Coninck, 2019).

PPPs can be categorized as conventional/synthetic PPPs and natural/bio-PPPs (biopesticides). Conventional pesticides (i.e., only pesticides synthesized by the agrochemical companies and not those used for centuries, such as sulfur and copper) offer numerous benefits. The most important benefits include increased crop yields, improved food safety, human health and quality of life, and reduced labour, energy use, and environmental degradation (Cooper and Dobson 2007). Synthetic PPPs have been standard practice in industrialized countries for decades, and together with optimized crop varieties, intense mechanization, irrigation, and crop nutrition through rigorous fertilization, they are believed to have increased agricultural production yields remarkably (Lamichhane et al., 2016). Much of the increase in yields per unit area is attributed to more effective control of pests (pathogens, animal pests, and weeds) based on the use of conventional pesticides rather than increases in yield potentials (Oerke 2006). Besides the notable benefits, the use of conventional pesticides over the past five decades has led to a range of problems in agriculture, the environment, and human health (Geiger et al., 2010). In addition to the direct costs, there are numerous indirect costs resulting from pesticide use. To give an illustration, they include monitoring and sanitation for contamination of soils, drinking water or food, poisoning of pesticide users and farmworkers, and the deleterious effects on non-target organisms such as bees and other beneficial insects, fish, and birds (Lamicchane, 2016). Although it is general knowledge that many pesticides cause harm to the environment and to human health., the calculation of the total external costs related to a pesticide and their varying formulations for individual applications is complex. Consequently, no estimation of such costs has been made at a practical level (Leach and Mumford 2008).

Bio-PPPs, on the other hand, have gained attention recently and are defined as mass-produced agents manufactured from a living microorganism or a natural product and sold for the control of plant pests used in organic agriculture (Chandler et al., 2011).

Lately, while the development of new conventional (synthetic) PPPs has decreased, the number of bio-PPPs has increased notably, partly because of legislation issues. Both health and environmental concerns about the risks posed using PPPs have led the European Union to introduce a series of measures in 2009, which is commonly referred to as the "pesticides package," consisting of four pieces of legislation related to pesticide use (Regulation EC No 1107/2009). Within this package, the Sustainable Use of Pesticides Directive has provided a framework for action to promote the adoption of low PPP input pest management approaches, in particular Integrated Pest Management (IPM) (EU 2009a). In this sense, EU's legislation is stringent to ensure a high level of protection for all, human health, and the environment, making PPPs among the best-studied categories of products[1].

PPPs usage contributes to crop losses reduction (Oerke, 2006). Crop losses can occur due to weeds, pathogens, viruses, and animal pests. The total crop loss without any crop protection is referred to in the literature as the potential loss. In practice, losses will be lower due to the

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[1] http://www.europarl.europa.eu/thinktank/en/document.html?reference=EPRS_IDA(2017)599428

use of synthetic PPPs (conventional agriculture), bio-PPPs (organic and conventional agriculture), and other cultivation measures, such as mechanical weed control, crop rotation, biological control (e.g., pheromones, biological control organisms) and resistant cultivars. Therefore, it becomes apparent that without PPPs, including bio-PPPs, the food security of 11 billion people in the future is threatened[2]. On the other hand, it is still ambiguous whether it is possible to reduce the use of PPPs without yield reduction.

The exact relation between PPPs application and their effect on productivity yield is difficult to be proved based on experimental data, and thus, evidence shows that quantitative studies on the impact of PPPs on yield quantity and quality are limited. However, rough estimates of the reduction in yield losses are estimated to be around 80% of the potential loss when PPPs are banned, and crop protection is carried out by other cultivation measures. This percentage depends to a vast extent on crop, region, and potential yield (Kawasaki and Lichtenberg, 2015). Many studies show inconsistent results of the effect of PPP reduction and productivity or profitability, especially when organic (lower use) and non-organic farmers (higher use) are compared (Seufert et al., 2019).

Overall, it becomes clear that PPPs have a negative effect on biodiversity and other environmental factors; however, these impacts are overruled at the global scale by the historical changes in land use of all agricultural systems. The contribution of PPPs to other environmental sustainability factors such as eutrophication and acidification has been deemed minor compared to those of nutrients, and these impacts are lower in conventional agriculture compared to organic farming. In any case, a reduction in PPP applications will contribute to more sustainable agriculture. Therefore, there is a need to reduce reliance on PPPs without affecting production yield. As the literature review indicated, it seems more promising to implement more sustainable practices as reduced uses of PPPs, in IPM production systems and in organic farming (Dicks et al., 2019).

PPPs are mainly applied, especially in conventional agriculture, using hydraulic and hydro-pneumatic sprayers. The principle of the operation is to convert a PPP mixture with water into droplets that will be sprayed upon the canopy of the selected crop. Unfortunately, this method is characterized by a high degree of inefficiency and a significant amount of active ingredients ending up elsewhere in the environment (Graham-Bryce, 1977), causing severe

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[2] http://www.europarl.europa.eu/thinktank/en/document.html?reference=EPRS_IDA(2017)599428

contamination to natural resources (water, air, soil). Bio-PPPs show attractive properties, such as their little or no toxic residue production, alongside significantly lower development cost compared to synthetic PPPs. Another vital advantage of bio-PPPs to be noted is that they can be applied with farmers existing spray equipment, and thus a potential shift to more sustainable PPPs usage would not entail unbearable investment costs related to the acquisition of new spraying equipment. On top of that, the literature identifies those agricultural practices that use fewer PPPs per hectare as possibly cheaper than practices more PPP intensive, without increasing the cost due to substitutes (Boussemart et al., 2012). Finally, another beneficiary aspect would be a favourable cost-benefit ratio regarding substitution of chemical control with biological as well as achieving cost dominance if size and scope dimensions are taken into consideration (Boussemart et al., 2012).

2.1.3 Environmental Impact of Agriculture

The pressure to increase crop production in many countries has resulted in the expansion of land area dedicated to agriculture and the intensification of cropland management through practices such as irrigation, use of large quantities of inputs like inorganic fertilizers and synthetic chemicals for pest and weed control (Oldfield, Bradford, and Wood, 2019).

These practices have resulted in degradation of soil properties and water quality, acceleration of soil erosion, contamination of groundwater, and decline of food quality. This has prompted sustainable intensification initiatives to increase yields on existing farmland while decreasing the environmental impact of agriculture (Ngoune and Shelton, 2020).

Agriculture plays a small part in the economies of the European Union (EU), accounting for about only 2% of the total EU gross domestic production (GDP) and 5% of the EU's employment (Brown, 2000). Besides, its impact on the environment and natural resources is particularly significant, accounting for 45% of the EU’s total land use and over 30% of total water use (World Energy Outlook, 2014). Additionally, the agricultural sector is responsible for significant environmental issues such as greenhouse gas (GHG) emissions.

There is growing recognition about the importance of reducing GHG emissions from agriculture to meet the Paris Agreement. The recent IPCC Special Report on Global Warming confirms that there is an essential role for land-use sectors, including agriculture, in stabilizing global temperatures[3] (IPCC, 2018). Fruit products are generally considered to have a lower environmental impact potential than most foods in the western diet. In fact, various studies examining the carbon footprint of different food choices have reported that fruit is the food category with the lowest environmental impact potential (e.g., Wallén et al., 2004; Berners-Lee et al., 2012). Moreover, the average quantified energy consumption of different diets is given below (Carlsson-Kanyama et al., 2003):

- 5 MJ per kg of in-season fruit (opposed to 26 MJ per kg of out-of-season fruit)
- 15 MJ per kg of vegetables,
- 17 MJ per kg of bread and flour products,
- 33 MJ per kg of dairy products
- 37 MJ per kg of meat
- 75 MJ per kg of fish products

Therefore, it becomes evident that the environmental impact potential of fruit production is the lowest in relation to most food categories, and thus further efforts should be undertaken in investigating how such potential could become standard practice to achieve maximum environmental benefit through widespread adoption and achieving economies of scales.

Although the low energy requirements, fruit production is considered an intensive agricultural system in terms of inputs of **pesticides and fertilizers** as well as in capital and material (Mouron et al., 2006a (cited in Cerutti, 2013). Unlike field crops, the life cycle of which is completed in under a year, fruit systems involve plants with very variable duration (10-30 years) depending on the crop and the management practice (Mouron et al., 2006a). The long cropping cycle of grapes implies that there are processes that occur only one time over the entire life cycle (e.g., during the establishment and disposal of the vineyard) and others that are repeated a couple of times depending on the length of the cycle (pruning and fertilization). Therefore, it is essential to reduce PPPs in fruit production, given the numerous applications that are executed in perennial crops.

2.2 Precision Agriculture (PA)

Precision Agriculture (PA) is a relatively new method of agricultural management, according to which, by definition, inputs and cultivation practices are applied according to the

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needs of the soil and crops, as they vary in timely and temporary aspects (Whelan & McBratney, 2000). In other words, the term smart farming or PA refers to the method of managing spatial and temporal needs accordingly to improve economic performance alongside reduced inputs and environmental impact.

PA systems were initially developed in the late 1980s and 1990s. A significant impetus to the development of PA systems was given by the first application of yield mapping sensors applied by Massey Ferguson to combine harvesters, a practice that was executed to identify the production variability of each land parcel and correlate it with soil and crop, management as well as climatic characteristics. These systems improved during the 1990s and even more in the 00s, mainly due to the improvement of positioning systems on the earth's surface by means of satellite signals (GNSS) (Gemtos et al., 2006).

The precondition for the application of PA and consequently the application of inputs with variable dosage (Variable Rate Application) is the knowledge of spatial variability. Variability exists in all fields and can be either spatial or temporal. The first (spatial) concerns measured characteristics of the crop and its soil in the area, while the second (temporal) may affect, for instance, some soil properties that are stable over time or change slightly from year to year, such as soil organic matter and mechanical composition. In addition, other soil properties, such as *nitrate levels* and *soil moisture*, together with the condition of the crop, can change within hours. (Blackmore et al., 2003).

When undertaking PA practices, there is potential for higher returns by (i) keeping either the same number of inputs but redistributed or (ii) even using a reduced inputs for the same returns. It is important to note that, with the term inputs, at this point, the author refers to fertilizers (Miller et al., 2003), PPPs (Miller and Salyani, 2005), irrigation water (Perry et al., 2002), and seed (Mason et al., 2007), as well as energy carriers (diesel, electricity, gas) to allow for field applications execution. Among others, one of the main goals of PA is to increase the efficiency of crops while at the same time improving the quality of the produce. The main objectives of PA can be summarized as follows (Balafoutis et al., 2017; Fountas & Gemptos, 2015, p.10):

- improving crop yields through better information and targeted interventions,
- improving product quality through the rational use of inputs (especially agrochemicals), saving resources and production rates (e.g., energy, irrigation)

- Improving environmental protection by minimizing the adverse effects on nature (e.g., soil, water resources).

2.2.1 Technologies employed in Precision Agriculture

The technologies used by PA are related to all production stages from seeding to harvesting, and those are briefly described below (Fountas & Gemptos, 2015, p. 11-12):

1. **Global Navigation Satellite System (GNSS):** refers to the general term for satellite navigation systems that provide autonomous geospatial information worldwide. The GNSS system allows the receivers to record their location (longitude, latitude, and altitude) with an accuracy of a few meters (Fountas & Gemptos, 2015, p. 52).
2. **Geographic Information Systems (GIS):** GIS refers to spatial data management systems that collect data for specific geographical locations, which they analyse using **specific** map-based software. They provide one thematic map, which is essentially an interactive data map for a particular geographical area. The thematic map can refer to altitude, precipitation, temperature, humidity, nutrient capacity, soli characteristics, and more. With the help of the geographic information system, the farmer can control the input levels by keeping a record of these results in a spatial order (Lei et al., 2011).
3. **Sensors** (e.g., yield mapping, measurement of soil parameters, etc.): refer to devices that detect a physical size and produce a measurable output from it. In this way, it is possible to map different properties of the crop and the soil, recording crop growth and soil fertility of the fields, respectively. Crop sensors measure canopy size and vigour, while soil sensors monitor water content, soil mechanical composition (Williams et al., 1987), organic matter (Janes et al., 1994), complex horizon depth, CEC (McBride et al., 1990), salinity as well as the exchangeable calcium and magnesium (Lund et al., 1999). Electrical conductivity mapping can be quickly done by connecting a conductivity measuring device to an attached vehicle and adjusting a GPS location receiver. The variability of all these factors in the field area is likely to cause the corresponding production variability.
4. **Remote sensing:** is the science and technology of observation and study of characteristics of the earth's surface from a distance, based on the interaction of the materials contained therein by electromagnetic radiation. Remote sensing collects information about an object without contact. The two most common methods of remote sensing are aerial photography and satellite imagery. Electromagnetic radiation is the key element of remote sensing. When electromagnetic radiation encounters an object, it can be reflected, absorbed, or transmitted. Depending on the object to which the electromagnetic radiation strikes,

different wavelengths of radiation react differently. By measuring the reflected radiation from the plants, one can gather information about water content, nutritional status, etc. For measuring such elements, vegetation indices are used, which are mathematical combinations of channels (spectral regions), mainly near-infrared (NIR) and red (R). The important and used indicator produced by these measurements is the Normalized Difference Vegetation Index (NDVI), which is given by the following equation:

$$NDVI = (NIP-R) / (NIR+R).$$

It takes values between -1 (no vegetation coverage) and 1 (full vegetation coverage). This indicator is used for measurements of characteristics such as biomass, concentration chlorophyll in the sexes, etc. Another indicator is the Normal Difference Soil Index (NDSI), which refers to the normalization of the soil difference and is used for measurements of soil characteristics. Finally, there is also the Normal Difference Water Index (NDWI) that is used for the measurement of water characteristics. These indicators are the most basic, and through them, the indicators listed below have emerged.

5. **Variable Rate Application Technology (VRA or VRT):** these regard agricultural engineering systems installed in agricultural machinery that change the amount of input and, if deemed necessary, change the type of inputs (e.g., the variety of the seed, the type of fertilizer, etc.). They apply the inputs according to the needs of the field at the given time, which may differ from plant to plant. VRA systems are based on both mapping techniques and on sensors. There are two methods of differential dose technology: map-based and sensor-based. Map-based requires a prescription map and a GPS to determine the location in the field. As the machine applying the inputs proceeds to the field, it changes the dose based on the application map (the coordinates of the management zones). The sensor-based method requires neither a map nor a GNSS device. Sensors are mounted on the applicator and measure soil or crop characteristics as it moves through the field. The information is transmitted to a program that calculates the needs of the soil or plants and transfers the information to an application device that distributes the inputs.

2.2.2 Benefits of Precision Agriculture

Among the various benefits of PA practices, one can easily recognize the creation of a database (regarding multiple years) that allows the farmer to combine production elements and weather conditions/characteristics to predict the production and apply adaptive measures for its best management. Another critical element of such practices is the GNSS usage, which is capable of recording machinery movements in the production field. This is a crucial aspect given that if it can be linked to the tasks performed, then it provides the opportunity for the farmer to create a database that could be used for traceability of production and later for their certification. These databases can be used as certification of work for certification bodies, but also for the certificate of compliance with cross-compliance by control mechanisms. At the same time, it creates the copestone for the estimation of the times of the tasks to be executed.

Other important aspects to take into consideration are that by using VRA technologies, significant accuracy in applying the required doses for cultivation can be achieved, as well as better *product quality*, alongside *saving resources*, *reducing production costs*, and *reducing the negative impact of agriculture on the environ*ment, which is highly desirable by both consumers and governance. Overall, PA can contribute to the saving of natural resources by streamlining inputs. The rational application of inputs contributes substantially to the protection of the environment, as it reduces the addition of polluting chemicals (fertilizers and PPPs). They limit the deep filtration of elements that pollute groundwater aquifers, but also the elements that are transferred to groundwater aquifers by erosion. It also reduces greenhouse gas emissions by adding the desired elements at the exact time and reducing the machinery passes through optimum routing and limited times of operation in the field (Fountas & Gemptos, 2015).

Besides all the above-mentioned benefits, the adoption of PA technologies on the European level remains at low levels. This might be the case due to the high investment cost related to its implementation as well as an incomplete understanding of its benefits. Shedding light in this direction, academic evidence proved that adaptation of PA practices is directly related to the size of the farm under investigation (Polling et al. 2010). For instance, research conducted in the largest plot of lands in Denmark showed that cost reduction could be achieved (Jensen et al., 2012);

- 25% - 27% regarding fuel consumption
- 3% - 5% with regards to fertilizers and Plant Protection Products (PPPs).

As it can be seen from the above, PA can make a significant contribution to better management of the agricultural system and is expected to be increasingly implemented in the coming years. A significant problem to be addressed is the cost of purchasing equipment and software, as well as training farmers. Today, many of the technologies are characterized by high cost; however, as in all electronic systems, the cost is constantly falling day after day, which is probable to make the new technologies more attractive and accessible (Fountas & Gemptos, 2015). By setting the variable inputs at the optimal level, one of the goals of PA is to preserve the environment in the long run and eliminate environmental degradation. On top of that, applying PPPs only where it is essentially needed contributes to the reduction of PPPs usage, which in turn can be both environmental and economically profitable (Bongiovanni and Lowenberg-Deboer, 2004). Economics is one of the most important reasons for the transition from traditional management to PA. Precision farming can affect production costs and crop yields (Fountas & Gemptos, 2015).

2.2.3 Integrated Pest Management (IPM)

Integrated Crop Management (IPM) is discussed in the literature as the middle-point between biological and conventional agriculture. That is because IPM can combine intensive production practices while at the same time accounting for natural resources protection, food quality, the health of both producer and consumer, as well as it incorporates innovative technologies to ensure agricultural income.

Besides, IPM incorporates a wide range of rules that are usually applied in biological/ organic agriculture, given that both approaches aim at minimizing the negative environmental impact resulting from the use of chemicals in agricultural practices. IPM, as it is described in the Sustainable Use Directive, is defined as a system based on three main principles:

(i) The use of integration measures that discourage the development of a population of harmful organisms (prevention).
(ii) The careful consideration of all available plant protection methods; and
(iii) Their use to levels that are economically and ecologically justified.

According to Lefebvre et al. (2014), since the introduction of IPM principles in 1959, academia has recognized many benefits resulting from its implementation. However, despite the various benefits expected from IPM, not all utilized agricultural areas in Europe are cultivated according to IPM principles. More specifically, although the adoption of IPM is rather commonly applied in orchards and protected (greenhouse) production systems, it remains marginal, mainly in arable and field crops. To the other end of the continuum, according to the EU legislation (EU 2009b), all professional users of PPPs should follow the general principles of IPM already since 2014.

2.2.4 Incentives for Integrating Pest Management Practices

Other than the above-mentioned jurisdictive incentives, in modern agricultural systems responding to market signals is an essential driver for the adoption of new technologies and practices (market pull). Above all, the profitability of new technology for a given farmer is determined by the characteristics of the production technology itself (its impact on quantity, quality, and costs), as well as by several farm-specific factors, such as farm size, human capital, labour availability, financial constraints, access to information, new inputs and importantly, markets (Goodhue et al., 2010). Therefore, the factors likely to encourage European Farmers to adopt IPM principles can be summarised in three categories;

(i) Cost-effectiveness of IPM principles
(ii) Opportunities offered to IPM principles in the market
(iii) Behavioural factors, non-financially related

There is a high diversity of IPM-based practices, ranging from "almost no IPM" to "ultimate IPM". At the same time, IPM is characterised in the literature as a dynamic and continuous process, where the different strategies that are part of the IPM are rarely simultaneously implemented (Lefebvre et al., 2014). Therefore, it becomes apparent that the profitability assessment of stepwise or partial adoption is rendered rather tricky, given that the efficiency of pest control is often obtained because of the complementarities of the different components within the IPM portfolio or spectrum (Zepeda et al., 2006, cited in Lefebvre).

Regarding IPM and costs analysis, the current literature states that PPPs use can be reduced without reducing the total production yield or undermining the quality of the product. Still, results indicate considerable differences noted across countries. For instance, Boussermart et al. (2012) showed that agricultural practices using fewer PPPs per hectare are deemed preferable as they are cheaper than more intensive PPP practices -without increasing the costs due to higher use of substitutes-.

2.2.5 Grapes Production

Grapes hold first place in fruit crops worldwide in terms of the total value of production, followed by apples, watermelons, bananas, mangoes, and oranges. The cultivation of grapes is widely spread around the world, and the fruit can be consumed both as fresh (table grape) and as a processed product (mainly wine) (Roselli et al., 2020). It is worth noting that, in 2012, world production of grapes was realised in 6.97 million (FAOSTAT, 2012). With regards to grapes production, Italy is the eighth highest producing country (followed by China, India, and Turkey) and comes second in terms of exports, with 450 thousand tons of table grapes, for a value of 550 million euros (OIV, 2016).

Regarding the aspects concerning the production of table grapes, the literature identifies that it is a system commonly managed through high levels of farming intensity (i.e., high yields obtained using high input quantities). Controlling pests in a vineyard is considered a "key factor". For accomplishing this correctly, the correct diagnosis of a specific disease before its outbreak and the knowledge of the weaknesses in its life-cycle is a must. Some of the most common diseases/pathogens for the grapevines are: Downy Mildew (Plasmopara viticola), Powdery Mildew (Uncinula necator), and Botrytis Bunch Rot (Botrytis cinerea) from the fungi's category (Goldammer, 2018).

2.2.6 Grape Downy mildew

Downy mildew is a highly destructive disease of grapevines in all grape-growing areas of the world where there is spring and summer rainfall at temperatures above 10 ºC (50 ºF). Crop losses in individual years can be 100% if the disease is not controlled during favourable weather (Ash, 2000). Additionally, early infection of young bunches can lead to significant crop loss, whereas severe leaf infection affects the source-sink relationship in the vine and may lead to defoliation and possible sunburn or lack of fruit ripening. It is said that this destruction of leaf tissue may affect sugar accumulation and growth in the subsequent. There are no suitable sources of resistance in commercially acceptable varieties, so fungicides are the primary means of disease control.

Grape downy mildew caused by the oomycete Plasmopara viticola is characterized as the most severe threat to vineyards (Ash, 2000). According to Ash (2000), the disease affects all green parts of the vine and particularly leaves, inflorescences, and youngberries, causing a significant impact on yield if control measures are not implemented. Current strategies for controlling grapevine downy mildew are mainly based on the use of preventive copper or mancozeb treatments from the beginning of the period during which plants are susceptible to infection. Systemic fungicides should be applied from before bloom to mid-summer, which is the period of the crop's fastest growth and the highest level of susceptibility. Later in the season, preventive contact fungicides are generally preferred.

1.1.1.1 Symptoms and Signs

The disease gets its name "downy mildew" from the presence of this downy growth. Although all green parts of the grapevine are susceptible, the first symptoms of downy mildew of grapes, caused by Plasmopara viticola, are usually seen on the leaves (Ash, 2000).

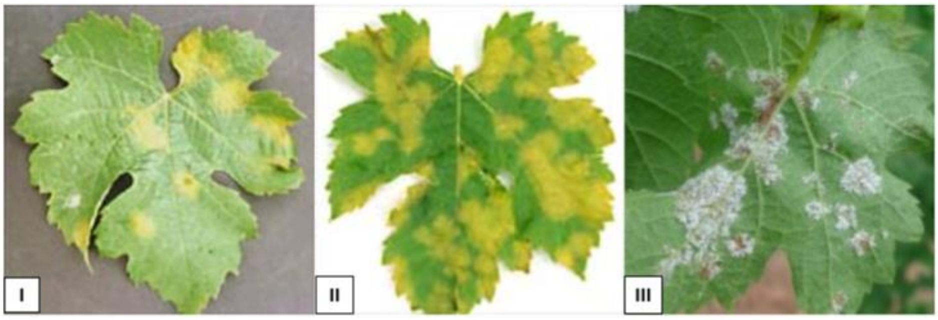


Figure 1 Symptoms and signs of downy mildew

Foliar symptoms appear as yellow circular spots with an oily appearance (oil spots). A brownish-yellow halo surrounds young oil spots on young leaves. This halo fades as the oil spot matures. The spots are yellow in white grape varieties and red in some red grape varieties (e.g., Ruby Red). Under favorable weather conditions, many oil spots may develop and coalesce to cover most of the leaf surface (Figure 2). After suitably warm, humid nights, a white downy fungal growth (sporangia) will appear on the underside of the leaves and other infected plant parts (Figure 3).In late summer and early fall, the diseased leaves take on a tapestry-like appearance when the growth of the pathogen is restricted by the veinlets (Figure 4).

Figure 2 Symptoms and signs of downy mildew 2

Although mature berries may be symptomatic and harbour the pathogen, they may not support sporulation even when provided with ideal conditions. Infected parts of young fruit bunches turn brown, wither, and die rapidly. If infections occur on the young bunch stalk, the entire inflorescence may die (Figure 5). Developing young berries will either die or become discoloured if between 3 and 5 mm in diameter (Figure 6).

2.3 Life Cycle Assessment (LCA)

Since sustainability gains importance for decision-making in policy and business cycles, interest in sustainability assessment tools is growing. To deal with the three pillars of sustainability, namely environmental, societal, and economic, different assessment tools have been developed (Gasparatos and Scolobig, 2012).

One of the most important sources of information for decision-making is cost accounting (Savic et al., 2019). However, the information generated by conventional costing systems has been criticized as an inadequate response to capture costs in relation to a products' Life Cycle. According to the most recent literature, one of the most recognized methods globally for assessing both socioeconomic and environmental impact associated with a product is called Life Cycle Assessment (LCA) (Hospido et al., 2003). The Life Cycle Assessment (LCA) approach is widely used to evaluate the environmental impacts of foods and products, while its use in agricultural systems has clearly risen in recent years (PréSustainability, 2014). It is basically an environmental management tool that aims at sustainable development, pollution prevention, and protection of non-renewable natural resources. LCA is a data-intensive methodology that offers a set of alternatives to decision-makers. By providing a quantitative basis for assessing the potential improvements in the environmental performance of a system throughout the life cycle and minimizing to the least the anthropogenic impact to the environment, LCA is argued to create a significant potential in the decision-making process.

Nowadays, such a process is standardized via the ISO 14040-14043 standards and incorporates four basic steps (ISO 14040: 2006):

- Goal and scope definition
- Life-Cycle Inventory
- Life Cycle Impact Assessment
- Life Cycle Interpretation

2.3.1 Life Cycle Costing (LCC)

As it was previously discussed, LCA is a systematic method that takes a full life-cycle approach to evaluate the environmental benefits and burdens from the production, transportation, use, and end of life of goods and services. Life Cycle Costing (LCC), which also employs a life-cycle approach, applies it to the direct monetary costs from a product or service from production through transport, use, and end of life and does not include environmental impacts. Already in the early 1990s, the concept of LCC was incorporated into British quality standards and later into international ISO standards (ISO 14040: 2006). On a European level, LCC is to assess, evaluate and finance investment plans and the formulation of political actions (Schneiderova Heralova, 2013). LCC aims to evaluate the cost-effectiveness of alternative design strategies by considering the potential initial and operational costs that will be incurred over a specified period. Only values that can be expressed in monetary terms are considered in LCC calculations; thus, intangible impacts such as comfort and environmental load are neglected (Gundes, 2015).

LCC can be employed throughout different stages of the life cycle of a project or asset under examination and is employed mostly for two reasons. On the one hand, as an absolute analysis, when used to support the processes of planning, budgeting, and contracting for investment in constructed assets. On the other hand, as a relative analysis, when used to undertake robust financial option appraisals, for example, in relation to the potential acquisition of assets, design approaches, or alternatives (Langdon, 2007, p.10)

Generally, LCC is applied for the purpose of determining whether the higher initial cost is counterbalanced by reduced future cash-flows (FCFs), but also to assess and evaluate whether an alternative to the option which does not contain initial investment costs in the early stages but exhibits higher costs in the future, is more cost-efficient (Clift, 2003). More specifically, LCC is often employed to a great number of applications to support decision-making in various ways. Some examples are provided below (Langdon, 2007, p.10):

- Facilitation of effective choices between different means of achieving desired objectives (e.g., reducing energy use or lengthening a maintenance cycle).
- Helping to achieve an appropriate balance between initial capital costs and future revenue costs.
- Assisting in identifying opportunities for greater cost-effectiveness (e.g., selection of components with a longer service life or reduced maintenance requirements).

- Acting as a tool for the financial assessment of alternative options identified during a sustainability analysis (e.g., components with less environmental impact or systems with greater energy efficiency).
- All-embracing, by instilling greater confidence in decision-making in a project.

2.3.2 Limitations of LCC

Although the numerous advantages of an LCC assessment, the literature suggests that one will face some difficulties once deciding to run it. First and foremost, LCC is a time-consuming and human capital-intensive process (Raymond & Stener, 2000). Therefore, it is argued that there is a strong need for incentives provision in order to create value-added for a possible customer (Ashworth, 2014). Furthermore, another prevalent limitation related to the implementation of an LCC is discussed in the international literature as the "data problem" (Flangan & Jewell, 2005), described as lack of information on the extent of application of LCC in organizational contexts. In addition, there is little systematic data available, while even more are not considered valuable or properly documented (Emblemsvag, 2003). At the same time, there is a lack of an institutional framework for data collection, storage, and knowledge diffusion in research (Bakis et al., 2003).

Literature also identifies another limiting factor of this method, namely ignorance of its benefits from the customer's perspective, as the majority seems not to be aware of the capabilities of LCC. Thus, there is the need for raising awareness and informing the customer to the point that one is convinced (Raymond and Sterner, 2000) to "pay the cost" that comes with it.

Speaking of, one of the main reasons for the unwillingness to employ an LCC is that it comes with the initial costs, while its benefits are to be actualized later in the future. This is because it is difficult to determine the economic and quantitative benefits in order to convince the farmer to adopt it (Fountas et al., 2005). In this sense, it becomes apparent that when customers are forced to make decisions that will increase their initial costs, in order to achieve and actualize cost savings from the total operating costs in the future, then they will bear the high costs only if the benefits are clearly and distinctly (Drake, 1976).

Therefore, the literature review suggested three main factors that can influence the extent to which LCC analysis is used in business. Those are:

i) Identifying customer characteristics

ii) Information technology (IT)

iii) Obtaining Competitive Advantage

2.3.3 The Different Types of LCC

When one is seeking to employ an LCC assessment, one will find oneself upon the decision of which is the most appropriate LCC type to be employed. There are three types of LCC, and all three have a function-oriented systems perspective, implying a life cycle approach of some sort (Figure 3).

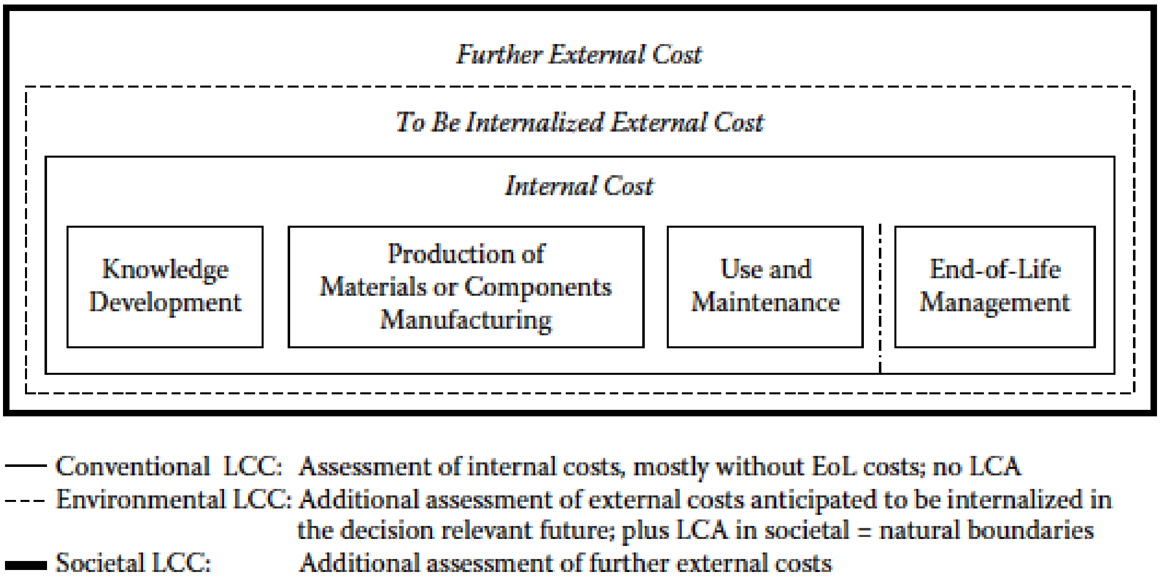


Figure 3 Types of LCC

Table 1 Types of Life Cycle Costing

Aspect	Conventional	Environmental	Societal
Value-added compared to conventional LCC	-	Consistent environmental assessment (LCA)	Opportunity costs or credits considered
Product system (model)	Life cycle, without EoL phase	Complete life cycle	Complete life cycle
System boundaries	Only internal costs	Internal costs, plus external costs expected to be internalized	Internal plus all (costs of) externalities
Perspectives: actors	Mainly 1 actor, (manufacturer, user, or consumer)	One or more actors connected to the product life cycle	Society overall, including governments

Reference unit	Item or product	Functional unit	System
Cost categories	acquisition costs (R&D costs and investment costs) and ownership costs (operating costs, maybe disposal costs)	development, materials, energy, machines, labour, waste management, emission controls, transport, maintenance and repair, liability, taxes, and subsidies	construction, maintenance, and environmental damages; taxes and subsidies have no net cost-effect
Cost model	**quasi dynamic model(generally)**	steady-state model	quasi-dynamic model (generally)
Discounting of result LCC	recommended (but usually not applied)	inconsistent and not recommended	recommended
Discounting of Cash flows for calculation	recommended	recommended	recommended
LCA according to ISO 14040/44	no ISO 15663 (2000-1)	yes	not recommended
Standards and guidance	Various (ISO, IEC, SAE, AS/NZS, etc.)	None (LCA: ISO 14040/44 2006)	For various elements thereof, including from the UN and OECD (Dasgupta et al. 1972; Little and Mirrlees 1969)
Use in the Life Cycle Management	Mostly internal decision making to private organization and supply chain considerations	Mostly internal decision making of producer or user of product, but also for external communication (similar to LCA)	Mostly internal to public organizations

According to Rebitzer and Hunkeler (2003), there are two types of costs to be identified, the distinction of which is presented below:

- ***Internal Costs:*** This category refers to internal costs along the life cycle of a product, implying that someone — a producer, transporter, consumer, or other directly involved stakeholder — is paying for the production, use, or EoL expenses, and, thereby, the internal costs can be connected to a business cost. This cost definition concerns all the costs and revenues within the economic system (inside the fine lines in Figure 3). Internal costs can be divided into costs inside or outside an organization, depending on the perspective.
- ***External Costs:*** This category, also called externalities, refers to costs that are already priced in monetary units due to their to-be-internalized character in the decision-relevant future and remain so; there is no conversion from environmental measures to monetary measures or vice versa. There should be no double counting of externalities in LCC and the complementary LCA.

Referring to the views of Hunkeler and his colleagues, in their book *Environmental Life Cycle Costing* (2007), they highlight two traditional critical approaches to costing that are closely related to LCC, namely, Total Cost of Ownership (TCO) and Activity-Based costing (ABC). On the one hand, TCO is perceived as to help consumers and enterprise managers to assess the total costs related to the use of an item (Ellram, 1993). TCO and user's or consumers' LCC do overlap, as the TCO has a strict user perspective focusing on the acquisition and use phase (investment, maintenance, operation, support, etc.). On the other hand, ABC supports manufactures to calculate the true cost of an item by assessing the overhead and other general costs to products (and services) in addition to direct and indirect costs (see Roztochi, 1998). Although in both approaches, no environmental assessment or external costs are included, the ABC method has been criticized as lacking the life cycle perspective; hence it is not considered qualified as LCC in the literature.

2.3.4 Life Cycle Costing - Implementation procedure

According to Hunkeler and his colleagues (2015), there is a specific procedure for information gathering and for both identifying and quantifying and finally calculating the cost data. Cost data calculation can be tailor-made per unit process or subsystem of the product system model to allow for aggregation to life cycle costs for the production, use, and end-of-life phase. This procedure consists of six stages, and those are summarized as follows (Hunkeler et al., 2015, p. 44 -46);

- ***Step 1)*** Identification of the subsystems or unit processes that could result in different costs or revenues (in the following steps, only the term “costs” is used, denoting both costs and revenues).
- ***Step 2)*** Assignment of costs or prices to the respective product flows of the unit processes or subsystems identified in step 1, with the process output as a reference unit (e.g., 1 kg intermediate product).
- ***Step 3)*** Identification of additional cost or price effects of the unit processes or subsystems identified in step 1 that differ between the studied alternatives (other operating costs of the processes taken into account investments, tooling, labor, etc.)
- ***Step 4)*** Assignment of costs or prices to the additional process operating costs identified in Step 3, with the process output as the reference unit.

- ***Step 5)*** Calculation of the costs per unit processor subsystem by multiplying the costs per reference unit from steps 2 and 4 with the absolute quantities of the process outputs for providing the reference flow(s) of the complete production system.
- ***Step 6)*** Aggregation of the costs and prices (from the same perspective, both are outflows) of all unit processes or subsystems (from step 5) over the complete life cycle.

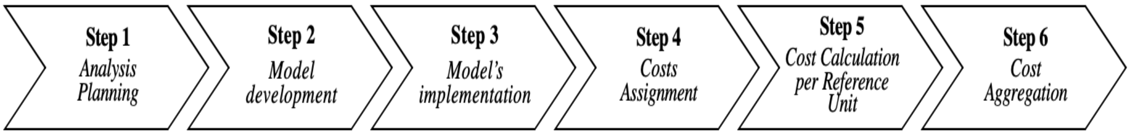


Figure 4 Graphic representation of the six stages of Life Cycle Costing (Hunkeler et al., 2015)

To calculate the costs related to the life cycle of a product (Step 5 & 6: Calculation of the costs per unit process or subsystem = life cycle phase, aggregation of the costs) the following equation is used (Hunkeler et al., 2015, p. 47):

$$LCC = \sum_{life\ cycle\ phase\ 1}^{Life\ Cycle\ phase} \ \sum_{process\ 1}^{process\ i} (\mu i \times \sum_{cost\ el.1}^{cost\ el.\ p} \ \sum_{flow\ 1}^{flow} amount\ q \ \times \ costs\ p) \tag{1}$$

Where:

i = process -specific variable

p = cost category – specific variable

q =process flow- specific variable (can be either input or output)

μ = process scaling factor related to the product system

n = life cycle phase- specific variable

To sum up, LCC Analysis is deemed as a precious tool that can be utilized in all different life stages of a product's life cycle. It can be possibly utilized to assist decision-making, given that it can provide cost accounting information from a life cycle perspective. Therefore, one can argue that the objective of LCC is to achieve capturing all the costs that arise from the creation of an idea, through the development of products, its production, and its post-sales services, up to the withdrawal of the production from use (Savic et al., 2019). In this sense, the concept should provide a picture of overall costs over the life of a product, which is at the same time the starting point for assessing the viability of the product being monitored. While traditional cost accounting_systems primarily focus on the production and sales phase, cost accounting by product life stages, includes and monitors costs incurred in all: market research phase, design and product development during the manufacturing process, quality control, storage, distribution, disposal and handling environmental protection. Finally, LCC is a systemic approach of applying cost accounting having as its primary goal to provide information that will contribute to the realization of the goal of optimizing costs.

2.4 Cost optimization

Cost optimization is a very delicate task whose importance becomes particularly apparent in terms of intensifying possible increases in cost related to the product maintenance and disposal phase, due to violations of environmental regulations and consequently penalty fines associated with these, as well as intensifying competition (Dhillon, 1998).

Cost optimization involves undertaking actions to reduce the value of a target function. In this case, the goal is to achieve cost leadership. In doing so, it is necessary to bear in mind that cost-reduction efforts do not impair the quality and functionality of the products, as those are of utmost importance.

When analysing costs arising from various activities that the company applies in the production process, it is necessary to identify **the key cost drivers** to make efforts to reduce the amount of costs incurred and based on that, make decisions about the type and extent of production in the upcoming periods. In addition to the expenditure component, it is necessary to also look at uses or **incremental incomes** that can be achieved by choosing an environmentally friendly alternative (Savic et al., 2019). These are revenues that can be realized among others, on the basis of, ecological premium, building reputation, increasing market share, customer loyalty. Cost optimization through the prism of the concept of a product life cycle in agricultural business entities is argued to contribute to finding economically, socially, and environmentally acceptable solutions for the production recipe, packaging, and transport of food products (Notarnicola et al., 2017). However, to achieve comparability on the costs and revenues resulting from cash flows actualized in different time periods, it is necessary to apply the appropriate discount rate to determine their present value.

2.5 Establishing a baseline for IPM impact

According to the Guide for Impact Evaluation of IPM Programs (Ortiz & Pradel, 2010), baseline studies should be made, both in the communities that are going to participate in the IPM project and those that are not (control group), as well as these communities, should be sufficiently similar so that the situation of pest control after the implementation of IPM program can be evaluated.

The baseline describes the currently existing situation in the function of variable or state of an environment defined for a specific project. In this case, the baseline scenario describes the knowledge and control methods used by farmers as well as the damage caused by pest organisms. Some examples of such variables are; *farming systems, productivity, pest damage, farmer knowledge, types of technologies used to control pests, etc*.

Once the baseline scenario has been assessed and evaluated, then it is possible to compare its results with both the survey results and with the evaluation after the completion of the project to allow for assessing whether the IPM's project implementation has shifted the indicators significantly. The baseline constitutes the initial measurement of variables, employing the indicators that are most likely to be modified by the IPM implementation. With regards to economic evaluation, economic indicators are to be selected on the basis that those can be measured both in the baseline scenario and afterward. For the economic indicators, one should record data on; *cost control, levels of damaged caused by the pest, economic losses, and net income of crops where IPM will implement* (Ortiz & Pradel, 2010)**.**

2.6 Principles for Partial Budget Analysis

Partial budgeting is a planning and decision-making framework used to compare the costs and benefits of alternatives faced by a farm business. It focuses only on the changes in income and expenses that would result from implementing a specific alternative, thus assuming that all aspects of farm profits that are not affected by the decision can be safely ignored. Partial budget analysis is a farm management analytical method that can be applied to determine the profitability of changing methods of pest control (William et al., 2015). It involves estimating comparative financial returns by quantifying the net economic effect of only proposed changes in production systems. Furthermore, the partial budget framework can be used to analyse several essential farm decisions, including the adoption of new technology (Roth, 2017). For instance, to change from pesticides to using IPM.

The aim is to estimate the changes in income or losses for the farmer's plot due to changes in the pest management approach. In a nutshell, partial budgeting allows you to get a better handle on how a decision will affect the profitability of the enterprise and, ultimately, the profitability of the farm itself. Therefore, it does not calculate the Income or Total Expense for plots with or without IPM; instead, it assumes that only the costs of pest control change and all other costs remain constant. However, one should bear in mind that the value of partial budget analysis is highly dependent and limited to the quality of the information used in the analysis. For instance, if the analysis is required to focus on effects that occur more than a year or two in the future, then one should use a Net Present Value (NPV) approach, which discounts the euro amounts in future years to account for their lower value compared to current-year euro, in other words, the so-called Time-value-for-Money principle.

Net Income (NI) derives from the sale of agricultural produce or in other words, Net Income captures the amount of money obtained once Total Costs (TC) are subtracted from Total Benefits.

$$NI = TB - TC$$

Total costs include the costs of all inputs (such as seed, fertilizers, etc.), but for the partial budget, it is not necessary to estimate total costs, just the costs that vary due to the change in technology. In this case, these are the costs that vary in changing the pest control method. It is assumed that the rest of the costs are the same. When deciding whether to adopt IPM, a farmer wants to know if their income will increase. The Net Income (NI) is the difference between Total Benefits (TB) and pest control related costs (either of IPM or traditional pest control practices). The difference in Net Income using OPTIMA IPM (ref 6) compared to Net Income using the traditional method (ref Historical, Reference 0) will be the additional income the farmer obtains by implementing the OPTIMA IPM.

$$NI\ (IPM) = TB\ (IPM) - TC\ (IPM)$$

$$NI\ (Traditional) = TB\ (Traditional) - TC\ (Traditional)$$

$$Increase\ in\ Income = NI\ (IPM) - NI\ (Traditional)$$

According to (Ortiz & Pradel, 2010), when making recommendations, one should bear in mind three distinctive criteria:

- **1st**: If Net Income remains the same or decreases, the new technology should not be recommended because it is not more profitable than the technology being used by the farmer.
- **2nd**: If Income increases and costs of control remain the same or decrease, the new technology should be recommended because it is clearly more profitable than the farmer’s old technology.
- **3rd:** If both net income and the control costs increase, the marginal return (gains) should be analysed to try to find out how much money is earned for each unit of money that increases the cost of control.

The analysis of investment in an IPM project evaluates whether the money invested in acquiring the technology will generate sufficient accumulated profit at the farmer level within a given time. The assessment is carried out to determine if the accrued benefits cover accumulated costs and generate profit. Accumulated income and costs are the sums of all the income and costs generated by IPM during the years; it is projected that the technology will continue to be used in the field. The annual income is the additional benefit per hectare generated by the IPM multiplied by the total number of hectares where the technology was adopted in a particular year. The annual cost is the sum of the costs related to utilizing the technology in a particular year (diesel, PPPs, labour, software subscriptions, etc.). Generally, these are values recorded by the accounting department of the institutions implementing the projects.

To evaluate economic impact, it is necessary to estimate the additional benefit per hectare generated by IPM to calculate profitability using IRR or NPV (Ortiz & Pradel, 2010). With the annual income and costs during the life of a project, one can calculate the Net Present Value (NPV) of the IPM project. Total income and total costs data from the initial investment in the project are used for the calculation of NPV. Two basic elements are needed for this analysis: the initial investment required to start up the project and the annual income and costs during the life of the project. The years of the life of the IPM project is the period from which research was begun in a country or determined zone projected for up to 15 or 20 years (Ortiz & Pradel, 2010). The assumption is that the IPM technology developed will completely wear off after that period.

2.7 Profitability Measures

In a capital budget analysis, NPV and other cash flow measures such as Internal Rate of Return (IRR) and Return on Equity (ROI), are key metrics that evaluate and rank the attractiveness of several different investment alternatives.

The literature has revealed a wide variety of economic evaluation methods for LCC analysis. They all have their advantages and disadvantages. The methods have been formed for different purposes, and the user should be aware of their limitations. Furthermore, the literature review resulted that the most suitable approach for LCC in the construction industry is the net present value (NPV) method. Herein, Table 2 below illustrates the six main economic evaluation methods that the reviewed literature revealed.

Table 2 The advantages and disadvantages of economic evaluation methods for LCC (adopted from Jutta Schade, 2007)

Method	**What does it calculate**	**Advantage**	**Disadvantage**
Simple payback	Calculate the time required to return the initial investment. The investment with the shortest pay-back time is the most profitable one (Flanagan et al., 1989).	Quick and easy calculation. Result easy to interpret (Flanagan et al., 1989).	Does not take inflation, interest or cash flow into account (Öberg, 2005, Flanagan et al., 1989).
Discount payback method (DPP)	Basically the same as the simple payback method, it just takes the time value into account (Flanagan et al., 1989).	Takes the time value of money into account (Flanagan et al., 1989)	Ignores all cash flow outside the payback period (Flanagan et al., 1989)
Net present value (NPV)	NPV is the result of the application of discount factors, based on a required rate of return to each years projected cash flow, both in and out, so that the cash flows are discounted to present value. In general if the NPV is positive it is worth while investing (Smullen and Hand, 2005). But as in LCC the focuses is one cost rather than on income the usual practice is to treat cost as positive and income as negative. Consequently the best choice between tow competing alternatives is the one with minimum NPV (Kishk et al., 2003).	Takes the time value of money into account. Generates the return equal to the market rate of interest. It use all available data (Flanagan et al., 1989).	Not usable when the comparing alternatives have different life length.Not easy to interpret (Kishk et al., 2003).
Equivalent annual cost (ECA)	This method express the one time NPV of an alternative as a uniform equivalent annual cost, for that it take the factor present worth of annuity into account (Kishk et al., 2003)	Different alternatives with different lifes length can be compared (ISO, 2004).	Just gives an average number. It does not indicate the actual coast during each year of the LCC (ISO, 2004)
Internal rate of return (IRR)	The NS is calculated as the difference between the present worth of the income generated by an investment and the amounted invested. The alternative with the highest net saving is the best (Kishk et al., 2003).	Result get presented in percent which gives an obvious interpretation (Flanagan et al., 1989).	Calculations need a trail and error procedure. IRR can be just calculated if the investments will generate an income (Flanagan et al., 1989).
Net saving (NS)	The NS is calculated as the difference between the present worth of the income generated by an investment and the amounted invested. The alternative with the highest net saving is the best (Kishk et al., 2003).	Easily understood investment appraisal technique (Kishk et al., 2003).	NS can be only use if the investment generates an income (Kishk et al., 2003).

2.7.1 Net Present Value (NPV)

The Net Present Value (NPV) is a top-rated and effective tool in investment analysis and is commonly used to select the most profitable investment from among several alternatives or simply determine the profitability of single investment projects. Based on the work of Vosti et al. (2000), NPV has been deemed as an effective tool in addressing long-term economic feasibility of changes to existing cropping systems. In addition, this method has been extensively used to evaluate the profitability of investments in fruits and vegetables (Jefferson-Moore et al., 2008). The NPV has the advantage of including the time value of money, unlike other economic approaches, which in forestry and agricultural investments that have a long-term nature are deemed crucial and necessary (Mendell, 2020).

As reported by Krupnik et al. (2006), comparing NPVs of alternative cropping systems alongside the relative changes in costs and returns over time, one can easily identify whether alternative cropping systems could be more profitable and economically sustainable for farmers when compared to current systems. On top of that, they argued that this type of analysis could also assist in identifying whether incentives are needed to encourage changes in agricultural practices and if so, provide an estimate of their magnitude and duration. Therefore, it becomes apparent that such importance is further highlighted in cases where environmentally beneficial practices have significant positive externalities that might warrant consideration of a payment subsidy to encourage adoption. The formula for NPV calculation is shown in the following equation.

$$NPV = \sum_{t=0}^{T} \frac{Rt - Ct}{(1+r)^{t}} \tag{2}$$

Where;

t: represents time measured in years;

T: Time Horizon of the investment

R_t: represents revenues

C_t: represents costs in year t.

r: stands for representing the discount rate.

The NPV criterion for investment is quite simple. For an investment to be economically viable, the present value of revenue flows over the analysis horizon should be greater than the present value of all costs aggregated.

Explained in other words; if the NPV is > 0, the system generates profits over the period considered. Conversely, if NPV< 0, invested funds are lost because the investment costs outweigh the benefits. Where access to credit is working and challenging capital minimal, a positive NPV may not be sufficient to encourage the adoption of a new cropping system because it is possible, despite an overall positive NPV, for producers to experience losses in individual years. Thus, this analysis also shows the path of revenues and costs attributable to the activity over time and can identify short-term cash flow barriers to adopting new systems.

Accordingly, the most appropriate method for LCC seems to be the method of NPV. In this method, the investment's future cash flows (both direct and indirect) are identified and actualised by applying an appropriate discount rate and finally aggregated to the NPV. In this way, costs are estimated throughout their whole life cycles. Therefore equation [1] can be adjusted to:

$$LCC = Io + \sum_{i=1}^{N}[(Oi + Mi \times (1 + r)^{-1})] - (R \times (1 + r)^{-N}) \qquad (3)$$

2.8 Pest Management Cost Allocation to Combat Downy Mildew in Grapes Production

In 2017 Vinpro Agricultural Economics conducted a comprehensive analysis across various wine districts, with the primate objective to provide an on-farm financial analysis of each participant's farming unit. For the purposed of this dissertation, the author has adopted the scheme employed by VinPro (2017)

The way the total income is calculated for a specific vineyard is by assuming that although most producers realize their income at different stages over the financial year, depending on their business model, time value for money is irrelevant, and thus it is not considered. On the other hand, the total cost of production can be assessed on three levels, namely, Cash Expenditure, Provision for Renewals and Machinery Costs.

2.8.1 Cash Expenditure

Cash Expenditure can be specified as *direct cost, labour, mechanization, fixed improvements, and general expenses.* Current literature identifies that cash expenditure is a very important cost factor, given that it can be increased above inflationary levels due to higher direct costs (pesticides, herbicides, etc.) that can reach a 13% increase year on year (VinPro, 2017). Additionally, the 9% year-on-year increase in administration cost is concerning, as primary producers have limited influence in these cost items. According to the current literature, precision cost management, remain critical in a cycle of above-inflationary increases in costs, given that it tries to balance between input requirements for each block aligned with product quality and consumers' demand.

2.8.2 Provision for Renewals

Annual production costs make up the biggest part of the Total Production Cost, however, capital expenses are not limited to that. Other than annual production costs, there are costs occurring because capital items are depleted over time, with the renewal of such items deemed critical to ensure long term sustainable production. However, it is important to note that capital items are often written off over different periods at renewal value. By calculating relevant replacement values of tractors, tools, and other means of production, a realistic and practical non-cash flow provision can be estimated. In this direction, by using the principle 'provision for renewals', a larger amount can be recovered than in the case of depreciation (Vin Pro, 2017). Lastly, an interesting aspect to be observed through the provision for renewals estimate is that, although year after year the ageing vineyard status might be concerning for the producer, participants still have the means to replace capital gains positively.

Especially, this can be achieved through economies of scale. Economies of scale have been impacting many agriculture commodities, depending on the producers' position in the value chain. This may differ from business to business, however, in many cases, the increased bargaining power with higher turn rationale seems to be more common than the traditional cost-saving effect on overheads costs. On the other side, machinery that is too large for a particular farming situation can result in machinery ownership costs being unnecessarily high in the long run.

2.8.3 Machinery Costs

Machinery and equipment are major cost items in farm businesses. Large machines, new technology, higher prices for compartments and new machinery, as well as higher energy prices have caused machinery cost and power costs to rise in recent years (Edwards, 2015, file A3-29). However, good machinery managers, making smart agricultural decisions can control the above-mentioned costs per hectare. Obviously, such decision-making requires accurate estimates of the costs of owning and operating farm machinery.

Farm machinery costs can be divided into two categories, namely: ownership costs, which occur regardless of machine operation, and operating costs, which can vary directly with the hours of machine usage. The accurate value of these costs cannot be known until the machine is sold or worn out. However, costs can be estimated on an assumption basis about machine life annual use as long as fuel and labour prices. Overall, putting together an ideal machinery system is not an easy task to perform. One should bear in mind that equipment that works best one year might not work well the next because of changes in parameters such as weather conditions and crop production practices, as well as technological improvements and design characteristics may make older equipment obsolete (Edwards, 2017,).

1.1.1.2 2.8.3.1. Ownership costs

This category is also called fixed costs and includes depreciation, interest (opportunity cost), taxes, insurance, and housing and maintenance facilities.

- ***Depreciation***

Depreciation is a cost resulting from the wear, obsolescence, and age of a machine. The degree of mechanical wear may cause the value of a particular machine to be somewhat above or below the average value for similar machines when it is traded or sold. The introduction of new technology or a major design change may make an older machine suddenly obsolete, causing a sharp decline in its remaining value. But age and accumulated hours of use are usually the most important factors in determining the remaining value of a machine.

Before an estimate of annual depreciation can be calculated, and economic life for the machine and a salvage value at the end of the economic life need to be specified. The economic life of a machine is the number of years over which costs are to be estimated. It is often less than the machine's service life because most farmers trade a machine for a different one before it is completely worn out. According to the literature, a good rule of thumb is to use an economic life of 10 to 12 years for most farm machines and a 15-year life for tractors, unless one knows you will trade sooner.

Salvage value is an estimate of the sale value of the machine at the end of its economic life. It is the amount you could expect to receive as a trade-in allowance, an estimate of the used market value if you expect to sell the machine outright, or zero if you plan to keep the machine until it is worn out.

- ***Interest***

In case where the capital used for acquiring the necessary equipment is borrowed, then the lender will determine the interest rate to charge. However, if one's own capital is employed, the rate to charge as the interest rate is going to be determined depending on the opportunity cost, thus, the cost of capital as to if the money were invested elsewhere in the farm business**.**

- ***Taxes, Insurance, Housing (TIH)***

The costs accounting for taxes, insurance, and housing are usually much smaller than depreciation and interest payments, but they do also need to be considered if applicable.

- ***Total ownership Cost***

Total Ownership Cost consists of depreciation, interest, taxes, insurance, and housing**.**

2.8.3.2. Operating costs

This category is also called variable costs and includes repairs and maintenance, fuel, lubrication, and operator labor.

- ***Repairs and Maintenance***

Repair costs occur because of routine maintenance, wear and tear, and accidents. Repair costs for a particular type of machine can vary widely from one geographic region to another because of differences in soil type, rocks, terrain, climate, and other conditions. Within a local area, repair costs can vary from farm to farm because of different management policies and operators' skills. According to Edwards (2015), the best approach for estimating repair costs is by utilizing records of one's own past repair expenses. In this way, it is possible to assess whether a machine has had above or below average repair costs and when major overhauls may be needed. Furthermore, this way allows for obtaining information regarding the farmer's maintenance program and their own mechanical ability. With the absence of these types of data, repair costs shall be estimated using average data.

The relationship between the sum of all repair costs for a machine and the total hours of use during its lifetime is assessed based on historical repair data. The total accumulated repair costs are calculated as a percentage of the current List Price of the machine, following the guidance of the literature indicating that repair and maintenance costs usually change at about the same rate as new list prices (Edwards, 2015, p. 4).

- ***Fuel***

Fuel cost is dependent upon fuel market price and can fluctuate dramatically over time.

- ***Lubrication***

Surveys indicate that total lubrication costs on most farms average about 15 percent of fuel costs. Therefore, once the fuel cost per hour has been estimated, those can be multiplied by 0.15 to estimate total lubrication costs (Edwards, 2015).

- ***Operating Labour***

Because different size machines require different quantities of labour to accomplish such tasks as planting or harvesting, it is important to consider labour costs in machinery analysis. Labour cost is also an important consideration in comparing ownership to custom hiring. Actual hours of labour usually exceed field machine time by 10 to 20 percent because of travel and the time required to lubricate and service machines. Consequently, labour costs can be estimated by multiplying the labour wage rate times 1.1 or 1.2 (Edwards, 2015).

3 Materials & Methods

The following chapter concentrates on the research methodology, which guided the research throughout the process. LCC is presented briefly followed by the description of the Farm under examination and the proposed systems. Additionally, LCC systems boundaries are defined and LCC Inventory is documented.

3.1 Methodology of Life-Cycle Costing

Life-cycle Costing can be implemented by a wide range of methodologies, the selection of which would vary depending on the point of view of the analysis. One of the most used methods is called “Overarching Methodology” where the focus point is covering the interrelations and dependencies among different cost elements (Geake, 2002). Given that this study will focus on the Life-Cycle Cost of a production equipment -machining systems for PPPs application in vineyards cultivation to best combat downy mildew-; it is inevitable that there will be many interdependencies among the cost elements. Another aspect of great importance in LCC, is the repetitive structure of the method since LCC is a continuous process that might need to be repeated until the optimum result is achieved.

3.2 Goal

The objective of this LCC study is to develop an accurate depiction of the current costs of owning and operating the Integrated Pest Management (IPM) system for downy mildew management in grapes production. The current investigation is taking place in an effort to understand the **cost variability** and **profitability** in relation to the different Pest Management Practices (downy mildew management) under the spectrum of LCC.

3.3 Scope

The scope of this LCC is one production cycle of grapes in a year, where the vineyard under investigation is assumed to be at full production, in which vine growth is complete and production is stable, so that revenues and costs are constant (Roselli et al., 2020). In this study, only ***pest management practices to combat downy mildew*** are considered to change; fertilization, irrigation as well as other field operations (such as pruning, trimming etc.), final grapes production alongside end-of-life operations are considered as constant in order to evaluate the IPM system impact on farm economics.

Therefore, we consider a farmer who wants to invest in a new IPM System (among the spraying systems under investigation) and wants to realize which investment is the most profitable. We assume that the farmer already possesses a plot of land (5,91 hectares) as well as an average tractor for field operations and the respective machinery required for all operations, and we take into account the operational costs of all practices (including only the investment costs for acquiring new hardware and software for the IPM system selected).

3.4 Defining the Farm under investigation

The above-mentioned settings were tested in a vineyard farm located in Nizza Monferrato (Asti), Strada Bricco 22, in the Piedmont region, Italy. The farm under examination has the following coordinates and characteristics;

- *Farm coordinates: 44°46’42’’ N; 8°20’14’’, Piemonte, Italy*
- *Farm characteristics: 5.92 hectares of trellis vineyards, with Barbera variety.*

Figure 5 Aerial view of the Italian farm - all parcels

Most vineyards are planted transverse to the hill slope, with an average transversal slope of 20%. Typical layout is 2.5 m x 1 m, and the maximum height of the canopy is 1.80-1.90 m. Specific location of the experimental parcel of 5.91 ha was defined according to the detailed requirements of the field trials protocol, selecting the area within the farm where the intensity of downy mildew is usually higher. In the farm under investigation, PPPs are usually applied using a pneumatic sprayer, but, for the experiments, a conventional air-assisted sprayer was used as reference to represent the most common practice employed in the region. At last, there is no animal farming nearby and the nearest water line is 700 meters away from the field.

3.5 Data Inventory

Inventory analysis refers to the process of compelling quantitative data on the inputs Both primary and secondary data were utilised for the preparation of Spraying PPPs for grapes production budgets. The activities covered comprise: soil management, fertilization, weed, pest and disease management, manual harvesting. Primary data were collected via questionnaires that were sent to Agenso for the DSS, Caffini for the smart sprayer, Wageningen University for the EDS, and Agricultural University of Athens for the bio-PPPs. In addition, farmers in the Pusabren Farm were asked for data on the farm costs. Based on the grower's responses to the survey, auxiliary market research was conducted to collect primary data on input prices for agrochemicals, fertilizer blends, and soil amendments. The primary data related to all agricultural operations (including pest management associated data) for grapes production in the selected farm based on Historical data (2018) are summarized in the table below.

Table 2 Characteristics of the farm under consideration

Required data	Reference value	Unit
General Data		
Grape variety	Barbera	-
Age of vineyard	40	yr
Region of cultivation	Piedmont	-
Cultivation area	4.71	ha
Productivity	9 (7-12)	t/ha
Slope	20-30	%
Annual irrigation	N.A.	m^3 / yr
Tillage type (no tillage, reduced or conventional)	No tillage	-
Mean air temperature	14,4	ºC
Days of rain per year	94	days
Relative humidity	84	%
Energy		
Total electricity consumption per year	600	kWh/yr
Total diesel consumption per year	565	L/(yr.ha)
Diesel consumption in PPP spraying per year	130	L/(yr.ha)
Costs and Labour		
Diesel cost	0.7	euros/L
Electricity cost	0.36	euros/kWh
Water cost	2	euros/m^3

Total cost of PPPs	491.47	euros/(ha.yr)
Cost of PPPs for downy mildew	244.25	euros/(ha.yr)
Worker's pest management	1	-
Work hours per worker in pest management	1	h/ha per application
Total man hours	83.1	h/(yr.ha)
Hourly wage of workers	11	euros per h
Work accidents / incidents in pest management	0	-
Workdays lost due to accidents	N.A.	h
Wholesale price (Barbera grapes)	1	euro/kg
Number of applications	12	-

Table 3 Labor Cost of all other farm operations

Labor (Pusabren Farm 2021)	*n/year*	*h/ha*	*hrs.ha/year*	Cost €/h	*Cost operation €*
Fertilizer distribution	1	2,5	2,5	42,00	105,00 €
Soil management between the rows	0,5	3,5	1,8	42,00	73,50 €
Prune and cane removal	1	90	90,0	14,00	1.260,00 €
Cane tying	1	25	25,0	14,00	350,00 €
Cane shredding	1	1,5	1,5	42,00	63,00 €
Chemical weeding	2	2,5	5,0	42,00	210,00 €
Desuckering	2	4,5	9,0	42,00	378,00 €
Desuckering	1	40	40,0	14,00	560,00 €
Shoot positioning	2	35	70,0	14,00	980,00 €
Topping	3	4,5	13,5	42,00	567,00 €
Leaf stripping	1	4,0	4,0	42,00	168,00 €
Green pruning	1	35	35,0	14,00	490,00 €
Soil management on the rows	1	13,0	13,0	42,00	546,00 €
Spray	10	1,5	15,0	42,00	630,00 €
Grass shredding	3	3,0	9,0	42,00	378,00 €
Assistance with manual harvesting	1	9,0	9,0	42,00	378,00 €
Manual harvest	1	90	90,0	14,00	1.260,00 €

3.6 Description of all pest management systems under Investigation

To commence a study in LCC analysis, main problem of the case should be defined in detail at first. Proper definition of a problem should express the nature of the system clearly, i.e., all the useful information about the asset, which can be used in interpreting the cost drivers (Geake, 2002). Thus, it is essential to analyse in depth the settings under investigation. Accordingly, all the alternatives that are going to be comparatively evaluated should be proposed. LCC usually involves at least two alternatives to be compared with each other. Besides, the differences between these alternatives should be stated (Emblemsvåg, 2003).

In this study six (6) pest management systems (Reference 0 to Reference 5, Historical) were considered during the experimentation, with different levels of automation and plant protection product origin (chemical or biological). They were a combination of four (4) different sprayers (Pneumatic CIMA, Axial-fan Dragone Virgola 700, Caffini Synthesis 1000 and Smart Caffini Synthesis 1000), a software for prediction of downy mildew outbreak (Decision Support System – DSS), a combined hardware (camera) and software (Artificial Intelligence) system for the detection of downy mildew on vine leaves and fruits (Early Detection System – EDS) and a series of biological PPPs (different volumed of PPPs dosages) that confront downy mildew (Bio-PPPs), as shown in the following *Table (4).*

Table 4 Components of each pest management strategy

	Historical data	**Ref. 0**	**Ref. 1**	**Ref. 2**	**Ref. 3**	**Ref. 4**	**Ref. 5**
Sprayer	Pneumatic CIMA	Axial fan (Dragone Virgola 700)	Caffini Synthesis 1000	Smart Caffini Synthesis 1000	Caffini Synthesis 1000	Smart Caffini Synthesis 1000	Smart Caffini Synthesis 1000
DSS						X	X
EDS				X		X	X
Bio-PPPs					X		X

DSS: Decision Support System; EDS: Early Detection System

3.6.1 Complete IPM strategy description

The complete IPM strategy (Reference 5) is described below to show all the components that form the references under investigation. First, the Smart Sprayer, depicted in the picture below (Figure 6), will actuate different nozzle types, sprayer settings and adopt variable rate application control (VAR), based on optimal selection of spray parameters, canopy, and disease characteristics, together with the integration of innovative drift reducing technologies in order to minimize losses to the environment. In fact, the so-called Smart Sprayer results from improving thoroughly the previous model named Synthesis 1000 ATS/102 E developed by Caffini S.P.A, by:

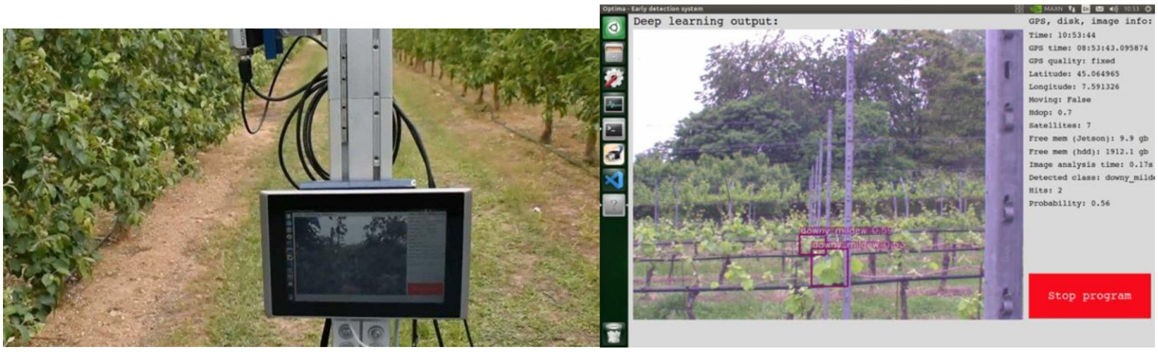
a. integrating ultrasonic sensors for detecting canopy size and density
b. adding individual controlled nozzles with Pulse Width Modulation (PWM) technology
c. changing the mechanically driven fan with an electrical one
d. applying a controller to run the above-mentioned components to provide different PPP quantities throughout the vineyard based on a prescription map

Figure 6 The smart sprayer

The DSS is based on existing disease outbreak prediction models that are based on meteorological conditions (temperature and relative humidity) and were improved to become more precise by adding high quality of weather prediction model for at least 3 days in advance. It has a graphical user interface (GUI) for the farmers to see the outbreak potential, but it also provides an output for the prescription map development.

Figure 7 The Decision Support System (DSS)

The EDS is a system that is carried by a tractor on a frame and combines a camera that is directed to the side of the vines and a computing unit (NVIDIA Jetson) that run software trained using Artificial Intelligence (AI) to identify the downy mildew disease on leaves and grapes.



```
Deep learning output:
```

```
GPS, disk, image info:
Time: 10:53:44
GPS time: 08:53:43.095874
GPS quality: fixed
Latitude: 45.064965
Longitude: 7.591326
Moving: False
Hdop: 0.7
Satellites: 7
Free mem (Jetson): 9.9 gb
Free mem (hdd): 1912.1 gb
Image analysis time: 0.17s
Detected class: downy_milde
Hits: 2
Probability: 0.56
```

Figure 8 The Early Detection System (EDS)

Finally, the full IPM system is completed by using a combination of bio-PPPs together with specific synthetic PPPs to confront downy mildew with minimum environmental impact, without compromising on productivity yield reduction. A full list of all PPPs applied (both Bio and Synthetic) is provided in Table 5 below.

Table 5 PPPs applied

All Synthetic PPPs		
Polyram DF	Actlet F	Coragen
Thiopron	Douro 100 ED	Lieto
Polyram	Ridomil Gold MZ	Sivanto Prime
Pergado F	Kusabi	Almada F
Prosper 300 CS	Liquizol M	Optix Star Disperss
Slogan Top	R6 Erresei Albis	Tiovit Jet
Sercadis	Talendo	Airone Extra
Trebon Up	Brezza	Cuprotek Disperss

Bio-PPPs	**Synthetic PPPs (to be substituted)**
Ampexio	Pergado F, Ridomil Gold MZ
Zorvec Zelavin Vel	Slogan Top, Actlet F
Forup Top	R6 Erresei Albis
Century	Almada F, Lieto
Amylox	Cuprotek Disperss, Liquizol M, Tiovit Jet, Airone Extra, Trebon Up, Brezza, Thiopron

The incorporation of all above-mentioned components provides a holistic integrated approach that includes all critical aspects related to integrated disease management, leading to minimum PPP use for the same positive impact on pest management. More particularly, i) the use of novel bio-PPPs reduces chemical active ingredients application in agriculture, ii) the disease prediction models provide knowledge to prevent the disease expansion by applying PPPs in a preventive manner, iii) the spectral early disease detection systems identifies the exact location of the disease within the vineyards to avoid applying the same quantity of PPPs in heavily and almost non-diseased areas and finally iv) the precision spraying techniques comes in the system to apply variably the right PPP quantity in the correct spatial and temporal rate.

Therefore, the full system can interact and follow recommendations from its components to provide a variable rate for both the applied liquid and airflow produced by the fan according to the vineyard canopies characteristics. In this sense, the parameters that may be affected by the new IPM system in a positive manner are:

1. Volume of PPPs
2. Reduced preparation time (labour rate for skilled labour)
3. Wholesale grapes price
4. Labour wage (Skilled labour)

This holistic IPM system is expected to contribute significantly to the reduction of the European agriculture reliance on chemical PPPs resulting in reduced use of agrochemicals, lower residues, and reduced impacts on human health.

3.7 Life Cycle Costing Constituents of the Investigated Systems

Estimating the cost of production for agricultural products involves estimating all economic costs and revenues associated with the production of a commodity (Handbook on Agricultural Cost of Production Statistics, 2016, p. 47). All costs should be measured, whether purchased or owner supplied. The basic concept is that if it is necessary for production, the cost must be valued. Inputs that are purchased and used during the production period include expenses, such PPPs, energy requirements, labour etc.

Cost items for inputs that contribute to production over several production periods, such as machinery and buildings (capital service costs), must also be measured. However, in this study, only investments costs related to the acquisition of the components of the above-described IPM system references as well as operational expenses for spraying PPPs to combat downy mildew are considered.

Moreover, to allow for direct comparison and drawing conclusions, all other operating costs (electricity, diesel, mineral fertilizers, trimming, pruning, etc.) related to the production of vineyards are included as a constant cost of all cases under investigation. The system boundaries are illustrated in the scheme below.

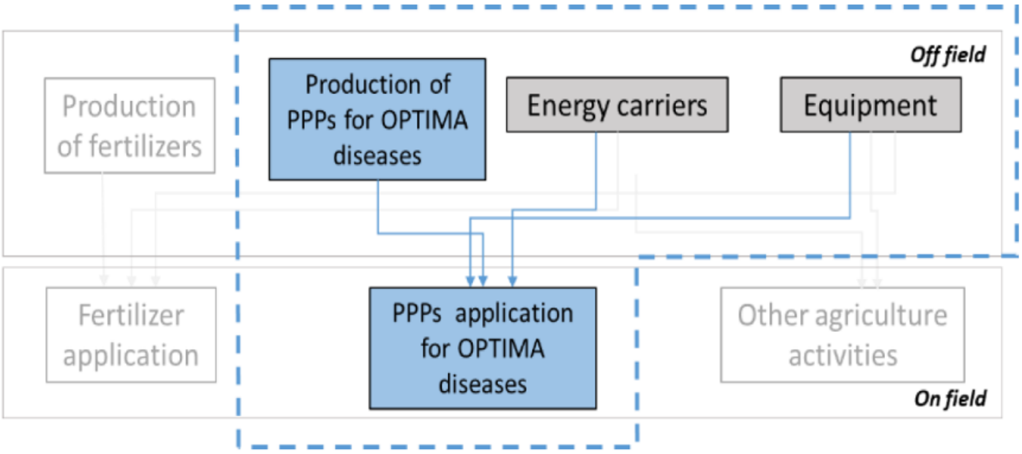
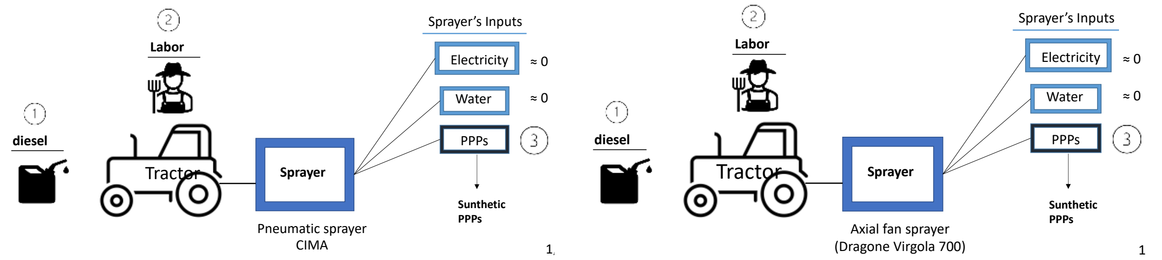


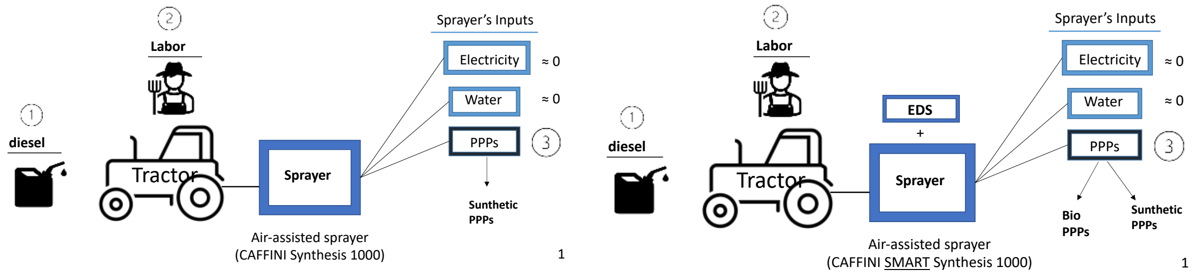
Figure 9 System Boundaries encompassing only the PPPs used to combat downy mildew

Each of the references described above, are illustrated in the Figure below, in terms of the cost constituents that will be analysed through the LCC conducted in this work.



Historical

Reference 0



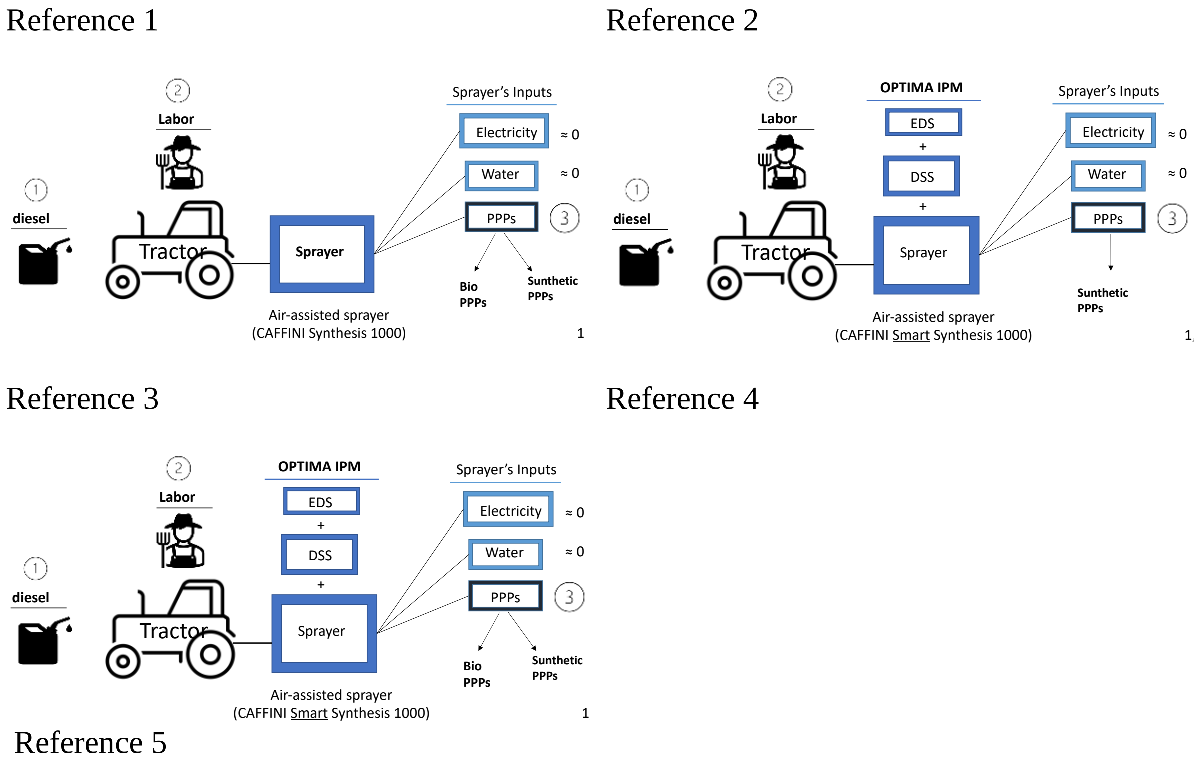


Figure 10 References of the study

3.7.1 Life Cycle Inventory Analysis

Inventory analysis refers to the process of compiling quantitative data on the inputs and emissions from the supply chain under study. Meaning that at this stage of LCC, all the cost drivers and savings for each alternative are identified (Emblemsvåg, 2003). Since there can be a vast variety of different cost drivers, the examples should be given from the case study of this project to keep the content simple to understand. In this study, the following cost drivers will be used:

1. Purchase cost (Spraying System Acquisition- both Hardware and Software-)
2. Operating Cost (Labor, Diesel, PPPs)

Since this study focuses on PPP application specifically to combat downy mildew in vineyards, the activities covered comprise the process of spraying PPPs (System: sprayer, labour) and the inputs considered include the PPPs, the liquid fuels (diesel), machinery (sprayer, EDS), software (DSS and EDS) and labour expenses, while all other expenses are also calculated as a constant cost. The Operating LCC data required are shown in the table below.

Table 6 Scheme for LCC data collection (adopted from Strano et al., 2013)

Considered Elements	Measurement Unit	Description
Fuel consumption	per hour of spraying application	Fuel Consumption per single hour of farming operation.
PPP Treatments	kg/ha/year	Active principles distributed regarding for synthetics and bio-PPPs.
Labour	euro/ ha/year euro/hour	Labour Cost related to Spraying PPPs to combat downy mildew on vineyards.
fertilization	Kg euro/ ha/year euro/hour	Quantities of fertilizers considering titrations of nutritive elements.
Water Consumption	m^3/ha/year	Water Consumption per irrigation and pesticides distribution.
Electricity	KW/ha/year	Energy consumption per spraying operation per hour.
Yield	t/ha/year	Average table grapes produced.

3.7.2 Cost Structure of the Systems

Having defined the system boundaries, it is possible to look at the cost structure that characterizes the above-presented settings for spraying PPPs on vineyard at full production scale (adopted from VinPro 2017). The structure is based on the following:

1. **Direct Cost:** PPPs Distribution, Fertilizer distribution
2. **Labour Cost:**
   - Labour Cost For applying PPPs to Combat Downy Mildew
   - Labour for All Other Operations
     (*Soil management between the rows, Prune and cane removal, Cane tying, Cane shredding, Chemical weeding, Desuckering, Shoot positioning, Topping, Leaf stripping, Green pruning, Soil management on the rows, Spray, Grass shredding, Assistance with manual harvesting, Manual harvest)*
3. **Mechanisation:**

   Proposed Sprayer (and additional compartments if applied): Acquisition Cost

4. **Fixed Improvements:** excluded
5. **General Expenditure:** electricity & water (negligible therefore excluded), (administration: excluded, due to data limitation)
6. **Provision for Renewals:** excluded

The cost centres (for both Investment/Acquisition & Operational Cost) that are considered for the LCC analysis under development are summarized in the table 7 below.

Table 7 Cost Centres for the proposed IPM System

	Investment Cost	**Operating Costs**
Sprayers	X	
EDS	X	annual expense for accessing EDS platform
DSS	X	annual expense for subscription
PPPs		X
Diesel		X
Labour		X

The **Cost Data for the different Spraying Systems** utilised, as well as the additional compartments, EDS and DSS, needed in each of the tested references [References 0-5, Historical] are presented in the Table X below.

Table 8 Cost Data for Spraying Systems

OPTIMA IPM	List Price
Pneumatic CIMA sprayer	6.000 €
Dragone Virgola 700	5.000 €
CAFFINI Synthesis 1000	7.746 €
CAFFINI Smart **Synthesis 1000**	60.000 €
EDS	10.000 €
DSS	800 €
EDS Annual Subscription	500 €
DSS Annual Subscription	200 €

Table 9 Cost Data for Plant Protection Products (Pusabren Farm)

	Synthetic PPPs	Bio-PPPs
Historical	1.879,29 €	
Ref 0	1.978,25 €	
Ref 1	1.978,25 €	
Ref 2 (100% of Ref 1)	1.978,25 €	
Ref 2 (79% of Ref 1)	1.563,87 €	
Ref 3	138,29 €	2.654,00 €

Ref 4 (100% of Ref 1)	1.978,25 €	
Ref 4 (60% of Ref 1)	1.186,95 €	
Ref 4 (40% of Ref 1)	791,30 €	
Ref 5 (100% of Ref 3)	300,82 €	2.654,00 €
Ref 5 (65% of Ref 3)	195,53 €	1.725,10 €
Ref 5 (50% of Ref 3)	150,41 €	1.327,00 €

3.8 Cost Analysis

Before the NPV to be assessed and determined, the Cash Flows of each year of produce were estimated accordingly for each reference under examination. The tables (in APPENDIX) show the Cash Flows of each year for all 6 reference systems (and their variations) examined and represents the basis for both formulas calculations.

3.8.1 Investment Cost

With regards to the investment cost, the farmer is to consider the acquisition cost of the spraying machinery with which the application of plant protection products is to be actualized in the agricultural operations. Therefore, the investment cost varies according to the setting under investigation.

The Cost Data for the different Spraying Systems utilised, as well as the Cost of the additional compartments, EDS and DSS, needed in each of the tested references [References 0-6] are presented in the Table X below. It is important to note that Purchase Price of hardware (sprayer and DSS) is discounted down to 85% of given List Price due to dealer discounts. However, EDS acquisition price as well ass, DSS and EDS annual subscription price are not subject to dealer's discounting:

Table 10 List and Purchase Prices of IPM components

OPTIMA IPM	List Price	Purchase Price
Pneumatic CIMA sprayer	6.000 €	5.100 €
Dragone Virgola 700	5.000 €	4.250 €
CAFFINI Synthesis 1000	7.746 €	6.584 €
CAFFINI Smart **Synthesis 1000**	60.000 €	51.000 €
EDS	10.000 €	10.000 €
DSS	800 €	680 €
EDS Annual Subscription	500 €	500 €
DSS Annual Subscription	200 €	200 €

3.8.1.1. Financial Assumptions

In order to calculate the total cost of owning and operating the sprayer, to finally assess the NPV, a series of assumptions were taken, based on the most common practices identified in the literature review. The financial assumption includes the equipment's salvage value, the discount rate, and the tax rate.

Salvage Value: the salvage Value gives the price of the sprayer when sold, and thus varying according to the moment in time this could happen. Given the 15-year life and following the recommendations from the American Society of Agricultural Engineers (ASAE), a Salvage Value equal to 30%bof sprayer's List Price is assumed.

Discount rate: is used to downweigh the present values of Cash Flows in future periods. The discount rate in financial analysis represents the marginal cost of money to the farm or under investigation (Swinton et al., 1997). This is often based on the rate at which the farm can borrow money, adjusted for risk and inflation expectations (Barry et al., 1995). In this analysis, where inflation is assumed zero, the discount rate is assumed to be 10%.

Tax Rate: The tax rate was assumed to be 20%. For Income tax purposes, depreciation was taken over the Service Life of the Sprayer (T=15 years) following straight line depreciation.

Table 11 Financial Assumptions

Financial Assumptions	Units	Value
Remaining salvage value as percentage of new List price	percentage	30%
Discount rate	percentage	10%
Tax rate	percentage	20%
Service Life	Years/hours	15 years /4500 hrs

Finally, the NPV analyse is also subject to farm characteristics, the equipment used, financial conditions and other matters. Later in this study, several assumptions are varied in the different scenarios employed.

3.8.2 Operational Cost

Operational expenses include the Cost of acquiring PPPs as well as the cost related to the means needed for PPPs application. In this sense operational expenses comprise of; Cost of PPPs, labour cost, diesel, water, and electricity charge. Water and electricity charges related to spraying PPPs are considered negligible and thus are not included.

The final operating costs are given by the following equation and is used for measuring the costs to combat only downy mildew (including cost of labour, diesel, and PPP for this specific applications) or for all operations in the vineyard (including cost of labour, diesel, and PPP for all practices).

$$\boldsymbol{Total\ Operating\ Cost = \ Labor\ Cost\ +\ Diesel\ Cost\ \ +\ PPP\ Cost}$$

Operating Cost have been calculated on a 15 years basis for a given cultivated area 5,91 hectares, where PPPs are applied 12 times a year.

3.8.2.1. Labour Cost

Labour costs are estimated for two occupations distinguishing between Conventional Labour Cost and Skilled Labour Cost. Thus, for the purpose of this study we considered "farmworkers and laborers" as unskilled or conventional Labor (for convectional sprayers), and "agricultural equipment operators" as skilled Labor for the operator of the Smart Sprayer. The wages used in this study are 11 euro/hour and 67 euro/ hour respectively.

The labour cost of each system is calculated based on the equation below and the respective costs are given in Table 10. According to Edwards (2015). Actual hours of labour usually exceed field machine time by 10 to 20 percent, because of travel and the time required to lubricate and service machines, we set labour rate for Conventional Labour at 1,1 and Labour Rate for Skilled Labour at 1,04, to account for time-efficiency implied using IPM systems. Consequently, labour costs can be estimated using the formula below:

$$\begin{aligned}\boldsymbol{Labour\ Cost}&\\ &\boldsymbol{= hourly\ wage\ \times\ operating\ hour\ per\ application}\\ &\boldsymbol{\times No\ of\ applications \times Labor\ rate}\end{aligned}$$

Therefore, using the data from the following table, the labour cost for each of the proposed references was calculated (see Table 12).

Table 12 Labor Data

	Conventional Labor	*Skilled Labor*	*Units*
wage	*11,00 €*	*67,00*	*euro*
Operating hour per ha	*1,5*	*1,50*	*hours/ha*
labor rate	*1,1*	*1,04*	*rate*
Application times	*12*	*12*	*-*
Labor Cost/ha.year	***217,80 €***	***1.254,24 €***	***euro/ha.year***

Table 13 Labor costs of the proposed systems (5,91ha, T=15 years

References	Labor Cost
Historical	19.308 €
Ref 0	19.308 €
Ref 1	19.308 €
Ref 2 (100% of Ref 1)	111.188 €
Ref 2 (79% of Ref 1)	111.188 €
Ref 3	19.308 €
Ref 4 (100% of Ref 1)	111.188 €
Ref 4 (60% of Ref 1)	111.188 €
Ref 4 (40% of Ref 1)	111.188 €
Ref 5 (100% of Ref 3)	111.188 €
Ref 5 (65% of Ref 3)	111.188 €
Ref 5 (50% of Ref 3)	111.188 €

As one can easily observe, the difference in Labour Cost among the various systems under examination results from the differences in Labour Wage and Labour Rate that are implied between Skilled and Convectional Labour requirements. Having set the Skilled Labor Wage almost six times as the conventional one, creates a big difference in Labor Cost.

3.8.2.2. Diesel Cost

The table below included the information related to the Cost for diesel with regards to each proposed system. Diesel Cost remain constant in the systems under examination

$$\boldsymbol{Diesel\ Cost} = \boldsymbol{Diesel\ Consumption\ per\ ha} \times \boldsymbol{Diesel\ Cost\ per\ ha} \\ \times \boldsymbol{Diesel\ Price} \times \boldsymbol{No\ of\ applications}$$

Table 14 Diesel Cost of the proposed systems

References	Diesel Cost
Historical	6.925 €
Ref 0	
Ref 1	
Ref 2 (100% of Ref 1)	
Ref 2 (79% of Ref 1)	
Ref 3	
Ref 4 (100% of Ref 1)	
Ref 4 (60% of Ref 1)	
Ref 4 (40% of Ref 1)	
Ref 5 (100% of Ref 3)	
Ref 5 (65% of Ref 3)	
Ref 5 (50% of Ref 3)	

3.8.2.3. PPPs Cost

In most cases, PPP use is simply estimated by collecting annual PPP sales data and calculating PPP use measured as kilograms of active ingredient per hectare. As each reference attempts to assess the impact from a set of different parameters employed in each setting, Variable Rates (VAR) PPPs have been applied in **Reference 3, Reference 4, and Reference 5 ,** where the **Smart Sprayer** is tested, and therefore they result in different PPPs Cost for each system setting.

Table 15 PPP Cost of the proposed systems

References	Synthetic PPPs Cost	Bio PPPs Cost
Historical	28.189,28 €	
Ref 0	29.673,81 €	
Ref 1	29.673,81 €	
Ref 2 (100% of Ref 1)	29.673,81 €	
Ref 2 (79% of Ref 1)	23.458,10 €	
Ref 3	2.074,41 €	39.810,06 €
Ref 4 (100% of Ref 1)	29.673,81 €	
Ref 4 (60% of Ref 1)	17.804,29 €	
Ref 4 (40% of Ref 1)	11.869,53 €	
Ref 5 (100% of Ref 3)	1.2474,30 €	31.848,04 €
Ref 5 (65% of Ref 3)	2.0932,59 €	25.876,94 €
Ref 5 (50% of Ref 3)	2.258,36 €	19.902,81€

3.9 Farm data

The cost data related to all other operations taking place at a vineyard at full production stage were taken from the Pusabren Farm. More specifically, the farm under investigation follows specific practices that require specific energy use (Table 16), labour (Table 17) and fertilisers (Table 18).

Table 16 Energy Requirements

All other operations	Units	Value
Electricity consumption	kwh/ha.yr	600
Diesel consumption	L(ha.yr)	565

Table 17 Labour Cost for all Other Operations in Vineyards Produce

Labor (Pusabren Farm 2021)	*n/year*	*h/ha*	*hrs.ha/year*	Cost €/h	*Cost operation €*
Fertilizer distribution	1	2,5	2,5	42,00	105,00 €
Soil management between the rows	0,5	3,5	1,8	42,00	73,50 €
Prune and cane removal	1	90	90,0	14,00	1.260,00 €
Cane tying	1	25	25,0	14,00	350,00 €
Cane shredding	1	1,5	1,5	42,00	63,00 €
Chemical weeding	2	2,5	5,0	42,00	210,00 €
Desuckering	2	4,5	9,0	42,00	378,00 €
Desuckering	1	40	40,0	14,00	560,00 €
Shoot positioning	2	35	70,0	14,00	980,00 €
Topping	3	4,5	13,5	42,00	567,00 €
Leaf stripping	1	4,0	4,0	42,00	168,00 €
Green pruning	1	35	35,0	14,00	490,00 €
Soil management on the rows	1	13,0	13,0	42,00	546,00 €
Spray	10	1,5	15,0	42,00	630,00 €
Grass shredding	3	3,0	9,0	42,00	378,00 €
Assistance with manual harvesting	1	9,0	9,0	42,00	378,00 €
Manual harvest	1	90	90,0	14,00	1.260,00 €
Total			433,3		**8.396,50 €**

Table 18 Fertilisation rates

Fertilization	Units	Value
LABIN 8-5-15 (organic Bio product)	kg/ha.yr	400
LABIN 8-5-15 (organic Bio product)	euro/kg	0,50 €

3.10 Equations used to determine NPV

Revenues: Revenue Measuring revenues consists of adding together returns from the sale of agricultural products, government programme receipts and other miscellaneous revenues. In principle, measuring revenues from the sale of farm products is straightforward: it is equal to the unit price received from the sale of the product multiplied by the quantity sold.

Revenues from selling the product are estimated based on estimated future sales:

Revenues= Product Quantity (units of sale) x Unit Product Price

Production Cost is incurred during the preparation of the Production Budget:

Production Cost= Product Quantity (units of production) x Unit product Cost

Basically, is the per unit division of production (both Direct Costs of raw material & labour as well as the Indirect Costs of Production (GIE: General Industrial Expenses)

Gross Profit: is the profit a company makes after deducting the costs associated with making and selling its products, or the costs associated with providing its services. Gross profit will appear on a company's income statement and can be calculated by subtracting the cost of goods sold (COGS) from revenue (sales).

Gross Profit = Revenues – Production Cost (Cost of Goods Manufactured -COGM)

Operational Cost: is determined by the sum of the individual budgets of the other parts of the business (such as: Sales Department, Management Department, Logistics Department)

Gross Profit – Operational Cost = EBITDA (Earnings Before Interest, Taxes & Amortization)

EBITDA: As value it attributes the ability of the investment to create profitability from its operation without accounting for the financial cost and taxation.

EBIT: Earnings Before Interest & Taxes are calculated by adding to EBITDA Income from other investments and deducting the Depreciation from Fixed Assets of the Investment and Amortization of borrowings. This value just like EBITDA is a measure profitability estimation of the investment considering the devaluation of the assets over time as well as repayment of loan funds.

EBIT = EBITDA + Income from other Investments – Depreciation – Amortization

EBT: Earnings before Taxes are estimated by deducting borrowing interest from EBIT

EBT = EBIT - Interest

Taxable Income arises when Interest payments and depreciation are deducted from EBITDA. Then the Tax can be estimated by multiplying the Taxable Income with the Tax Rate

NOCF: Net Operating Cash Flow is estimated by adding Depreciation Expenses to Net Profit

NOCF = EBT + Depreciation – Taxes

4 RESULTS & DISCUSSION

This chapter of the studyanalyzes the findings of the empirical study and discusses them in the context of the research question and framework. The most notable findings are presented in such a way as to clearly display if and how they answer the research question, identifying patterns and linkages in the results. Moreover, the systematic analysis compares and contrasts the findings of the research with the existing literature.

4.1 Operating Cost

Based on the data gathered for each reference, the final Operating Costs regarding crop protection solely from downy mildew are given in the following table.

Table 19 Operating Costs of Spraying PPPs to Combat Downy Mildew (all Systems Proposed

Operating Cost of Spraying PPPs (15 years, 5.91 ha)						
	PPPs (€)	**Labor (€)**	**Diesel (€)**	**EDS (€)**	**DSS (€)**	**Total (€)**
Historical	28.189	19.308	6.925	-	-	54.423
Ref 0	29.674	19.308	6.925	-	-	55.907
Ref 1	29.674	19.308	6.925	-	-	55.907
Ref 2 (100% of Ref1)	29.674	111.188	6.925	7.500	-	155.288
Ref 2 (79% of Ref1)	23.458	111.188	6.925	7.500	-	149.072
Ref 3	41.884	19.308	6.925	-	-	68.118
Ref 4 (100% of Ref1)	29.674	111.188	6.925	7.500	3.000	158.288
Ref 4 (60% of Ref1)	17.804	111.188	6.925	7.500	3.000	146.418
Ref 4 (40% of Ref1)	11.870	111.188	6.925	7.500	3.000	140.483
Ref 5 (100% of Ref3)	44.322	111.188	6.925	7.500	3.000	172.936
Ref 5 (65% of Ref3)	28.810	111.188	6.925	7.500	3.000	157.423
Ref 5 (50% of Ref3)	22.161	111.188	6.925	7.500	3.000	150.775

As for the total operating costs related to all other operations in the selected vineyard (5.91 ha) over 15 years, with regards to all references, are given in the table below.

Table 20 Total Operating Costs of all Other Operations in Vineyard Cultivation (5.91 ha, T= 15 years

Other Operating Costs						
References	**Electricity (€)**	**other diesel (€)**	**mineral fertilisers (€)**	**Other labor (€)**	**Other PPPs (€)**	**Total (€)**
Historical	19.148	35.061	17.730	125.948	1.820	225.187
Ref 0					2.104	229.449
Ref 1					2.104	229.449

Ref 2 (100% of Ref1)	2.104	229.449
Ref 2 (79% of Ref1)	2.053	229.449
Ref 3	2.104	228.688
Ref 4 (100% of Ref1)	2.104	229.449
Ref 4 (60% of Ref1)	2.104	229.449
Ref 4 (40% of Ref1)	2.104	229.449
Ref 5 (100% of Ref3)	1.891	226.251
Ref 5 (65% of Ref3)	1.891	226.251
Ref 5 (50% of Ref3)	1.891	226.251

As one can easily observe, regarding the non-PPPs related tasks, energy requirements (Electricity and Diesel) ,as well as Operating Labour are constant in all references. A fact that does not come by surprise, given that we consider “ceteris paribus” –“all things being equal”- among the vineyard cultivation but the VAR of PPPs. As far as it concerns the other PPPs applied within the general pest and disease management of grapes production, the inventory shows that the Other PPPs Cost is the same for the References (**Ref 0, Ref 1, Ref 2(100%), Ref 3 and Ref 4 (100%,60%,40%)** and equal to 1,820 (€) while in Reference 5 (100%,65%,50) is 1,891 (€) and in the Historical Data equals 1,820(€). This can be explained by the fact that the proposed IPM (Reference 5) can combine different nozzle/air support settings and target PPP applications for achieving the maximum possible reduction in PPP usage. As for **Reference 2,** reduced Other PPPs stands for applying 79% of the PPPs dosage applied in Reference 1.Finally, Historical data, concern data retrieved in the year 2018, and thus other PPPs applied do not much perfectly with the examined settings.

4.2 Net Present Value

In the fifth step on an LCC assessment, comparative analysis between existing alternatives is taking place with the assistance of accessible data regarding cost drivers. Alternative options are evaluated with respect to how much they fulfil the success criteria (Geake, 2002). In this stage, all cost elements are gathered on a table which constitutes the baseline evaluation of the alternatives on focus (Brooks, 1996). In the case where there are missing cost drivers in the evaluation table, extrapolation and assumptions can be employed based on existing database and sources in order to derive missing data (Brooks, 1996).

The NPV analysis of the NOFCs values resulted to the following NPV estimations for the Different Spraying Systems under examination. The NPVs with regards to each system are presented in the table below, and they are ranked according to the success criterion.

Table 21 NPV Results

References	NPV	RANK
Historical	205.568 €	1
Ref 0	204.014 €	2
Ref 1	201.881 €	3
Ref 2 (100% of Ref 1)	112.214 €	9
Ref 2 (79% of Ref 1)	114.736 €	8
Ref 3	197.236 €	4
Ref 4 (100% of Ref 1)	110.401 €	11
Ref 4 (60% of Ref 1)	115.216 €	6
Ref 4 (40% of Ref 1)	117.624 €	5
Ref 5 (100% of Ref 3)	105.756 €	12
Ref 5 (65% of Ref 3)	112.049 €	10
Ref 5 (50% of Ref 3)	114.746 €	7

The results indicate that the most profitable investment is the Historical Spraying system as it has the highest positive NPV among all spraying systems examined. The least profitable investment seems to be the Ref 5 (100% of Ref 3), indicating that the huge capital expenditure in Initial Investment (Purchase Cost), alongside the additional subscription costs for the utilisation of the EDS and DSS but mostly the extremely high labour cost for skilled employees, cannot counterbalance for the given setting of 5,91 hectares cultivated area and a horizon of 15 years of table-grapes cultivation.

4.3 Scenarios Analysis

The final step in LCC is the application of sensitivity and risk analyses on the baseline life-cycle cost evaluation. Sensitivity analysis is performed in order to find out the relative impact of each cost driver on the total life cycle cost. This is basically performed via changing a single cost driver each time and observing the impact on the total cost (Brooks,.1996). Once the NPVs were determined for each reference, the author wanted to assess the NPVs Volatility on proportional alternations on nine parameters, that were identified to have diversified impacts on the NPVs of the systems under examination as they would affect different cost centres. We considered the parameters that could impact the cost centres (**Labor** {labour wage, labour, rate**}, IPM acquisition cost** {sprayer's price, EDS's price, and annual subscription fee, DSS price EDS's price and annual subscription fee } as well as the **cost of Bio-PPPs and premium grapes price resulting from the cultivation with IPM.**

Table 22 Parameters

Parameters	
1.	**Change in Skilled Labour Wage**
2.	**Change in Skilled Labour Rate**
3.	**Change in Smart Sprayers Acquisition Price**
4.	**Change in Premium Grapes Price**
5.	**Change in Bio-PPPs Price**
6.	**Change in EDS's Acquisition Price**
7.	**Change in DSS's Acquisition Price**
8.	**Change in EDS's Annual Subscription Cost**
9.	**Change in EDS's Annual Subscription Cost**

Each of above-presented parameters has been alternated to percentage changes of: 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% in order to observe the impact of each percentage alternation on the NPVs of the proposed spraying systems.

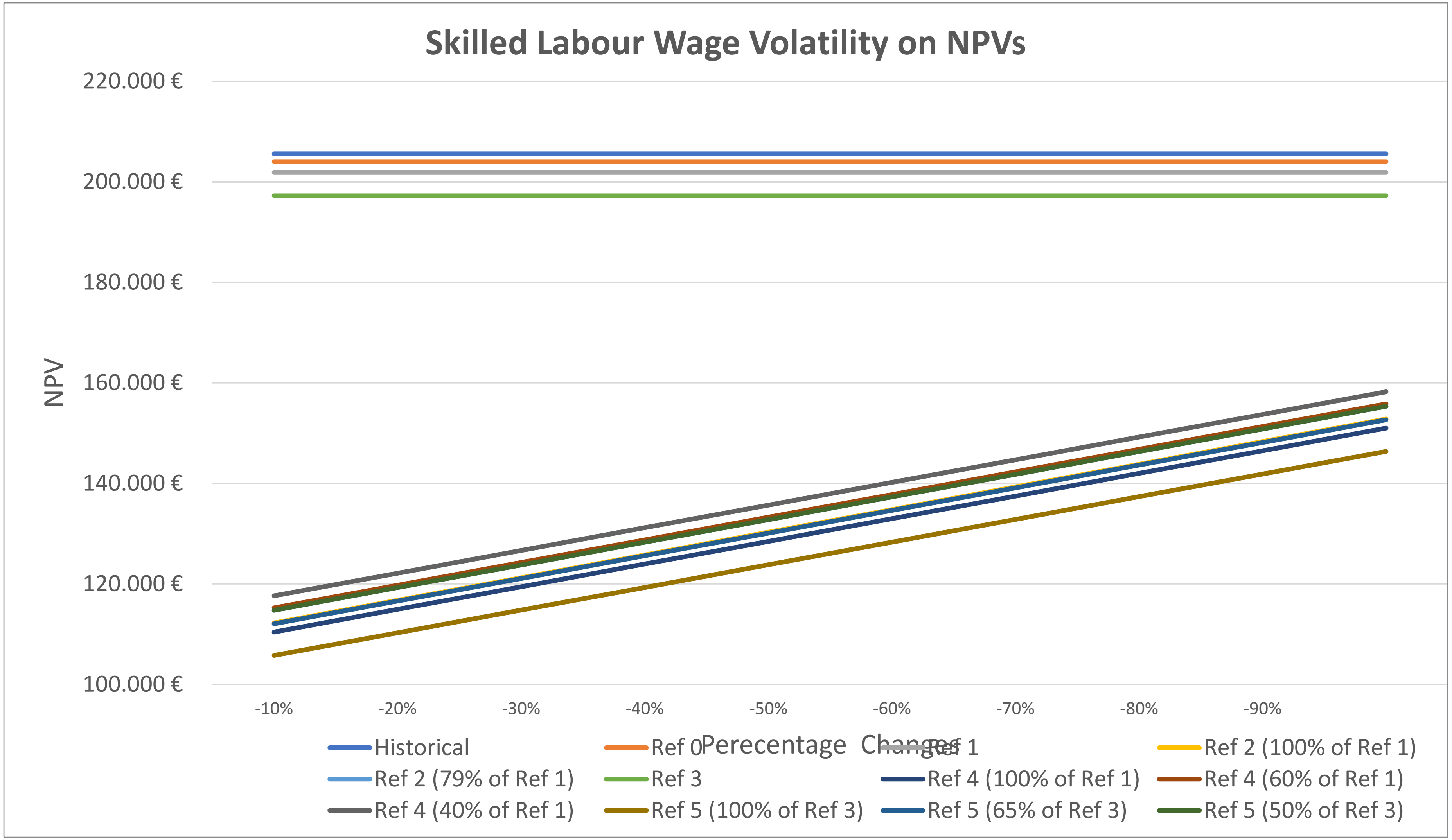
4.3.1 Skilled Labour Wage Volatility on NPVs

Skilled Labour Wage Cost was initially at 67(€/hour). Alternating the initial value to percentage reductions of 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% resulted in the following NPVs for the spraying systems under investigation, displayed in Table (23). As one can easily observe, any percentage change in Skilled Labour Wage does not have any impact on the NPVs Ranking of the corresponding systems **(Reference 2, Reference 4, and Reference 5)**. In fact, even an 80% or 90% reduction which would set the Skilled Labour Wage at a more competitive price of 13,40 (€/hr) compared to the Conventional Labour Wage at 11(€/hour) will not affect the rankings of the NPVs. Meaning that although one of the main cost drivers is reduced dramatically the Proposed Full IPM does not result in a more economically profitable investment. All things considered, the results from the examination of different Skilled Labour Wages, implied by the proposed IPM, have revealed that even if there was cheaper Labour than the one employed in Conventional practices, the accumulated costs implied by the acquisition and utilisation of the proposed IPM will result being the least profitable investment among the others.

Table 23 Skilled Labour Wage Volatility on NPVs

	Scenario Summary	Labor Wage Volatility on NPVs																			
		Current Values:		-10%		-20%		-30%		-40%		-50%		-60%		-70%		-80%		-90%	
	Changing Cells:																				
	% change of Skilled Labor Wage	0%		-10%		-20%		-30%		-40%		-50%		-60%		-70%		-80%		-90%	
	Skilled Labor wage (euro/hour)	€ 67,00		€ 60,30		€ 53,60		€ 46,90		€ 40,20		€ 33,50		€ 26,80		€ 20,10		€ 13,40		€ 6,70	
	Result Cells:		rank		rank		rank		rank		rank		rank		rank		rank		rank		rank
	Historical	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1
	Ref 0	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2
	Ref 1	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3
	Ref 2 (100% of Ref 1)	112.214 €	9	116.725 €	9	121.235 €	9	125.746 €	9	130.256 €	9	134.767 €	9	139.277 €	9	143.787 €	9	148.298 €	9	152.808 €	9
smart & EDS	Ref 2 (79% of Ref 1)	114.736 €	8	119.246 €	8	123.757 €	8	128.267 €	8	132.778 €	8	137.288 €	8	141.798 €	8	146.309 €	8	150.819 €	8	155.330 €	8
Bio	Ref 3	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4
	Ref 4 (100% of Ref 1)	110.401 €	11	114.912 €	11	119.422 €	11	123.932 €	11	128.443 €	11	132.953 €	11	137.464 €	11	141.974 €	11	146.485 €	11	150.995 €	11
smart &EDS	Ref 4 (60% of Ref 1)	115.216 €	6	119.727 €	6	124.237 €	6	128.747 €	6	133.258 €	6	137.768 €	6	142.279 €	6	146.789 €	6	151.300 €	6	155.810 €	6
&DSS	Ref 4 (40% of Ref 1)	117.624 €	5	122.134 €	5	126.644 €	5	131.155 €	5	135.665 €	5	140.176 €	5	144.686 €	5	149.197 €	5	153.707 €	5	158.218 €	5
	Ref 5 (100% of Ref 3)	105.756 €	12	110.267 €	12	114.777 €	12	119.288 €	12	123.798 €	12	128.309 €	12	132.819 €	12	137.329 €	12	141.840 €	12	146.350 €	12
smart EDS&	Ref 5 (65% of Ref 3)	112.049 €	10	116.560 €	10	121.070 €	10	125.581 €	10	130.091 €	10	134.601 €	10	139.112 €	10	143.622 €	10	148.133 €	10	152.643 €	10
DSS & Bio	Ref 5 (50% of Ref 3)	114.746 €	7	119.257 €	7	123.767 €	7	128.277 €	7	132.788 €	7	137.298 €	7	141.809 €	7	146.319 €	7	150.830 €	7	155.340 €	7

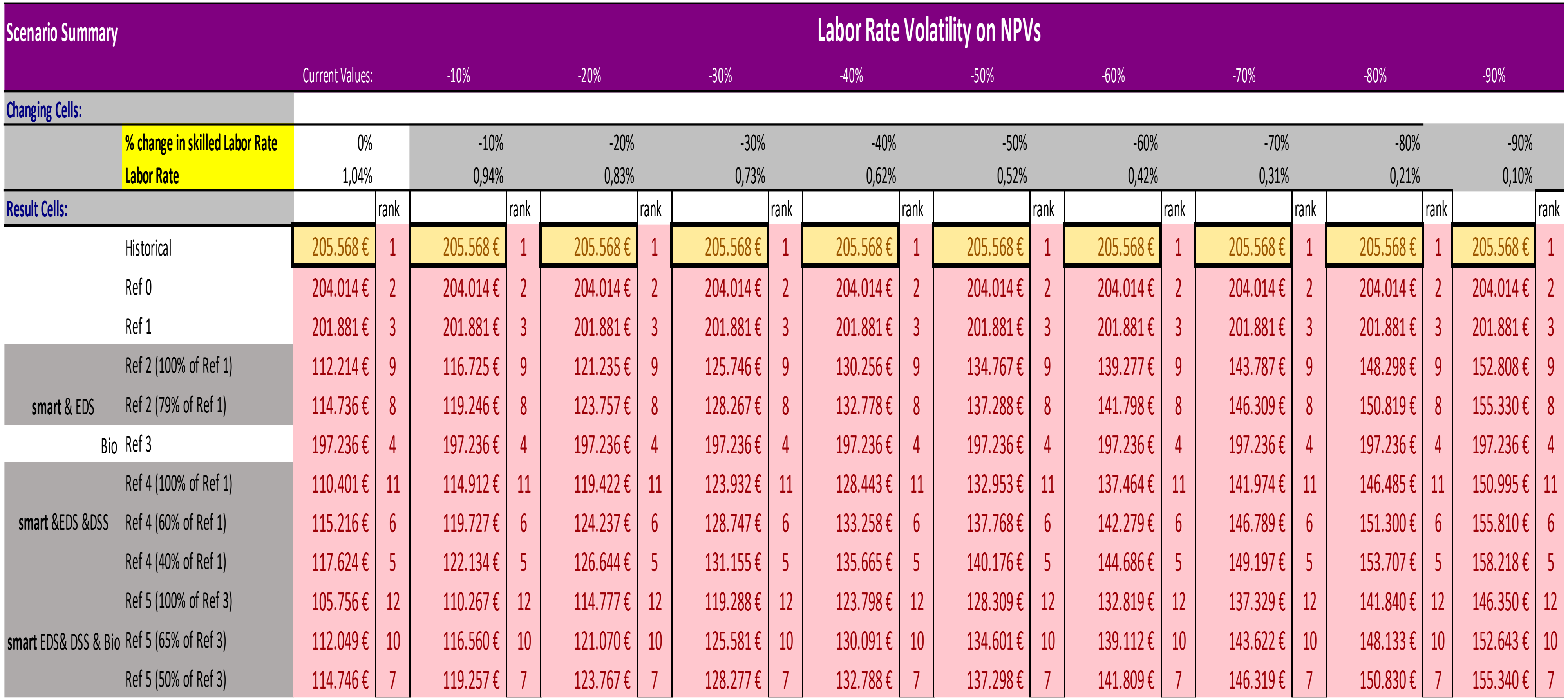
Figure 11 Skilled Labour Wage Volatility on NPVs



4.3.2 Skilled Labour Rate Volatility on NPVs

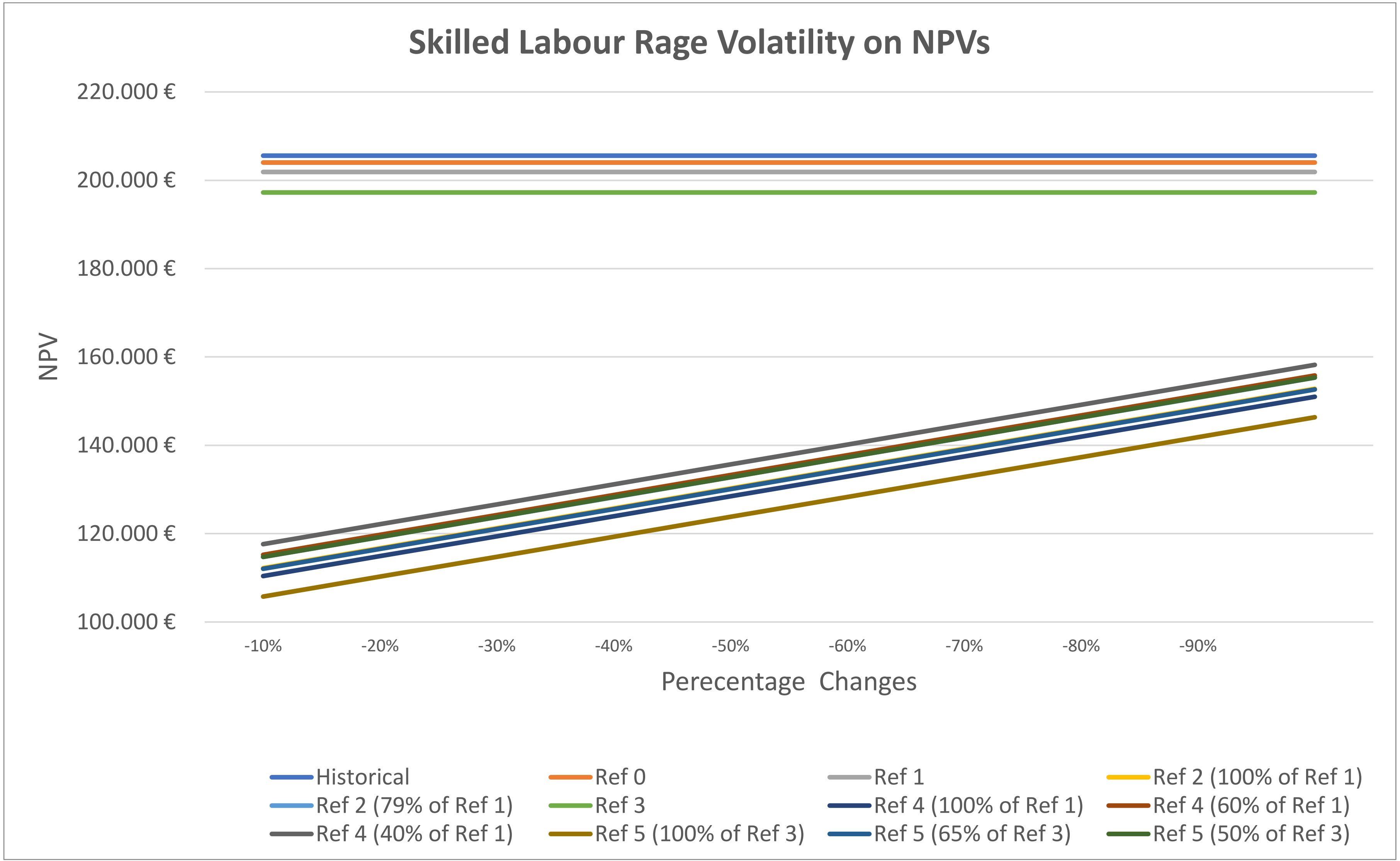
As machinery capacity increases, the number of hours required to complete field operations Skilled Labour Rate was initially set at 1,04 to account for the reduction in preparatory time for the Skilled Labour implied by the utilisation of the IPM, compared to 1,10 attributed to the Conventional practices. Alternating the initial value of Skilled Labour rate to percentage reductions of 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% resulted in the following NPVs for the spraying systems under investigation (Table 24). As one could expect any alternation in the Skilled Labour rate is not solely enough to counterbalance the Cost of Skilled Labour implied by the utilisation of the IPM alongside the huge expenses related to the Spraying System acquisition.

Table 24 Skilled Labour Rate Volatility on NPVs



Scenario Summary		Labor Rate Volatility on NPVs																			
		Current Values:		-10%		-20%		-30%		-40%		-50%		-60%		-70%		-80%		-90%	
Changing Cells:																					
	% change in skilled Labor Rate	0%		-10%		-20%		-30%		-40%		-50%		-60%		-70%		-80%		-90%	
	Labor Rate	1,04%		0,94%		0,83%		0,73%		0,62%		0,52%		0,42%		0,31%		0,21%		0,10%	
Result Cells:			rank		rank		rank		rank		rank		rank		rank		rank		rank		rank
	Historical	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1
	Ref 0	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2
	Ref 1	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3
smart & EDS	Ref 2 (100% of Ref 1)	112.214 €	9	116.725 €	9	121.235 €	9	125.746 €	9	130.256 €	9	134.767 €	9	139.277 €	9	143.787 €	9	148.298 €	9	152.808 €	9
	Ref 2 (79% of Ref 1)	114.736 €	8	119.246 €	8	123.757 €	8	128.267 €	8	132.778 €	8	137.288 €	8	141.798 €	8	146.309 €	8	150.819 €	8	155.330 €	8
Bio	Ref 3	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4
smart &EDS &DSS	Ref 4 (100% of Ref 1)	110.401 €	11	114.912 €	11	119.422 €	11	123.932 €	11	128.443 €	11	132.953 €	11	137.464 €	11	141.974 €	11	146.485 €	11	150.995 €	11
	Ref 4 (60% of Ref 1)	115.216 €	6	119.727 €	6	124.237 €	6	128.747 €	6	133.258 €	6	137.768 €	6	142.279 €	6	146.789 €	6	151.300 €	6	155.810 €	6
	Ref 4 (40% of Ref 1)	117.624 €	5	122.134 €	5	126.644 €	5	131.155 €	5	135.665 €	5	140.176 €	5	144.686 €	5	149.197 €	5	153.707 €	5	158.218 €	5
smart EDS& DSS & Bio	Ref 5 (100% of Ref 3)	105.756 €	12	110.267 €	12	114.777 €	12	119.288 €	12	123.798 €	12	128.309 €	12	132.819 €	12	137.329 €	12	141.840 €	12	146.350 €	12
	Ref 5 (65% of Ref 3)	112.049 €	10	116.560 €	10	121.070 €	10	125.581 €	10	130.091 €	10	134.601 €	10	139.112 €	10	143.622 €	10	148.133 €	10	152.643 €	10
	Ref 5 (50% of Ref 3)	114.746 €	7	119.257 €	7	123.767 €	7	128.277 €	7	132.788 €	7	137.298 €	7	141.809 €	7	146.319 €	7	150.830 €	7	155.340 €	7

Figure 12 Skilled Labour Rate Volatility on NPVs



4.3.3 Smart Sprayers Acquisition Price Volatility on NPVs

Smart Sprayer's Acquisition Price (Caffini Smart Synthesis 1000) was initially at 51,000 (euro) while the most affordable alternative was provided at only 5,100 (euro)(Pneumatic CIMA Sprayer). The author wanted to assess whether proportional alternation of the initial Smart Sprayers value to percentage reductions of 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% could result in different NPVs ranking.

The Table (25) below presents the new NPVs for the spraying systems under investigation with regards to the above-mentioned cost reduction. One can easily observe that even a reduction of 90% in the Smart Sprayer's acquisition price, setting it in this way equal to the most conventional alternative displayed in the Historical Reference (Pneumatic CIMA Sprayer), would not result in a greater NPV than the one of the Historical references. This is to say that there are production costs (Diesel, bio-PPPs, Skilled Labor) associated with the employment of the Smart Sprayer that always exceeds the cost associated with the most convectional practices. This is an interesting observation meaning that, although the Smart Sprayer reduces the synthetic PPPs applied in the field the additional expenses associated with EDS, DSS and bio-PPPs that result in the Smart options being less economically sustainable.

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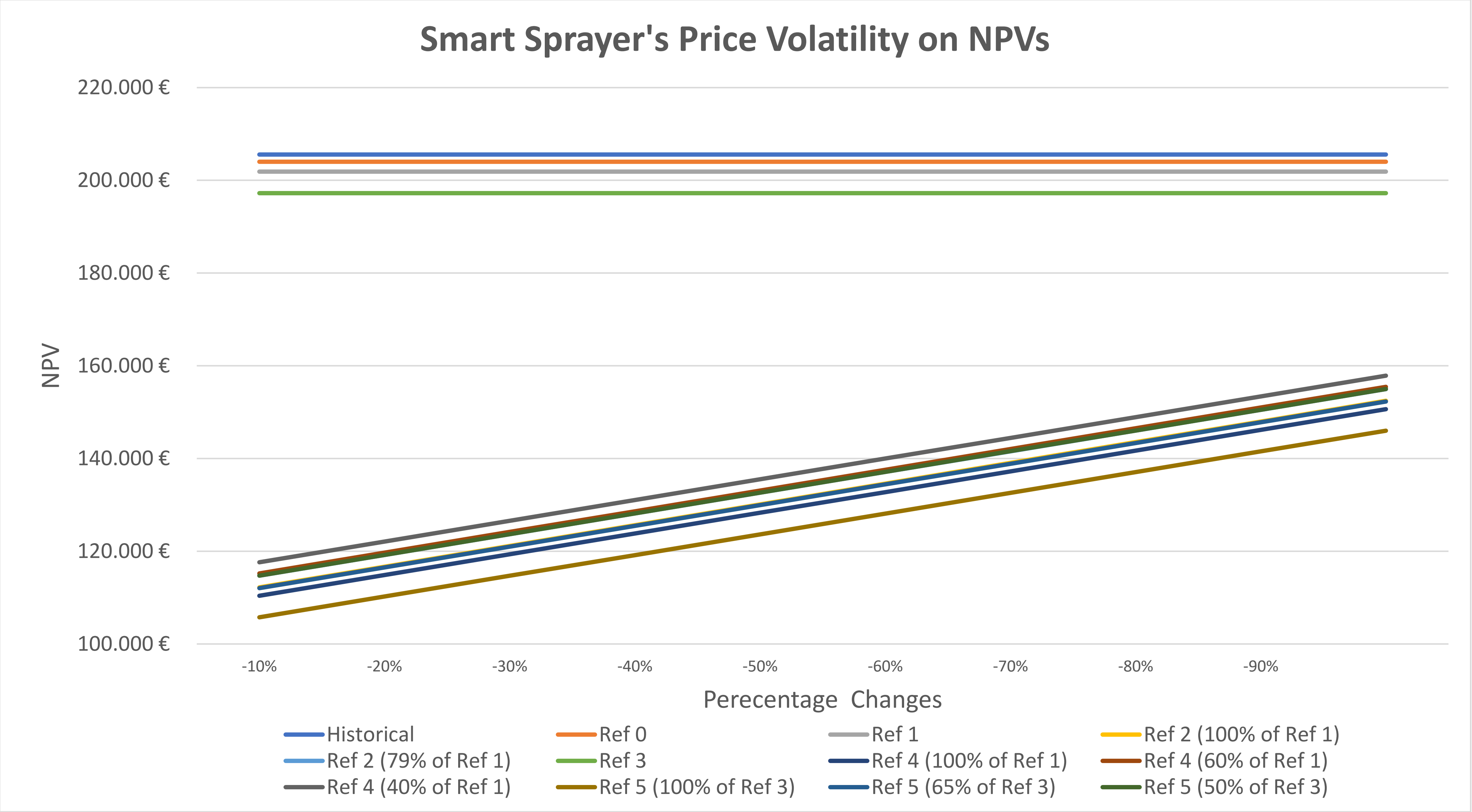
Table 25 Smart Sprayer's Price Volatility on NPVs

Scenario Summary		**Smart Sprayer's Price Volatility on NPVs**																			
		Current Values:		-10%		-20%		-30%		-40%		-50%		-60%		-70%		-80%		-90%	
Changing Cells:																					
	% change in smart Sprayer's Acquisition Cost	**0%**		**-10%**		**-20%**		**-30%**		**-40%**		**-50%**		**-60%**		**-70%**		**-80%**		**-90%**	
	Caffini Smart Synthesis 1000 Price	51.000,00 €		45.900,00 €		40.800,00 €		35.700,00 €		30.600,00 €		25.500,00 €		20.400,00 €		15.300,00 €		10.200,00 €		5.100,00 €	
Result Cells:			rank		rank		rank		rank		rank		rank		rank		rank		rank		rank
	Historical	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1
	Ref 0	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2
	Ref 1	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3
smart & EDS	Ref 2 (100% of Ref 1)	112.214 €	9	116.686 €	9	121.157 €	9	125.629 €	9	130.100 €	9	134.572 €	9	139.043 €	9	143.515 €	9	147.986 €	9	152.458 €	9
	Ref 2 (79% of Ref 1)	114.736 €	8	119.207 €	8	123.679 €	8	128.150 €	8	132.622 €	8	137.093 €	8	141.565 €	8	146.036 €	8	150.508 €	8	154.979 €	8
Bio	Ref 3	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4
smart &EDS &DSS	Ref 4 (100% of Ref 1)	110.401 €	11	114.873 €	11	119.344 €	11	123.816 €	11	128.287 €	11	132.759 €	11	137.230 €	11	141.702 €	11	146.173 €	11	150.645 €	11
	Ref 4 (60% of Ref 1)	115.216 €	6	119.688 €	6	124.159 €	6	128.631 €	6	133.102 €	6	137.574 €	6	142.045 €	6	146.517 €	6	150.988 €	6	155.460 €	6
	Ref 4 (40% of Ref 1)	117.624 €	5	122.095 €	5	126.567 €	5	131.038 €	5	135.510 €	5	139.981 €	5	144.453 €	5	148.924 €	5	153.396 €	5	157.867 €	5
smart EDS& DSS & Bio	Ref 5 (100% of Ref 3)	105.756 €	12	110.228 €	12	114.699 €	12	119.171 €	12	123.642 €	12	128.114 €	12	132.585 €	12	137.057 €	12	141.528 €	12	146.000 €	12
	Ref 5 (65% of Ref 3)	112.049 €	10	116.521 €	10	120.992 €	10	125.464 €	10	129.935 €	10	134.407 €	10	138.878 €	10	143.350 €	10	147.821 €	10	152.293 €	10
	Ref 5 (50% of Ref 3)	114.746 €	7	119.218 €	7	123.689 €	7	128.161 €	7	132.632 €	7	137.104 €	7	141.575 €	7	146.047 €	7	150.518 €	7	154.990 €	7

Figure 13 Smart Sprayer's Price Volatility on NPVs



4.3.4 Change in Bio PPPs Price

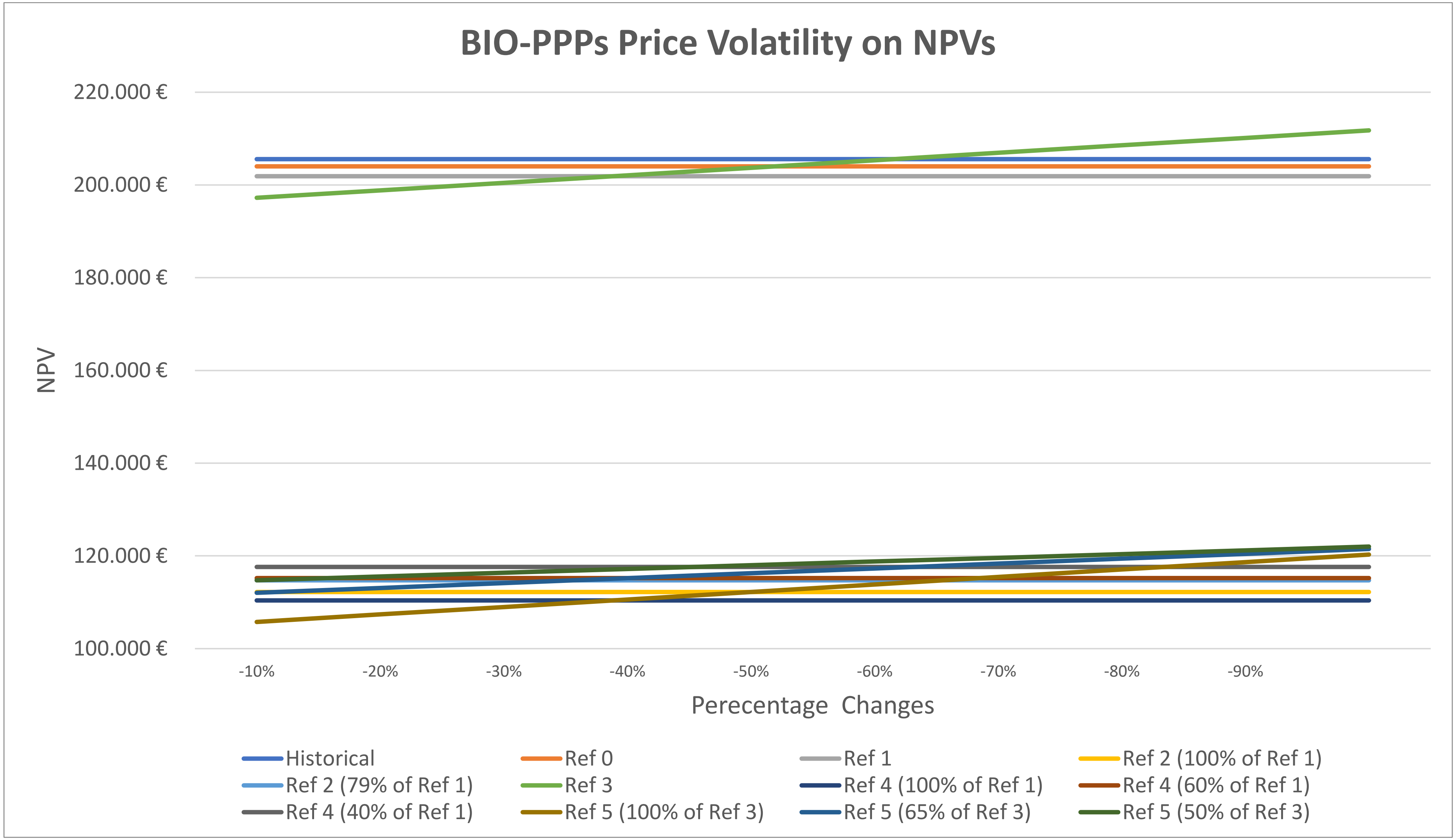
One of the most important aspects regarding the Spart Spraying Systems, is its ability to combine synthetic and Bio PPPs and apply them exactly in the area of the plant that needs treatment. In this way, it is possible to reduce the PPPs residues, both on grapes and in soil, while at the same time keeping the production yield unchanged. One could not help but notice that the cost of Bio PPPs is an important cost element, as Bio PPPs are offered in higher market prices than the conventional ones. Therefore, the author wanted to assess the impact of Bio PPPs price Volatility on the various NPVs. In line with this, the price of Bio-PPPs has been proportionally alternated to account for 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% reduction of their initial price. Table (26) below includes the new NPVs calculated for the above-mentioned reduction in Bio PPPs prices.

Variations in the NPV regard only the spraying systems that utilise Bio PPPs. This means that one would expect to see different NPVs only in Reference 3 and Reference 5 (100%,65%,50%). Results indicate that for up to 40% reduction in Bio PPPs Price, the Historical Reference remains ranked as the first and most economic viable option, followed by the Ref 0. An interesting observation is that for a 50% reduction in Bio-PPPs Price, Reference 3 turns out to be the second most profitable investment, while for any higher reduction in Bio PPPs price Reference 3 would be the most profitable investment option. However, the full IPM spraying setting examined at Reference 5 (100%, 65%, 50%) does exceed the threshold value set by the Historical Reference for any change in Bio PPPs Price. This illustrated that even if Bio PPPs were provided at a price 9 times cheaper than the current one, still, the NPV of Proposed IPM (Reference 5-all %) will not be any close to the threshold value.

Table 26 BIO-PPPs Price Volatility on NPVs

Scenario Summary		BIO-PPPs Price Volatility on NPVs																			
		Current Values:		-10%		-20%		-30%		-40%		-50%		-60%		-70%		-80%		-90%	
Changing Cells:																					
	Bio_PPPs_price	0%		-10%		-20%		-30%		-40%		-50%		-60%		-70%		-80%		-90%	
Result Cells:			rank		rank		rank		rank		rank		rank		rank		rank		rank		rank
smart & EDS	Historical	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	2	205.568 €	2	205.568 €	2	205.568 €	2
	Ref 0	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	3	204.014 €	3	204.014 €	3	204.014 €	3	204.014 €	3
	Ref 1	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	4	201.881 €	4	201.881 €	4	201.881 €	4	201.881 €	4	201.881 €	4	201.881 €	4
	Ref 2 (100% of Ref 1)	112.214 €	9	112.214 €	10	112.214 €	10	112.214 €	10	112.214 €	11	112.214 €	11	112.214 €	11	112.214 €	11	112.214 €	11	112.214 €	11
	Ref 2 (79% of Ref 1)	114.736 €	8	114735,7481	8	114.736 €	8	114.736 €	9	114.736 €	9	114.736 €	9	114.736 €	10	114.736 €	10	114.736 €	10	114.736 €	10
Bio	Ref 3	197.236 €	4	198.851 €	4	200.466 €	4	202.081 €	3	203.696 €	3	205.311 €	2	206.926 €	1	208.541 €	1	210.155 €	1	211.770 €	1
smart &EDS &DSS	Ref 4 (100% of Ref 1)	110.401 €	11	110.401 €	11	110.401 €	11	110.401 €	12	110.401 €	12	110.401 €	12	110.401 €	12	110.401 €	12	110.401 €	12	110.401 €	12
	Ref 4 (60% of Ref 1)	115.216 €	6	115.216 €	7	115.216 €	7	115.216 €	7	115.216 €	8	115.216 €	8	115.216 €	9	115.216 €	9	115.216 €	9	115.216 €	9
	Ref 4 (40% of Ref 1)	117.624 €	5	117.624 €	5	117.624 €	5	117.624 €	5	117.624 €	6	117.624 €	6	117.624 €	7	117.624 €	7	117.624 €	8	117.624 €	8
smart EDS& DSS& Bio	Ref 5 (100% of Ref 3)	105.756 €	12	107.371 €	12	108.986 €	12	110.601 €	11	112.216 €	10	113.831 €	10	115.446 €	8	117.061 €	8	118.676 €	7	120.291 €	7
	Ref 5 (65% of Ref 3)	112.049 €	10	113.099 €	9	114.149 €	9	115.198 €	8	116.248 €	7	117.298 €	7	118.347 €	6	119.397 €	6	120.447 €	6	121.497 €	6
	Ref 5 (50% of Ref 3)	114.746 €	7	115.554 €	6	116.361 €	6	117.169 €	6	117.976 €	5	118.783 €	5	119.591 €	5	120.398 €	5	121.206 €	5	122.013 €	5

Figure 14 BIO-PPPs Price Volatility on NPVs



4.3.5 Change in Premium Grapes Price

Another very important aspect related to Smart IPM adoption is its ability to add value to the production, by eliminating the PPPs residues on the grapes. In this way grapes cultivated with IPM can be considered premium grapes, or high-quality products. Empirical studies have shown that consumers are willing to pay a price premium for green products owing to the additional utility they gain from purchasing such products (Hopkins and Roche, 2009). Thus, it was deemed reasonable to project scenarios for different selling prices for the grapes cultivated with Smart IPM setting to account for **incremental incomes** that can be achieved by choosing an environmentally friendly alternative (Savic et al., 2019). Scenarios below alternate Grapes Price so as it is increased proportionally 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% from the initial price (1 euro/kg).

Table 24 below shows the new NPVs for the increased premium grapes price.

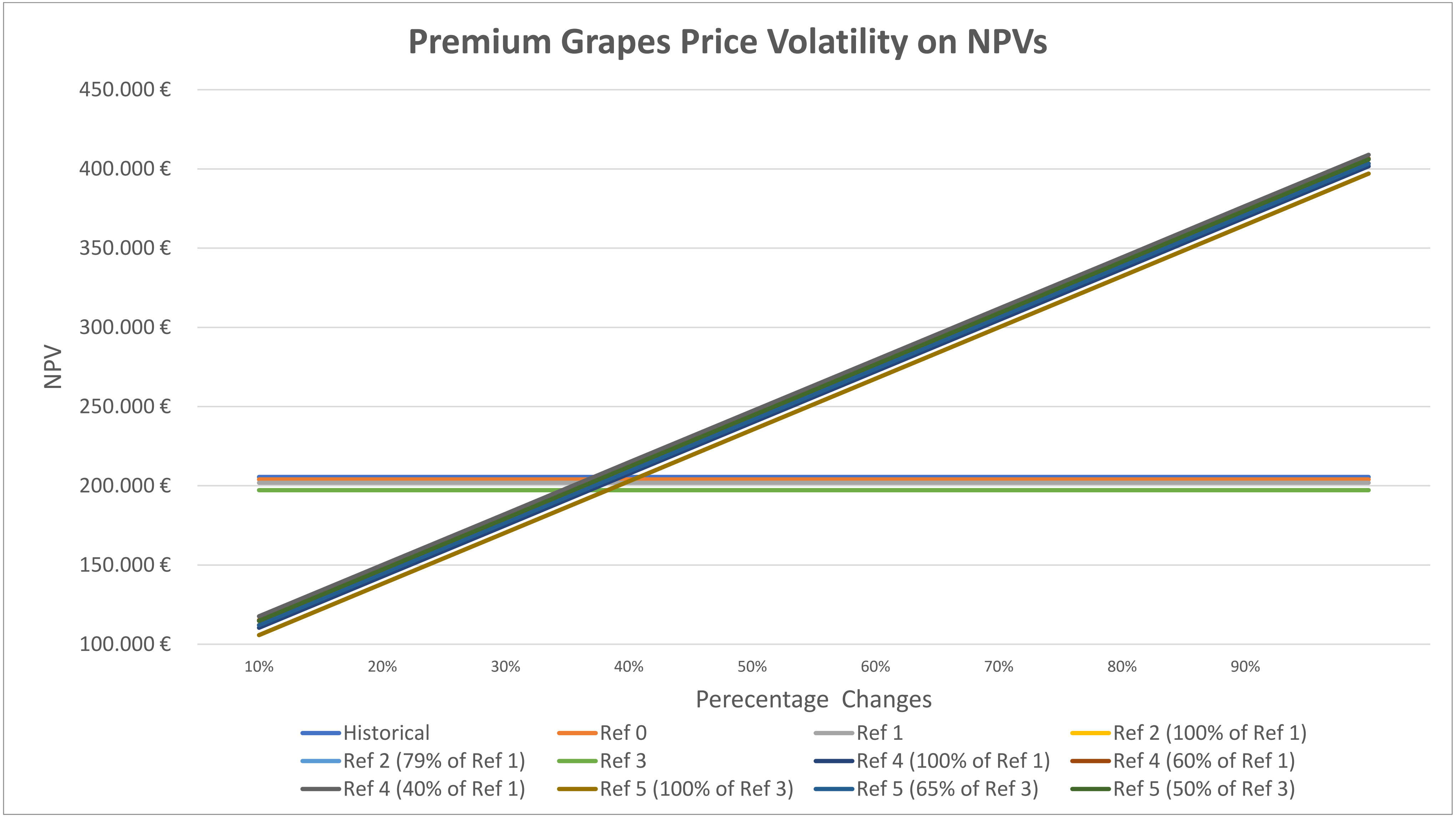
It becomes evident that for any increase in grapes price (for those cultivated with Smart IPM) higher than 30% Smart IPM adaptation can be proven more beneficial as the direct increase in the Revenue stream result in NPVs that exceed the threshold set by the Historical Reference. In fact, for a 30% increase in premium grapes price all reference settings including the Smart IPM turn out more profitable for the farmer, although the huge initial capital expenditure for the FULL IPM acquisition.

It becomes clear, that any increase in grapes price, justified as a premium price for premium products, have a direct impact on NPV through increasing farmer's Revenue. Finally, revenues can increase due to different reasons. It should be noted that measuring revenues consists of adding together returns from the sale of agricultural products, government programme receipts and other miscellaneous revenues. Government programme receipts are programme or support payments that relate to the sale or production of those same products, and thus can play an important role in the extent to which farmers are motivated, enabled, and legitimised motivated to consider employing IPM spraying systems.

Table 27 Premium Grapes Price Volatility on NPVs

Scenario Summary		Premium Grapes Price Volatility on NPVs																			
		Current Values:		10%		20%		30%		40%		50%		60%		70%		80%		90%	
Changing Cells:																					
	grapes_price_premium	**0%**		**10%**		**20%**		**30%**		**40%**		**50%**		**60%**		**70%**		**80%**		**90%**	
	grapes price	1,00 €		1,10 €		1,20 €		1,30 €		1,40 €		1,50 €		1,60 €		1,70 €		1,80 €		1,90 €	
Result Cells:			rank		rank		rank		rank		rank		rank		rank		rank		rank		rank
	Historical	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	8	205.568 €	9	205.568 €	9	205.568 €	9	205.568 €	9	205.568 €	9	205.568 €	9
	Ref 0	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	9	204.014 €	10	204.014 €	10	204.014 €	10	204.014 €	10	204.014 €	10	204.014 €	10
	Ref 1	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	11	201.881 €	11	201.881 €	11	201.881 €	11	201.881 €	11	201.881 €	11	201.881 €	11
smart & EDS	Ref 2 (100% of Ref 1)	112.214 €	9	144.580 €	9	176.945 €	9	209.310 €	5	241.676 €	5	274.041 €	5	306.407 €	5	338.772 €	5	371.137 €	5	403.503 €	5
	Ref 2 (79% of Ref 1)	114.736 €	8	147.101 €	8	179.467 €	8	211.832 €	4	244.197 €	4	276.563 €	4	308.928 €	4	341.293 €	4	373.659 €	4	406.024 €	4
Bio	Ref 3	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	12	197.236 €	12	197.236 €	12	197.236 €	12	197.236 €	12	197.236 €	12	197.236 €	12
smart &EDS &DSS	Ref 4 (100% of Ref 1)	110.401 €	11	142.767 €	11	175.132 €	11	207.497 €	7	239.863 €	7	272.228 €	7	304.593 €	7	336.959 €	7	369.324 €	7	401.690 €	7
	Ref 4 (60% of Ref 1)	115.216 €	6	147.581 €	6	179.947 €	6	212.312 €	2	244.678 €	2	277.043 €	2	309.408 €	2	341.774 €	2	374.139 €	2	406.505 €	2
	Ref 4 (40% of Ref 1)	117.624 €	5	149.989 €	5	182.354 €	5	214.720 €	1	247.085 €	1	279.451 €	1	311.816 €	1	344.181 €	1	376.547 €	1	408.912 €	1
smart EDS& DSS & Bio	Ref 5 (100% of Ref 3)	105.756 €	12	138.122 €	12	170.487 €	12	202.852 €	10	235.218 €	8	267.583 €	8	299.949 €	8	332.314 €	8	364.679 €	8	397.045 €	8
	Ref 5 (65% of Ref 3)	112.049 €	10	144.415 €	10	176.780 €	10	209.145 €	6	241.511 €	6	273.876 €	6	306.242 €	6	338.607 €	6	370.972 €	6	403.338 €	6
	Ref 5 (50% of Ref 3)	114.746 €	7	147.112 €	7	179.477 €	7	211.842 €	3	244.208 €	3	276.573 €	3	308.939 €	3	341.304 €	3	373.669 €	3	406.035 €	3

Figure 15 Premium Grapes Price Volatility on NPVs



4.3.6 Change in DSS price

The scenarios analysis for DSS's price volatility and its impact on NPV showed (Table 29) that there was a DSS price that would result in any change on the rankings of the NPVs. One can only observe minor changes in NPV values resulting from the reduced DSS's price, which obviously does not impact the profitability ranking of the proposed spraying systems. This implicates that, even, a 90% cost reduction in DSS acquisition price would not result in making the proposed IPM a more attractive investment option.

4.3.7 Change in EDS price

The scenario analysis regarding EDS's price(Table 28) has revealed that even the highest percentage change of 90% in the EDS acquisition price will imply minor changes in NPV values, which results in zero impact on the ranking of the proposed spraying systems. This does not come surprisingly as the EDS price is considered a minor investment cost accounting for only 680 euros. For the proposed IPM, this implies that even, a 90% cost reduction in EDS's Price would not result in making it look more attractive to investors.

4.3.8 Change in EDS Annual Subscription Fee

EDS Annual Subscription Fee amounts to only 200 euro, thus any reduction in this cost, would not impact the overall cost significantly. As it has been the case for reduction in EDS's price, the same hold for EDS's Annual Subscription fee, meaning that any related cost reduction will have a minor effect on NPV values, and there is zero impact on the ranking of the proposed spraying systems. This implicates that, even, a 90% cost reduction in EDS's Annual Sub Fee would not result in making the proposed IPM a more attractive investment option. Scenario analysis results are displayed in Table (31).

4.3.9 Change in DSS Annual Subscription Fee

DSS Annual Subscription Fee amounting to 500 euro, represents a small cost in the total cost structure of the proposed IPM. Therefore, only minor Changes in NPV values are noted due to percentage reductions in DSS's Annual Fee. Consequently, such negligible changes have no impact on the ranking of the proposed spraying systems, and thus even a 90% cost reduction in DSS's Annual Fee would not result in making it look more attractive it to investors.

Table 28 EDS Acquisition Price Volatility on NPVs

Scenario Summary		DSS Acquisition Price Volatility on NPVs																			
		Current Values:		-10%		-20%		-30%		-40%		-50%		-60%		-70%		-80%		-90%	
Changing Cells:																					
	% change in DSS_Acq_Price	**0%**		**-10%**		**-20%**		**-30%**		**-40%**		**-50%**		**-60%**		**-70%**		**-80%**		**-90%**	
	DSS_Acq_Price	680 €		612,00 €		544,00 €		476,00 €		408,00 €		340,00 €		272,00 €		204,00 €		136,00 €		68,00 €	
Result Cells:			rank		rank		rank		rank		rank		rank		rank		rank		rank		rank
	Historical	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1
	Ref 0	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2
	Ref 1	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3
	Ref 2 (100% of Ref 1)	112.214 €	9	112.214 €	9	112.214 €	9	112.214 €	10	112.214 €	10	112.214 €	10	112.214 €	10	112.214 €	10	112.214 €	10	112.214 €	10
smart & EDS	Ref 2 (79% of Ref 1)	114.736 €	8	114.736 €	8	114.736 €	8	114.736 €	8	114.736 €	8	114.736 €	8	114.736 €	8	114.736 €	8	114.736 €	8	114.736 €	8
Bio	Ref 3	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4
	Ref 4 (100% of Ref 1)	110.401 €	11	110.461 €	11	110.520 €	11	110.580 €	11	110.640 €	11	110.699 €	11	110.759 €	11	110.818 €	11	110.878 €	11	110.938 €	11
smart &EDS &DSS	Ref 4 (60% of Ref 1)	115.216 €	6	115.276 €	6	115.335 €	6	115.395 €	6	115.455 €	6	115.514 €	6	115.574 €	6	115.633 €	6	115.693 €	6	115.753 €	6
	Ref 4 (40% of Ref 1)	117.624 €	5	117.683 €	5	117.743 €	5	117.802 €	5	117.862 €	5	117.922 €	5	117.981 €	5	118.041 €	5	118.101 €	5	118.160 €	5
	Ref 5 (100% of Ref 3)	105.756 €	12	105.816 €	12	105.876 €	12	105.935 €	12	105.995 €	12	106.054 €	12	106.114 €	12	106.174 €	12	106.233 €	12	106.293 €	12
smart EDS& DSS & Bio	Ref 5 (65% of Ref 3)	112.049 €	10	112.109 €	10	112.168 €	10	112.228 €	9	112.288 €	9	112.347 €	9	112.407 €	9	112.467 €	9	112.526 €	9	112.586 €	9
	Ref 5 (50% of Ref 3)	114.746 €	7	114.806 €	7	114.865 €	7	114.925 €	7	114.985 €	7	115.044 €	7	115.104 €	7	115.164 €	7	115.223 €	7	115.283 €	7

Table 29 DSS Acquisition Price Volatility on NPVs

Scenario Summary		EDS Acquistion Price Volatility on NPVs																			
		Current Values:		-10%		-20%		-30%		-40%		-50%		-60%		-70%		-80%		-90%	
Changing Cells:																					
	EDS_Acq_Price	**0%**		**-10%**		**-20%**		**-30%**		**-40%**		**-50%**		**-60%**		**-70%**		**-80%**		**-90%**	
	EDS price	10.000,00 €		9.000,00 €	##	8.000,00 €	##	7.000,00 €	##	6.000,00 €	##	5.000,00 €	##	4.000,00 €	##	3.000,00 €	##	2.000,00 €	##	1.000,00 €	
Result Cells:			rank		rank		rank		rank		rank		rank		rank		rank		rank		rank
	Historical	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1
	Ref 0	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2
	Ref 1	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3
	Ref 2 (100% of Ref 1)	112.214 €	9	113.091 €	9	113.968 €	9	114.845 €	9	115.721 €	9	116.598 €	9	117.475 €	9	118.352 €	9	119.228 €	9	120.105 €	9
smart & EDS	Ref 2 (79% of Ref 1)	114.736 €	8	115.613 €	8	116.489 €	8	117.366 €	8	118.243 €	8	119.120 €	8	119.996 €	8	120.873 €	8	121.750 €	8	122.627 €	8
Bio	Ref 3	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4
	Ref 4 (100% of Ref 1)	110.401 €	11	111.278 €	11	112.155 €	11	113.031 €	11	113.908 €	11	114.785 €	11	115.662 €	11	116.538 €	11	117.415 €	11	118.292 €	11
smart &EDS &DSS	Ref 4 (60% of Ref 1)	115.216 €	6	116.093 €	6	116.970 €	6	117.846 €	6	118.723 €	6	119.600 €	6	120.477 €	6	121.353 €	6	122.230 €	6	123.107 €	6
	Ref 4 (40% of Ref 1)	117.624 €	5	118.500 €	5	119.377 €	5	120.254 €	5	121.131 €	5	122.007 €	5	122.884 €	5	123.761 €	5	124.638 €	5	125.514 €	5
	Ref 5 (100% of Ref 3)	105.756 €	12	106.633 €	12	107.510 €	12	108.387 €	12	109.263 €	12	110.140 €	12	111.017 €	12	111.894 €	12	112.770 €	12	113.647 €	12
smart EDS& DSS & Bio	Ref 5 (65% of Ref 3)	112.049 €	10	112.926 €	10	113.803 €	10	114.680 €	10	115.556 €	10	116.433 €	10	117.310 €	10	118.187 €	10	119.063 €	10	119.940 €	10
	Ref 5 (50% of Ref 3)	114.746 €	7	115.623 €	7	116.500 €	7	117.376 €	7	118.253 €	7	119.130 €	7	120.007 €	7	120.884 €	7	121.760 €	7	122.637 €	7

Table 30 EDS Sub Fee Volatility on NPVs

Scenario Summary		EDS Subscription's Price Volatility on NPV																			
		Current Values:		-10%		-20%		-30%		-40%		-50%		-60%		-70%		-80%		-90%	
Changing Cells:																					
	% change in EDS_Sub_F	0%		-10%		-20%		-30%		-40%		-50%		-60%		-70%		-80%		-90%	
	EDS_Acq_Price	500 €		450 €		400 €		350 €		300 €		250 €		200 €		150 €		100 €		50 €	
Result Cells:			rank		rank		rank		rank		rank		rank		rank		rank		rank		rank
	Historical	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1
	Ref 0	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2
	Ref 1	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3
	Ref 2 (100% of Ref 1)	112.214 €	9	118.299 €	9	124.384 €	9	130.469 €	9	136.554 €	9	142.639 €	9	148.723 €	9	154.808 €	9	160.893 €	9	166.978 €	9
smart & EDS	Ref 2 (79% of Ref 1)	114.736 €	8	120.821 €	8	126.905 €	8	132.990 €	8	139.075 €	8	145.160 €	8	151.245 €	8	157.330 €	8	163.415 €	8	169.500 €	8
Bio	Ref 3	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4
	Ref 4 (100% of Ref 1)	110.401 €	11	116.486 €	11	122.571 €	11	128.656 €	11	134.741 €	11	140.825 €	11	146.910 €	11	152.995 €	11	159.080 €	11	165.165 €	11
smart &EDS &DSS	Ref 4 (60% of Ref 1)	115.216 €	6	121.301 €	6	127.386 €	6	133.471 €	6	139.556 €	6	145.640 €	6	151.725 €	6	157.810 €	6	163.895 €	6	169.980 €	6
	Ref 4 (40% of Ref 1)	117.624 €	5	123.708 €	5	129.793 €	5	135.878 €	5	141.963 €	5	148.048 €	5	154.133 €	5	160.218 €	5	166.302 €	5	172.387 €	5
	Ref 5 (100% of Ref 3)	105.756 €	12	111.841 €	12	117.926 €	12	124.011 €	12	130.096 €	12	136.181 €	12	142.266 €	12	148.350 €	12	154.435 €	12	160.520 €	12
smart EDS& DSS & Bio	Ref 5 (65% of Ref 3)	112.049 €	10	118.134 €	10	124.219 €	10	130.304 €	10	136.389 €	10	142.474 €	10	148.558 €	10	154.643 €	10	160.728 €	10	166.813 €	10
	Ref 5 (50% of Ref 3)	114.746 €	7	120.831 €	7	126.916 €	7	133.001 €	7	139.086 €	7	145.170 €	7	151.255 €	7	157.340 €	7	163.425 €	7	169.510 €	7

Table 31 DSS Subscription's Price Volatility on NPV

Scenario Summary		DSS SUB FEE VILATILITY ON NPVs																			
		Current Values:		-10%		-20%		-30%		-40%		-50%		-60%		-70%		-80%		-90%	
Changing Cells:																					
	DSS_Sub_Fee	0%		-10%		-20%		-30%		-40%		-50%		-60%		-70%		-80%		-90%	
	DSS Annual Sub Fee	200 €		180 €		160 €		140 €		120 €		100 €		80 €		60 €		40 €		20 €	
Result Cells:			rank		rank		rank		rank		rank		rank		rank		rank		rank		rank
	Historical	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1	205.568 €	1
	Ref 0	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2	204.014 €	2
	Ref 1	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3	201.881 €	3
	Ref 2 (100% of Ref 1)	112.214 €	9	112.214 €	10	112.214 €	10	112.214 €	9	112.214 €	9	112.214 €	9	112.214 €	9	112.214 €	9	112.214 €	9	112.214 €	9
smart & EDS	Ref 2 (79% of Ref 1)	114.736 €	8	114.736 €	8	114.736 €	8	114.736 €	8	114.736 €	8	114.736 €	8	114.736 €	8	114.736 €	8	114.736 €	8	114.736 €	8
Bio	Ref 3	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4	197.236 €	4
	Ref 4 (100% of Ref 1)	110.401 €	11	110.815 €	11	111.229 €	11	111.642 €	11	112.056 €	11	112.470 €	11	112.884 €	11	113.298 €	11	113.711 €	11	114.125 €	11
smart &EDS &DSS	Ref 4 (60% of Ref 1)	115.216 €	6	115.630 €	6	116.044 €	6	116.457 €	6	116.871 €	6	117.285 €	6	117.699 €	6	118.112 €	6	118.526 €	6	118.940 €	6
	Ref 4 (40% of Ref 1)	117.624 €	5	118.037 €	5	118.451 €	5	118.865 €	5	119.279 €	5	119.692 €	5	120.106 €	5	120.520 €	5	120.934 €	5	121.348 €	5
	Ref 5 (100% of Ref 3)	105.756 €	12	106.170 €	12	106.584 €	12	106.998 €	12	107.411 €	12	107.825 €	12	108.239 €	12	108.653 €	12	109.066 €	12	109.480 €	12
mart EDS& DSS & Bi	Ref 5 (65% of Ref 3)	112.049 €	10	112.463 €	9	112.877 €	9	113.291 €	10	113.704 €	10	114.118 €	10	114.532 €	10	114.946 €	10	115.359 €	10	115.773 €	10
	Ref 5 (50% of Ref 3)	114.746 €	7	115.160 €	7	115.574 €	7	115.987 €	7	116.401 €	7	116.815 €	7	117.229 €	7	117.643 €	7	118.056 €	7	118.470 €	7

Figure 16 EDS Acquisition Price Volatility on NPVs

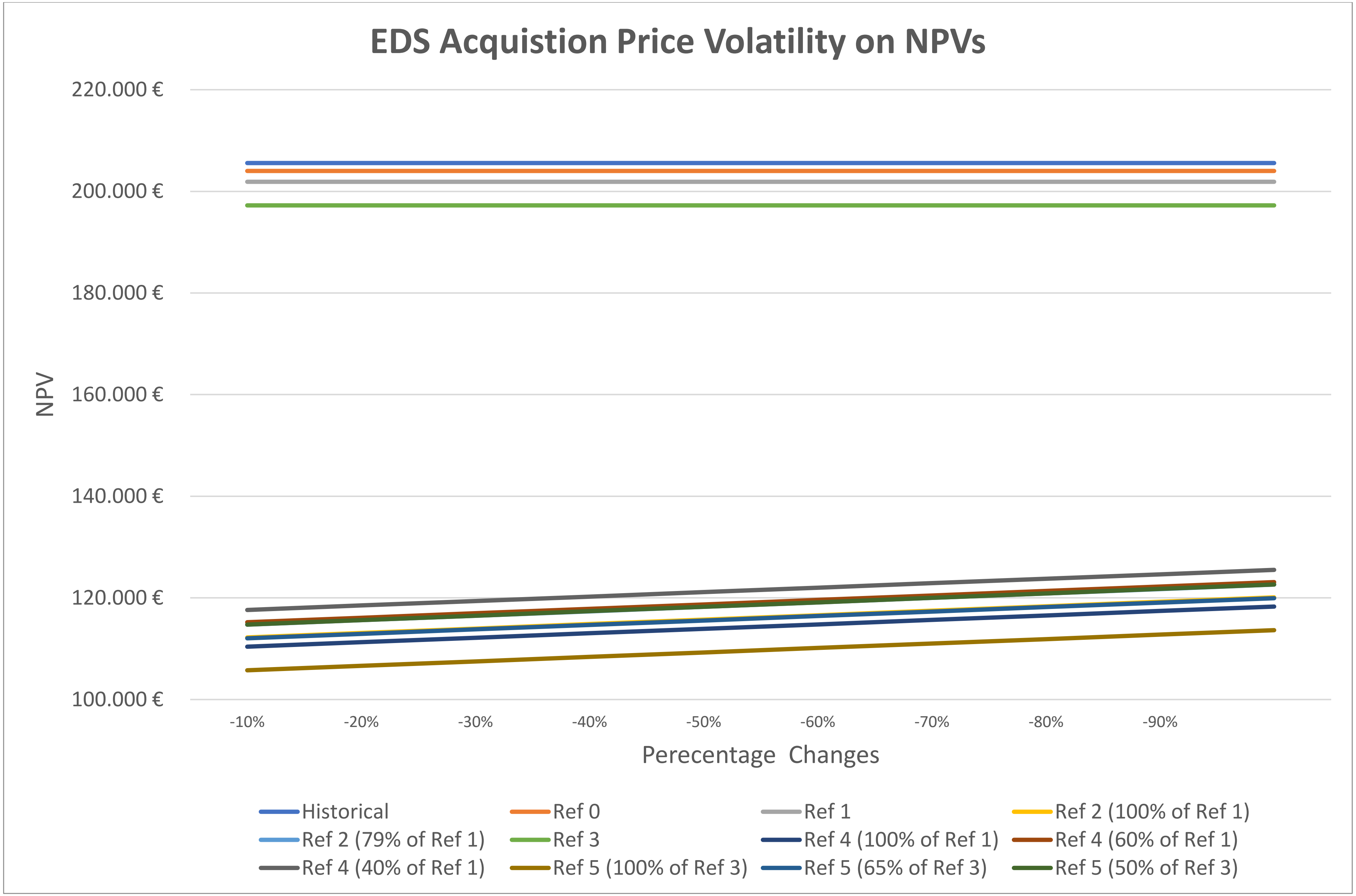


Figure 17 DSS Acqusition Price Volatility on NPVs

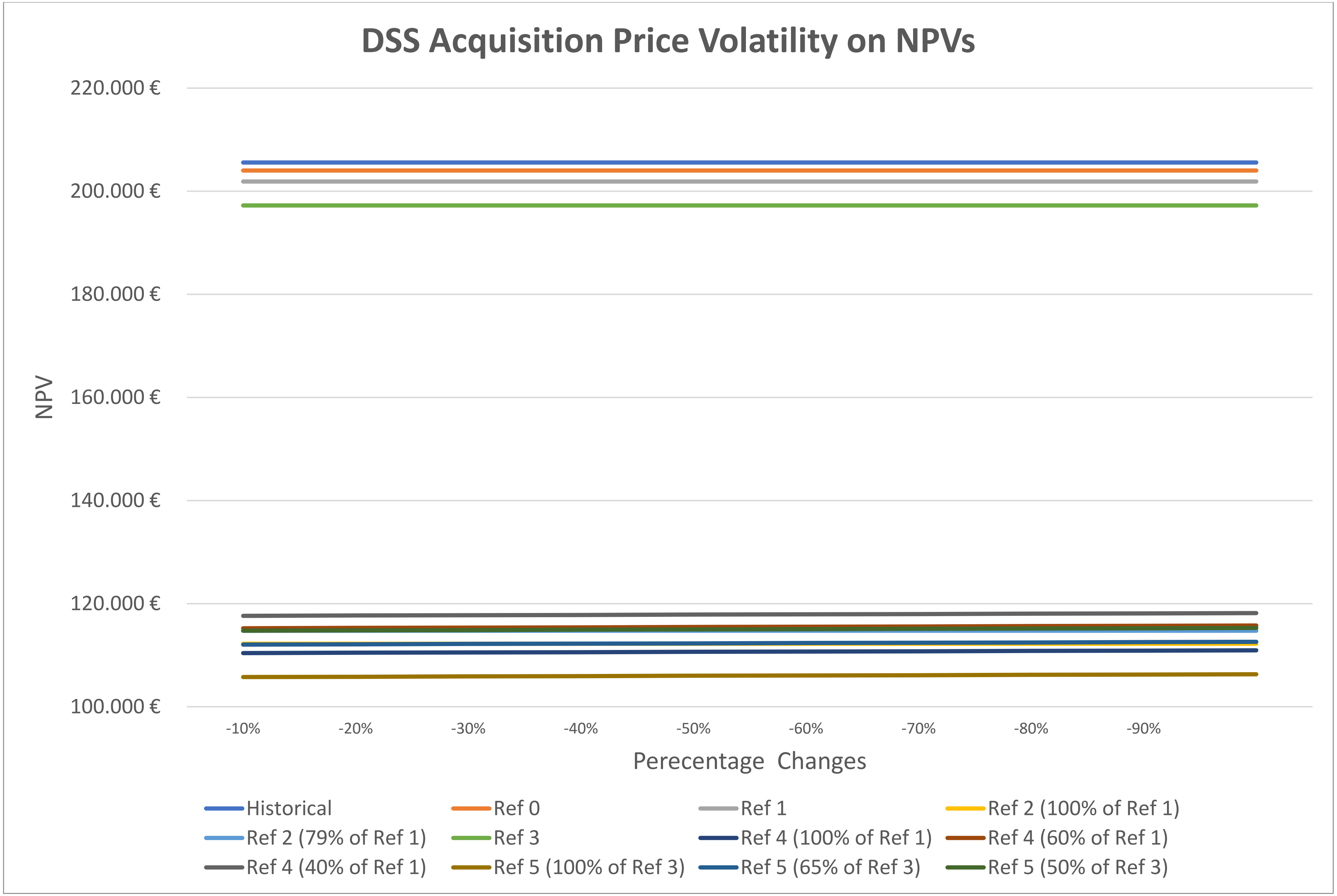


Figure 18 EDS Subscription's Price Volatility on NPVs

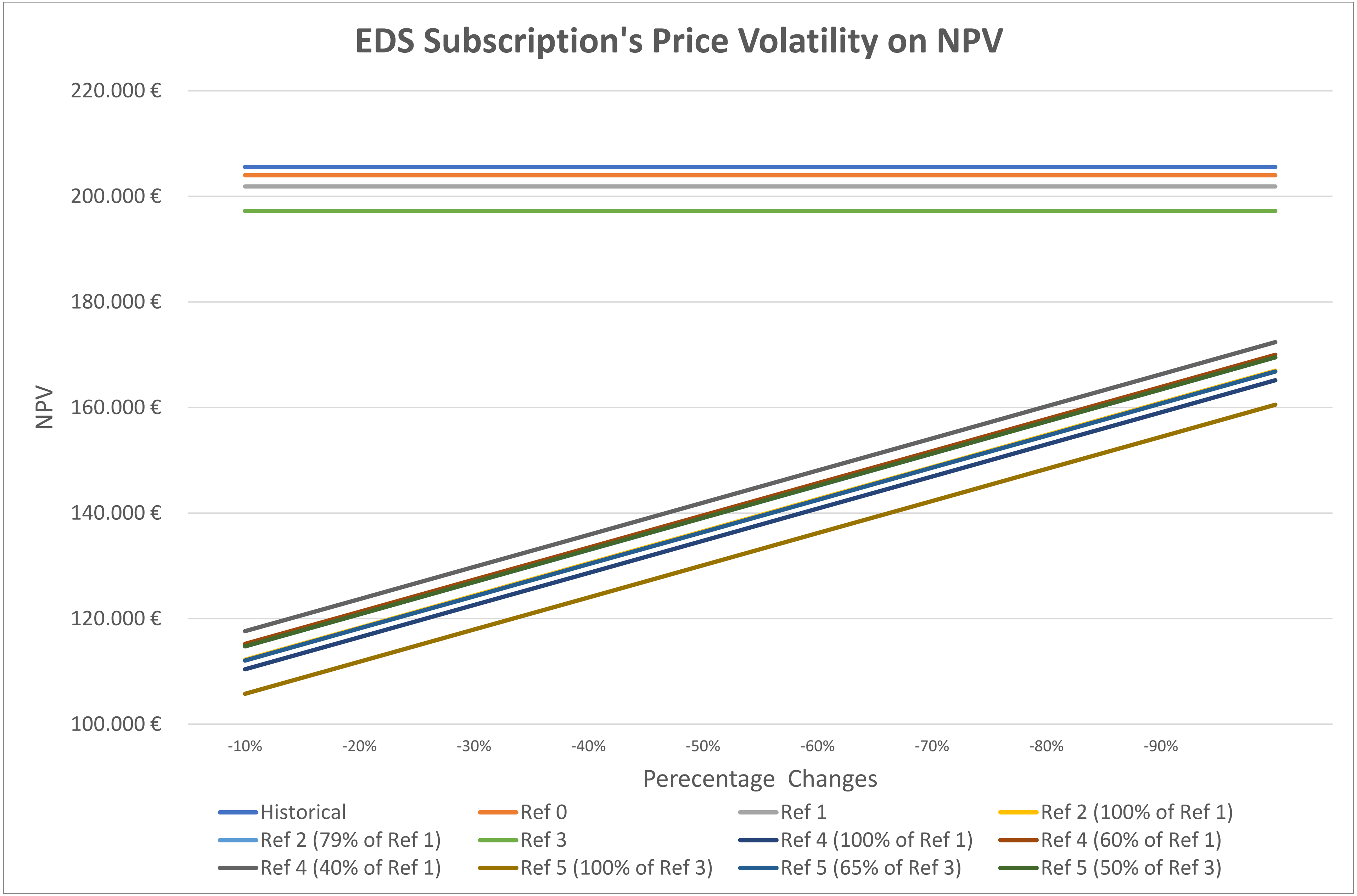
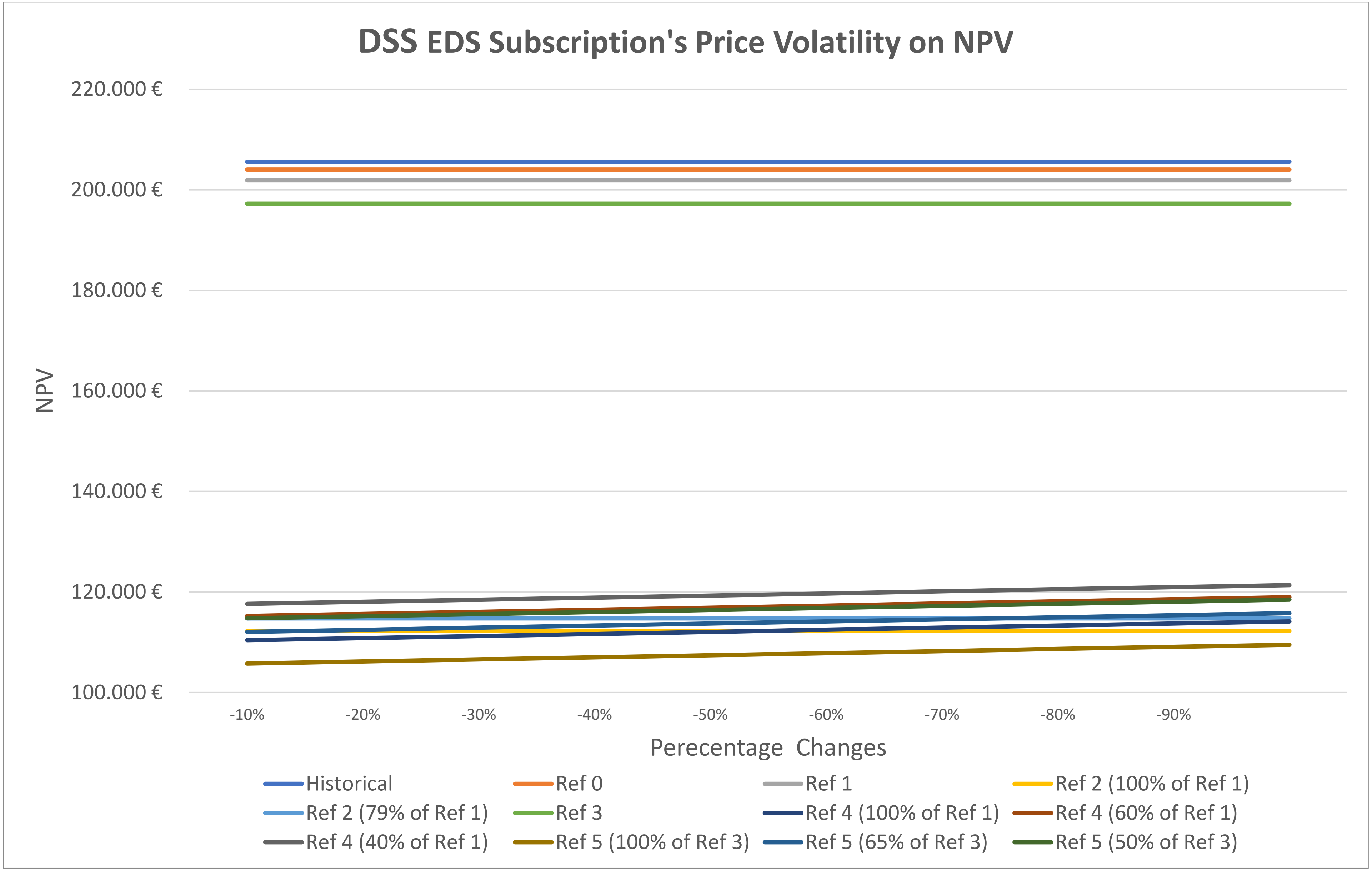


Figure 19 DSS Subscription's Price Volatility on NPVs



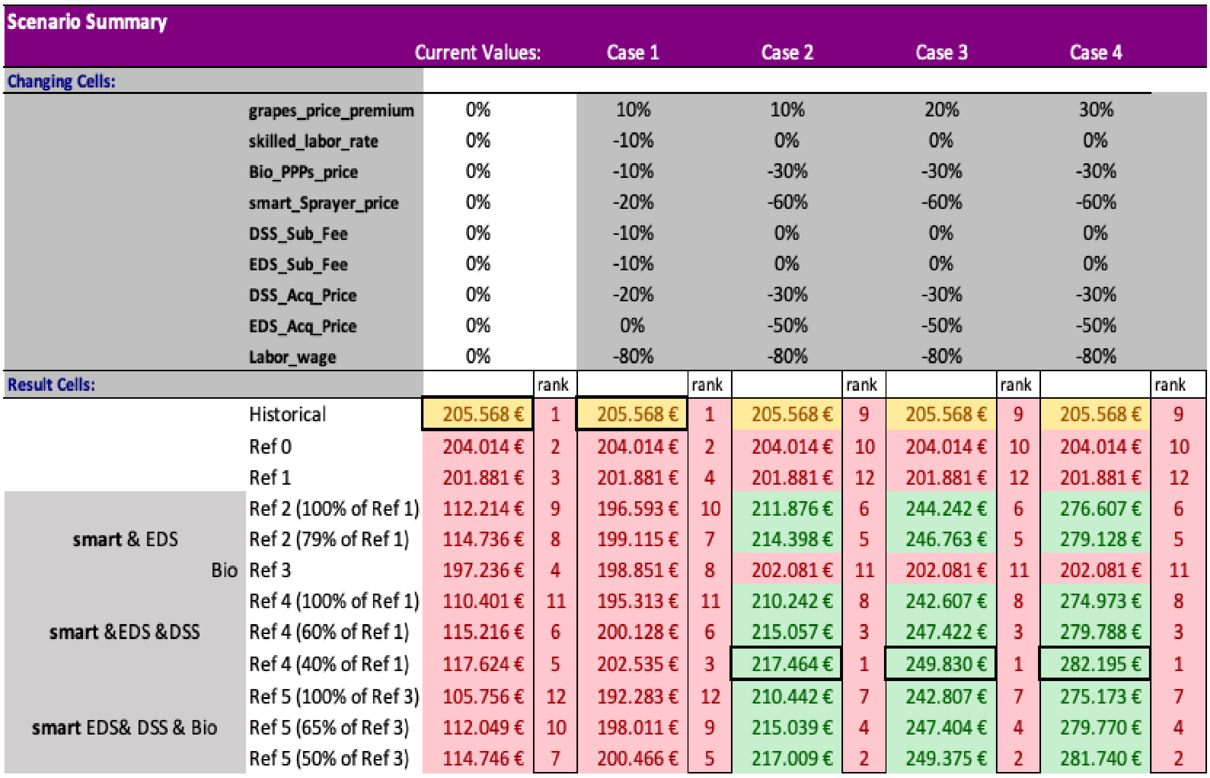
4.3.10 Best Cases Scenarios

Finally, the author considered alternating many parameters at once and assess the overall impact on NPVs from such alternations. Thus, a Worst-case scenario and a Best-Case Scenario have been projected, as well as two other variations of the Best-Case Scenario. Case 1 represents the Worst Case (WC) and Case 4 accounts for the Best Case (BC), while Cases 2 and 3 are intermediate variations of the Best-Case scenario. The WC is the one where although the Cost of Labor is reduced to 80% of its initial costs the other cost elements are not seeing a significant reduction. Under the WC, the proposed IPM is not considered an attractive investment.

Taking a closer look at Case 2, one can observe that the Proposed IPM becomes more profitable than the conventional ones in all References where it is employed. This is considered a very good scenario for the IPM's investment attractiveness. In Case 3 and Case 4 the same parameters are employed as of Case 2, but this time the price of premium grapes is increased to 20% and 30% respectively.

Notably, by comparing the NPVs in Cases 2 and 3 one can see that for only an additional 10% increase in premium grapes price the proposed system has an additional economic benefit of more than 20,000 euro, which for an additional 10% increase in premium grapes, results in extra over 30,000 euro, setting Reference 5 (100%) 0.8 times more profitable than the threshold value of Historical Reference.

Table 32 NPV's Volatility on Best Cases Scenario



Scenario Summary											
		Current Values:		Case 1		Case 2		Case 3		Case 4	
Changing Cells:											
	grapes_price_premium	0%		10%		10%		20%		30%	
	skilled_labor_rate	0%		-10%		0%		0%		0%	
	Bio_PPPs_price	0%		-10%		-30%		-30%		-30%	
	smart_Sprayer_price	0%		-20%		-60%		-60%		-60%	
	DSS_Sub_Fee	0%		-10%		0%		0%		0%	
	EDS_Sub_Fee	0%		-10%		0%		0%		0%	
	DSS_Acq_Price	0%		-20%		-30%		-30%		-30%	
	EDS_Acq_Price	0%		0%		-50%		-50%		-50%	
	Labor_wage	0%		-80%		-80%		-80%		-80%	
Result Cells:			rank		rank		rank		rank		rank
	Historical	205.568 €	1	205.568 €	1	205.568 €	9	205.568 €	9	205.568 €	9
	Ref 0	204.014 €	2	204.014 €	2	204.014 €	10	204.014 €	10	204.014 €	10
	Ref 1	201.881 €	3	201.881 €	4	201.881 €	12	201.881 €	12	201.881 €	12
	Ref 2 (100% of Ref 1)	112.214 €	9	196.593 €	10	211.876 €	6	244.242 €	6	276.607 €	6
smart & EDS	Ref 2 (79% of Ref 1)	114.736 €	8	199.115 €	7	214.398 €	5	246.763 €	5	279.128 €	5
Bio	Ref 3	197.236 €	4	198.851 €	8	202.081 €	11	202.081 €	11	202.081 €	11
	Ref 4 (100% of Ref 1)	110.401 €	11	195.313 €	11	210.242 €	8	242.607 €	8	274.973 €	8
smart &EDS &DSS	Ref 4 (60% of Ref 1)	115.216 €	6	200.128 €	6	215.057 €	3	247.422 €	3	279.788 €	3
	Ref 4 (40% of Ref 1)	117.624 €	5	202.535 €	3	217.464 €	1	249.830 €	1	282.195 €	1
	Ref 5 (100% of Ref 3)	105.756 €	12	192.283 €	12	210.442 €	7	242.807 €	7	275.173 €	7
smart EDS& DSS & Bio	Ref 5 (65% of Ref 3)	112.049 €	10	198.011 €	9	215.039 €	4	247.404 €	4	279.770 €	4
	Ref 5 (50% of Ref 3)	114.746 €	7	200.466 €	5	217.009 €	2	249.375 €	2	281.740 €	2

5. Conclusions & Recommendations

This final chapter serves to answer the research question while drawing conclusions from the study. Additionally, one can find presented the theoretical contributions, implications for practitioners and society.

5.1. General Conclusions

The food industry produces large quantities of branded products on a constant basis so that they become available to consumers and fulfil population needs. In this line, caring for quality and safety throughout the food chain is a common practice for many stakeholders. Consequently, the food industry has a leading role in improving nutrition and consumer protection and information. By undertaking Life Cycle Cost Analysis in Food Industries, and especially in cultivations of high-quality products, i.e., grapes, it becomes clear that there are numerous issues related to agricultural practices that aim for high production yields utilising a vast amount of Plant Protection Products (PPPs). Likewise, such methods are harmful to all as they can cause soil and water contamination but also pose serious health issues to both workers applying them and bystanders and to the final consumer.

The idea of a new way of managing inputs in a crop is called Precision Agriculture. Precision agriculture practices using high-tech equipment are considered as having the ability to reduce agricultural inputs by site-specific applications, as they better target inputs to spatial and temporal needs. Furthermore, Precision Agriculture is argued to positively impact *farm productivity* and *food quality* with Integrated Pest Management (IPM). This study assessed the economic suitability of an IPM framework that provides a holistic approach that includes the major elements related to integrated disease management:

a. combined use of bio-PPPs and synthetic PPPs,
b. DSS for disease prediction,
c. spectral disease detection systems,
d. precision spraying techniques.

For this fulfilling purpose, this study used a case farm (5,91 ha) located in the Piemonte region, where six different Spraying Systems were examined and evaluated in a comparative approach to illustrate the computations pertaining to machine acquisition and operating cost associated with the above-mentioned spraying settings. The main objective of this thesis study has been to develop a dynamic costing model that can be used in Life-Cycle Cost (LCC) analyses of different alternatives among varying production equipment designs to be utilised in table vineyards cultivation. To this end, the problem has been handled with an emphasis on the initial acquisition cost of the equipment (both hardware & software) as well as on the operating expenses. Special attention was paid to designing a methodology that can be modified according to alternating needs that are likely to emerge in the future. Therefore, the resulting model came out as a dynamic method that is applicable for decision-making processes in the future, where required modifications can be performed on the model, when necessary, just by introducing new cost elements and removing the factors which are out of date or accounting for variable hectares of cultivated area.

The entire life-cycle cost analysis model has been built on three main stages. The first stage included defining the correct cost drivers/centres that affect each spraying system's life-cycle cost under investigation. Once the set of cost drivers was identified, the main skeleton of the model was equally completed. Similarly, the model's outcomes were utilised to calculate the Net Present Value of each spraying alternative, which constituted the second stage. As a result, the accuracy and precision of data have been improved by considering the effects of time value for money reflected in interest rate. Finally, the ultimate stage to complete the LCC methodology was to perform different scenarios to assess the NPV's volatility due to fluctuations in the parameters that can alter in the future as the novelty of the proposed IPM will gradually decline.

To provide insights into how the model performs for Life-Cycle Cost Analysis, a comparative case study was conducted under six different settings utilising Historical Data supplied by the Pusabren Farm (20018) (Historical Reference).This approach can support informed long-term decision-making and promote the design of sustainable and cost-efficient interventions and more resource-efficient food supply chains. Referring to the Views of Bussemart et al. (2012), who identified that agricultural practices that use fewer PPPs per hectare could be cheaper than practices more PPP intensive, the present study provides evidence that this can be the case as different combination scenarios which alter the cost elements of the proposed IPM result in higher NPV achieved by IPM than conventional agricultural practices. The results can be helpful to highlight the main hot spots in spraying PPPs to Vineyards to combat Downy Mildew, linked to the life Cycle stage and to specific agricultural practices to suggest improvements for more sustainable management.

5.2. Theoretical Contributions

This study contributes to the literature in Precision Agriculture and Environmental Entrepreneurship as a subject of sustainable entrepreneurship. Firstly, this study contributes to the domain of PA by examining a novel IPM system in vineyards cultivation which includes the major elements related to integrated disease management. Considering Alec Ross, in his book "The Industries of the Future" (2016, p. 272), "The greatest hope for feeding an exponentially growing world population comes from the combination of big data and agriculture – precision agriculture. ». In this line, the present study proves economic evidence on the Profitability of IPM strategies that significantly reduce reliance on conventional pesticides while maintaining crop performance and yield (Lamichhane et al., 2015).

With the broader use of IPMs, the possibilities for obtaining up-to-date data from crops will increase. At the same time, the volume of data (temperature, humidity, etc.) will increase, which in addition to data collection by the appropriate sensors (cameras), will have to be collected (cloud), evaluated (data analysis) and extracted (data appropriate information for the proper management of inputs in a crop. Therefore, this study has contributed to supporting food security and food safety goals (SDG 2) promoted under the Agenda 2030 for Sustainable Development.

Secondly, by undertaking an LCC assessment (in Vineyards for PPPs Spraying), this study contributes by providing quantitative evidence on the potential of Integrated Pest Management to increase sustainability relative to non-IPM strategies under both regional and crop-specific growing conditions (Lamichhane et al. 2015). Therefore, this study contributes by providing evidence such as economic cost and benefits of IPM solutions within the European context, in a field that has been previously characterised as scarce (Lefebvre et al., 2014; Lamichhane et al. 2015).

5.3. Implications for Practitioners

For all farmers and entrepreneurs or consultants and business developers in the field of PA with a focus on intensive agricultural systems in terms of pesticides, such as speciality crops (i.e., table grapes), this study offers an opportunity to assess what aspects influence the investment decision of both mainstream Sprayers and the proposed IPM. When producers determine whether it is feasible to purchase the full OPTIMA IPM, it is imperative to compare machine investment costs and operating costs. If acquisition cost is relatively high for an IPM, the producer would expect operating expenses to be fairly reduced to counterbalance the initial investment. As noted in this study, the proposed IPM does not result in a more viable investment among the options considered for given input data. However, as the scenario analysis revealed, specific circumstances would set the proposed IPM more profitable in the long run.

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APPENDIX

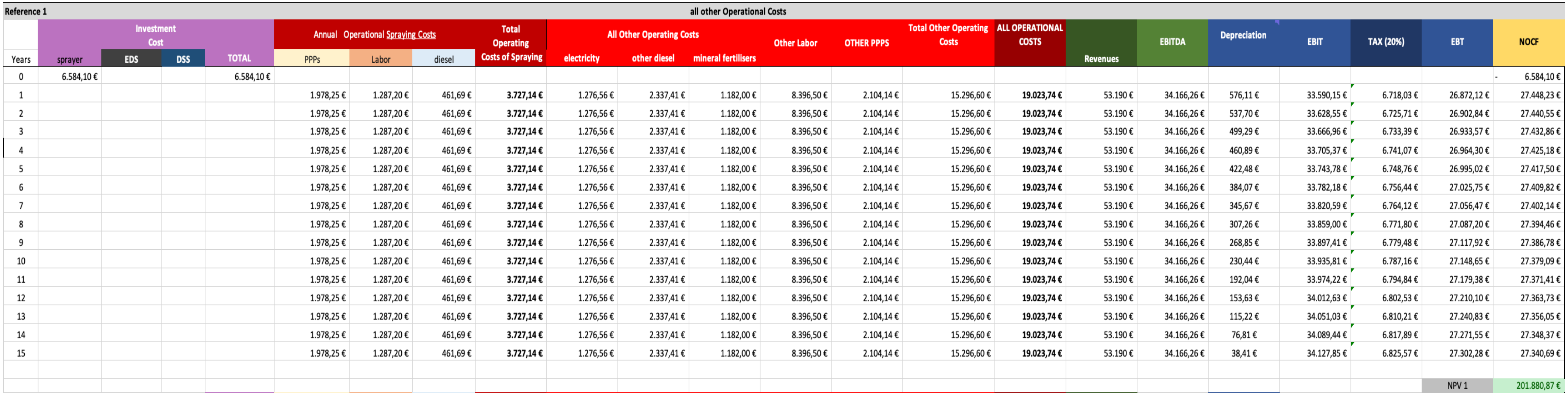
Cash Flow Streams for NPV Calculation – Historical Data

Historical Data	Cost of Chemical Weeding								all other Operational Costs													
	Investment Cost				Annual Operational Spraying Costs			Total Operating Costs of Spraying	All Other Operating Costs			Other Labor	OTHER PPPS	Total Other Operating Costs	ALL OPERATIONAL COSTS	Revenues	EBITDA	Depreciation	EBIT	TAX (20%)	EBT	NOCF
Years	sprayer	EDS	DSS	TOTAL	PPPs	Labor	diesel		electricity	diesel	mineral fertilisers											
0	5.100,00 €	-	-	5.100,00 €																		- 5.100,00 €
1					1.879,29 €	1.287,20 €	461,69 €	**3.628,17 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.820,02 €	**15.012,49 €**	**18.640,66 €**	53.190 €	34.549,34 €	446,25 €	34.103,09 €	6.820,62 €	27.282,47 €	27.728,72 €
2					1.879,29 €	1.287,20 €	461,69 €	**3.628,17 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.820,02 €	**15.012,49 €**	**18.640,66 €**	53.190 €	34.549,34 €	416,50 €	34.132,84 €	6.826,57 €	27.306,27 €	27.722,77 €
3					1.879,29 €	1.287,20 €	461,69 €	**3.628,17 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.820,02 €	**15.012,49 €**	**18.640,66 €**	53.190 €	34.549,34 €	386,75 €	34.162,59 €	6.832,52 €	27.330,07 €	27.716,82 €
4					1.879,29 €	1.287,20 €	461,69 €	**3.628,17 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.820,02 €	**15.012,49 €**	**18.640,66 €**	53.190 €	34.549,34 €	357,00 €	34.192,34 €	6.838,47 €	27.353,87 €	27.710,87 €
5					1.879,29 €	1.287,20 €	461,69 €	**3.628,17 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.820,02 €	**15.012,49 €**	**18.640,66 €**	53.190 €	34.549,34 €	327,25 €	34.222,09 €	6.844,42 €	27.377,67 €	27.704,92 €
6					1.879,29 €	1.287,20 €	461,69 €	**3.628,17 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.820,02 €	**15.012,49 €**	**18.640,66 €**	53.190 €	34.549,34 €	297,50 €	34.251,84 €	6.850,37 €	27.401,47 €	27.698,97 €
7					1.879,29 €	1.287,20 €	461,69 €	**3.628,17 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.820,02 €	**15.012,49 €**	**18.640,66 €**	53.190 €	34.549,34 €	267,75 €	34.281,59 €	6.856,32 €	27.425,27 €	27.693,02 €
8					1.879,29 €	1.287,20 €	461,69 €	**3.628,17 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.820,02 €	**15.012,49 €**	**18.640,66 €**	53.190 €	34.549,34 €	238,00 €	34.311,34 €	6.862,27 €	27.449,07 €	27.687,07 €
9					1.879,29 €	1.287,20 €	461,69 €	**3.628,17 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.820,02 €	**15.012,49 €**	**18.640,66 €**	53.190 €	34.549,34 €	208,25 €	34.341,09 €	6.868,22 €	27.472,87 €	27.681,12 €
10					1.879,29 €	1.287,20 €	461,69 €	**3.628,17 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.820,02 €	**15.012,49 €**	**18.640,66 €**	53.190 €	34.549,34 €	178,50 €	34.370,84 €	6.874,17 €	27.496,67 €	27.675,17 €
11					1.879,29 €	1.287,20 €	461,69 €	**3.628,17 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.820,02 €	**15.012,49 €**	**18.640,66 €**	53.190 €	34.549,34 €	148,75 €	34.400,59 €	6.880,12 €	27.520,47 €	27.669,22 €
12					1.879,29 €	1.287,20 €	461,69 €	**3.628,17 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.820,02 €	**15.012,49 €**	**18.640,66 €**	53.190 €	34.549,34 €	119,00 €	34.430,34 €	6.886,07 €	27.544,27 €	27.663,27 €
13					1.879,29 €	1.287,20 €	461,69 €	**3.628,17 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.820,02 €	**15.012,49 €**	**18.640,66 €**	53.190 €	34.549,34 €	89,25 €	34.460,09 €	6.892,02 €	27.568,07 €	27.657,32 €
14					1.879,29 €	1.287,20 €	461,69 €	**3.628,17 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.820,02 €	**15.012,49 €**	**18.640,66 €**	53.190 €	34.549,34 €	59,50 €	34.489,84 €	6.897,97 €	27.591,87 €	27.651,37 €
15					1.879,29 €	1.287,20 €	461,69 €	**3.628,17 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.820,02 €	**15.012,49 €**	**18.640,66 €**	53.190 €	34.549,34 €	29,75 €	34.519,59 €	6.903,92 €	27.615,67 €	27.645,42 €
																					NPV H	205.567,96 €

Cash Flow Streams for NPV Calculation – Reference 0

Reference 0	all other Operational Costs																					
	Investment Cost				Annual Operational Spraying Costs			Total Operating Costs of Spraying	All Other Operating Costs			Other labor	OTHER PPPS	Total Other Operating Costs	ALL OPERATIONAL COSTS	Revenues	EBITDA	Depreciation	EBIT	TAX (20%)	EBT	NOCF
Years	sprayer	EDS	DSS	TOTAL	PPPs	Labor	diesel		electricity	other diesel	mineral fertilisers											
0	4.250,00 €			4.250,00 €																		- 4.250,00 €
1					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**19.023,74 €**	53.190 €	34.166,26 €	371,88 €	33.794,38 €	6.758,88 €	27.035,50 €	27.407,38 €
2					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**19.023,74 €**	53.190 €	34.166,26 €	347,08 €	33.819,17 €	6.763,83 €	27.055,34 €	27.402,42 €
3					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**19.023,74 €**	53.190 €	34.166,26 €	322,29 €	33.843,96 €	6.768,79 €	27.075,17 €	27.397,46 €
4					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**19.023,74 €**	53.190 €	34.166,26 €	297,50 €	33.868,76 €	6.773,75 €	27.095,00 €	27.392,50 €
5					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**19.023,74 €**	53.190 €	34.166,26 €	272,71 €	33.893,55 €	6.778,71 €	27.114,84 €	27.387,55 €
6					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**19.023,74 €**	53.190 €	34.166,26 €	247,92 €	33.918,34 €	6.783,67 €	27.134,67 €	27.382,59 €
7					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**19.023,74 €**	53.190 €	34.166,26 €	223,13 €	33.943,13 €	6.788,63 €	27.154,50 €	27.377,63 €
8					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**19.023,74 €**	53.190 €	34.166,26 €	198,33 €	33.967,92 €	6.793,58 €	27.174,34 €	27.372,67 €
9					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**19.023,74 €**	53.190 €	34.166,26 €	173,54 €	33.992,71 €	6.798,54 €	27.194,17 €	27.367,71 €
10					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**19.023,74 €**	53.190 €	34.166,26 €	148,75 €	34.017,51 €	6.803,50 €	27.214,00 €	27.362,75 €
11					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**19.023,74 €**	53.190 €	34.166,26 €	123,96 €	34.042,30 €	6.808,46 €	27.233,84 €	27.357,80 €
12					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**19.023,74 €**	53.190 €	34.166,26 €	99,17 €	34.067,09 €	6.813,42 €	27.253,67 €	27.352,84 €
13					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**19.023,74 €**	53.190 €	34.166,26 €	74,38 €	34.091,88 €	6.818,38 €	27.273,50 €	27.347,88 €
14					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**19.023,74 €**	53.190 €	34.166,26 €	49,58 €	34.116,67 €	6.823,33 €	27.293,34 €	27.342,92 €
15					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**19.023,74 €**	53.190 €	34.166,26 €	24,79 €	34.141,46 €	6.828,29 €	27.313,17 €	27.337,96 €
																					NVP 0	204.013,62 €

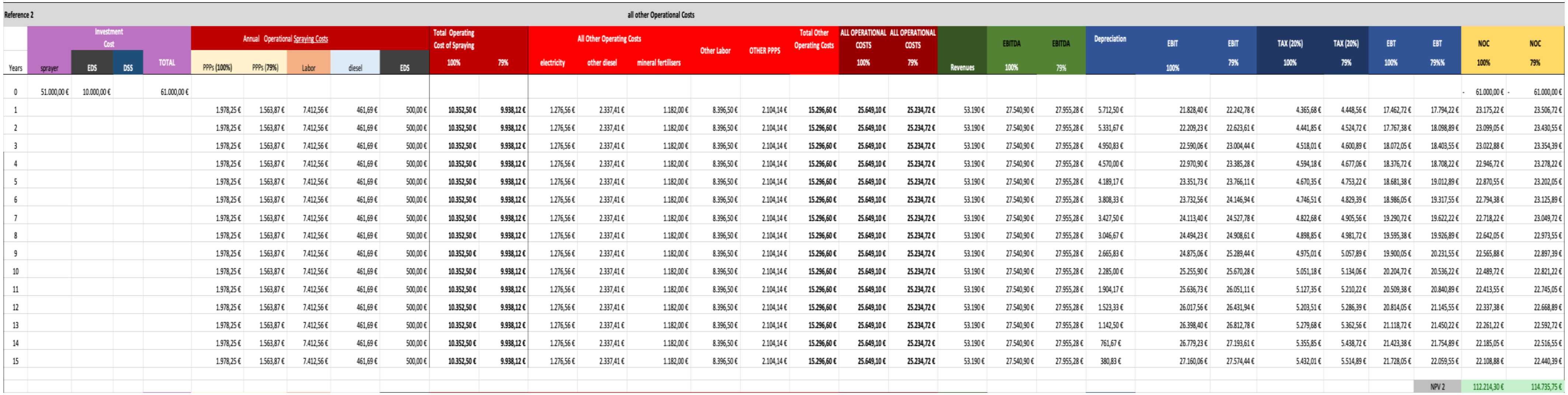
Cash Flow Streams for NPV Calculation – Reference 1



Reference 1 — all other Operational Costs

	Investment Cost				Annual Operational Spraying Costs			Total Operating Costs of Spraying	All Other Operating Costs			Other Labor	OTHER PPPS	Total Other Operating Costs	ALL OPERATIONAL COSTS	Revenues	EBITDA	Depreciation	EBIT	TAX (20%)	EBT	NOCF
Years	sprayer	EDS	DSS	TOTAL	PPPs	Labor	diesel		electricity	other diesel	mineral fertilisers											
0	6.584,10 €			6.584,10 €																		- 6.584,10 €
1					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	15.296,60 €	**19.023,74 €**	53.190 €	34.166,26 €	576,11 €	33.590,15 €	6.718,03 €	26.872,12 €	27.448,23 €
2					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	15.296,60 €	**19.023,74 €**	53.190 €	34.166,26 €	537,70 €	33.628,55 €	6.725,71 €	26.902,84 €	27.440,55 €
3					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	15.296,60 €	**19.023,74 €**	53.190 €	34.166,26 €	499,29 €	33.666,96 €	6.733,39 €	26.933,57 €	27.432,86 €
4					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	15.296,60 €	**19.023,74 €**	53.190 €	34.166,26 €	460,89 €	33.705,37 €	6.741,07 €	26.964,30 €	27.425,18 €
5					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	15.296,60 €	**19.023,74 €**	53.190 €	34.166,26 €	422,48 €	33.743,78 €	6.748,76 €	26.995,02 €	27.417,50 €
6					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	15.296,60 €	**19.023,74 €**	53.190 €	34.166,26 €	384,07 €	33.782,18 €	6.756,44 €	27.025,75 €	27.409,82 €
7					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	15.296,60 €	**19.023,74 €**	53.190 €	34.166,26 €	345,67 €	33.820,59 €	6.764,12 €	27.056,47 €	27.402,14 €
8					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	15.296,60 €	**19.023,74 €**	53.190 €	34.166,26 €	307,26 €	33.859,00 €	6.771,80 €	27.087,20 €	27.394,46 €
9					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	15.296,60 €	**19.023,74 €**	53.190 €	34.166,26 €	268,85 €	33.897,41 €	6.779,48 €	27.117,92 €	27.386,78 €
10					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	15.296,60 €	**19.023,74 €**	53.190 €	34.166,26 €	230,44 €	33.935,81 €	6.787,16 €	27.148,65 €	27.379,09 €
11					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	15.296,60 €	**19.023,74 €**	53.190 €	34.166,26 €	192,04 €	33.974,22 €	6.794,84 €	27.179,38 €	27.371,41 €
12					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	15.296,60 €	**19.023,74 €**	53.190 €	34.166,26 €	153,63 €	34.012,63 €	6.802,53 €	27.210,10 €	27.363,73 €
13					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	15.296,60 €	**19.023,74 €**	53.190 €	34.166,26 €	115,22 €	34.051,03 €	6.810,21 €	27.240,83 €	27.356,05 €
14					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	15.296,60 €	**19.023,74 €**	53.190 €	34.166,26 €	76,81 €	34.089,44 €	6.817,89 €	27.271,55 €	27.348,37 €
15					1.978,25 €	1.287,20 €	461,69 €	**3.727,14 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	15.296,60 €	**19.023,74 €**	53.190 €	34.166,26 €	38,41 €	34.127,85 €	6.825,57 €	27.302,28 €	27.340,69 €
																					NPV 1	201.880,87 €

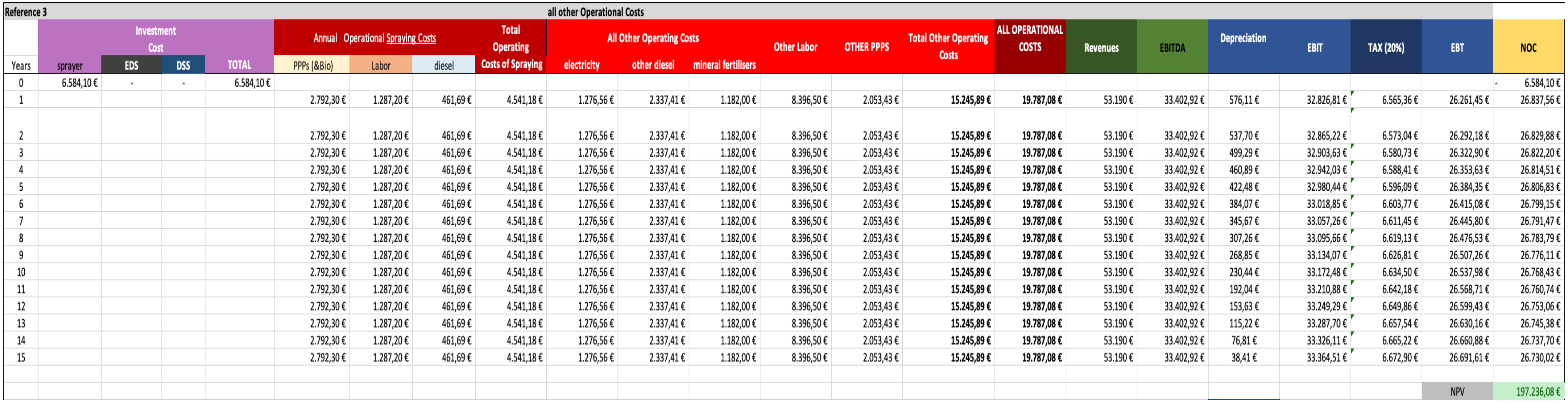
Cash Flow Streams for NPV Calculation – Reference 2



Reference 2 — all other Operational Costs

	Investment Cost				Annual Operational Spraying Costs					Total Operating Cost of Spraying		All Other Operating Costs			Other Labor	OTHER PPPS	Total Other Operating Costs	ALL OPERATIONAL COSTS	ALL OPERATIONAL COSTS		EBITDA	EBITDA	Depreciation	EBIT	EBIT	TAX (20%)	TAX (20%)	EBT	EBT	NOC	NOC
Years	sprayer	EDS	DSS	TOTAL	PPPs (100%)	PPPs (79%)	Labor	diesel	EDS	100%	79%	electricity	other diesel	mineral fertilisers				100%	79%	Revenues	100%	79%		100%	79%	100%	79%	100%	79%%	100%	79%
0	51.000,00 €	10.000,00 €		61.000,00 €																										- 61.000,00 €	- 61.000,00 €
1					1.978,25 €	1.563,87 €	7.412,56 €	461,69 €	500,00 €	**10.352,50 €**	**9.938,12 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.649,10 €**	**25.234,72 €**	53.190 €	27.540,90 €	27.955,28 €	5.712,50 €	21.828,40 €	22.242,78 €	4.365,68 €	4.448,56 €	17.462,72 €	17.794,22 €	23.175,22 €	23.506,72 €
2					1.978,25 €	1.563,87 €	7.412,56 €	461,69 €	500,00 €	**10.352,50 €**	**9.938,12 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.649,10 €**	**25.234,72 €**	53.190 €	27.540,90 €	27.955,28 €	5.331,67 €	22.209,23 €	22.623,61 €	4.441,85 €	4.524,72 €	17.767,38 €	18.098,89 €	23.099,05 €	23.430,55 €
3					1.978,25 €	1.563,87 €	7.412,56 €	461,69 €	500,00 €	**10.352,50 €**	**9.938,12 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.649,10 €**	**25.234,72 €**	53.190 €	27.540,90 €	27.955,28 €	4.950,83 €	22.590,06 €	23.004,44 €	4.518,01 €	4.600,89 €	18.072,05 €	18.403,55 €	23.022,88 €	23.354,39 €
4					1.978,25 €	1.563,87 €	7.412,56 €	461,69 €	500,00 €	**10.352,50 €**	**9.938,12 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.649,10 €**	**25.234,72 €**	53.190 €	27.540,90 €	27.955,28 €	4.570,00 €	22.970,90 €	23.385,28 €	4.594,18 €	4.677,06 €	18.376,72 €	18.708,22 €	22.946,72 €	23.278,22 €
5					1.978,25 €	1.563,87 €	7.412,56 €	461,69 €	500,00 €	**10.352,50 €**	**9.938,12 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.649,10 €**	**25.234,72 €**	53.190 €	27.540,90 €	27.955,28 €	4.189,17 €	23.351,73 €	23.766,11 €	4.670,35 €	4.753,22 €	18.681,38 €	19.012,89 €	22.870,55 €	23.202,05 €
6					1.978,25 €	1.563,87 €	7.412,56 €	461,69 €	500,00 €	**10.352,50 €**	**9.938,12 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.649,10 €**	**25.234,72 €**	53.190 €	27.540,90 €	27.955,28 €	3.808,33 €	23.732,56 €	24.146,94 €	4.746,51 €	4.829,39 €	18.986,05 €	19.317,55 €	22.794,38 €	23.125,89 €
7					1.978,25 €	1.563,87 €	7.412,56 €	461,69 €	500,00 €	**10.352,50 €**	**9.938,12 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.649,10 €**	**25.234,72 €**	53.190 €	27.540,90 €	27.955,28 €	3.427,50 €	24.113,40 €	24.527,78 €	4.822,68 €	4.905,56 €	19.290,72 €	19.622,22 €	22.718,22 €	23.049,72 €
8					1.978,25 €	1.563,87 €	7.412,56 €	461,69 €	500,00 €	**10.352,50 €**	**9.938,12 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.649,10 €**	**25.234,72 €**	53.190 €	27.540,90 €	27.955,28 €	3.046,67 €	24.494,23 €	24.908,61 €	4.898,85 €	4.981,72 €	19.595,38 €	19.926,89 €	22.642,05 €	22.973,55 €
9					1.978,25 €	1.563,87 €	7.412,56 €	461,69 €	500,00 €	**10.352,50 €**	**9.938,12 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.649,10 €**	**25.234,72 €**	53.190 €	27.540,90 €	27.955,28 €	2.665,83 €	24.875,06 €	25.289,44 €	4.975,01 €	5.057,89 €	19.900,05 €	20.231,55 €	22.565,88 €	22.897,39 €
10					1.978,25 €	1.563,87 €	7.412,56 €	461,69 €	500,00 €	**10.352,50 €**	**9.938,12 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.649,10 €**	**25.234,72 €**	53.190 €	27.540,90 €	27.955,28 €	2.285,00 €	25.255,90 €	25.670,28 €	5.051,18 €	5.134,06 €	20.204,72 €	20.536,22 €	22.489,72 €	22.821,22 €
11					1.978,25 €	1.563,87 €	7.412,56 €	461,69 €	500,00 €	**10.352,50 €**	**9.938,12 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.649,10 €**	**25.234,72 €**	53.190 €	27.540,90 €	27.955,28 €	1.904,17 €	25.636,73 €	26.051,11 €	5.127,35 €	5.210,22 €	20.509,38 €	20.840,89 €	22.413,55 €	22.745,05 €
12					1.978,25 €	1.563,87 €	7.412,56 €	461,69 €	500,00 €	**10.352,50 €**	**9.938,12 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.649,10 €**	**25.234,72 €**	53.190 €	27.540,90 €	27.955,28 €	1.523,33 €	26.017,56 €	26.431,94 €	5.203,51 €	5.286,39 €	20.814,05 €	21.145,55 €	22.337,38 €	22.668,89 €
13					1.978,25 €	1.563,87 €	7.412,56 €	461,69 €	500,00 €	**10.352,50 €**	**9.938,12 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.649,10 €**	**25.234,72 €**	53.190 €	27.540,90 €	27.955,28 €	1.142,50 €	26.398,40 €	26.812,78 €	5.279,68 €	5.362,56 €	21.118,72 €	21.450,22 €	22.261,22 €	22.592,72 €
14					1.978,25 €	1.563,87 €	7.412,56 €	461,69 €	500,00 €	**10.352,50 €**	**9.938,12 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.649,10 €**	**25.234,72 €**	53.190 €	27.540,90 €	27.955,28 €	761,67 €	26.779,23 €	27.193,61 €	5.355,85 €	5.438,72 €	21.423,38 €	21.754,89 €	22.185,05 €	22.516,55 €
15					1.978,25 €	1.563,87 €	7.412,56 €	461,69 €	500,00 €	**10.352,50 €**	**9.938,12 €**	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.649,10 €**	**25.234,72 €**	53.190 €	27.540,90 €	27.955,28 €	380,83 €	27.160,06 €	27.574,44 €	5.432,01 €	5.514,89 €	21.728,05 €	22.059,55 €	22.108,88 €	22.440,39 €
																													NPV 2	112.214,30 €	114.735,75 €

Cash Flow Streams for NPV Calculation – Reference 3

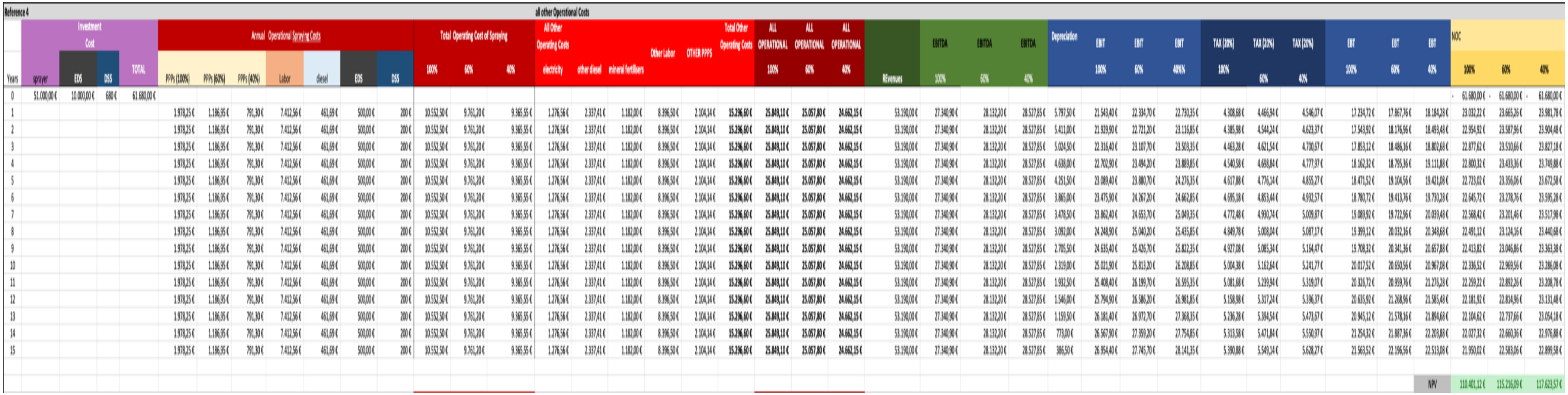


Reference 3

all other Operational Costs

	Investment Cost				Annual Operational Spraying Costs			Total Operating Costs of Spraying	All Other Operating Costs			Other Labor	OTHER PPPS	Total Other Operating Costs	ALL OPERATIONAL COSTS	Revenues	EBITDA	Depreciation	EBIT	TAX (20%)	EBT	NOC
Years	sprayer	EDS	DSS	TOTAL	PPPs (&Bio)	Labor	diesel		electricity	other diesel	mineral fertilisers											
0	6.584,10 €	-	-	6.584,10 €																		- 6.584,10 €
1					2.792,30 €	1.287,20 €	461,69 €	4.541,18 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.053,43 €	**15.245,89 €**	**19.787,08 €**	53.190 €	33.402,92 €	576,11 €	32.826,81 €	6.565,36 €	26.261,45 €	26.837,56 €
2					2.792,30 €	1.287,20 €	461,69 €	4.541,18 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.053,43 €	**15.245,89 €**	**19.787,08 €**	53.190 €	33.402,92 €	537,70 €	32.865,22 €	6.573,04 €	26.292,18 €	26.829,88 €
3					2.792,30 €	1.287,20 €	461,69 €	4.541,18 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.053,43 €	**15.245,89 €**	**19.787,08 €**	53.190 €	33.402,92 €	499,29 €	32.903,63 €	6.580,73 €	26.322,90 €	26.822,20 €
4					2.792,30 €	1.287,20 €	461,69 €	4.541,18 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.053,43 €	**15.245,89 €**	**19.787,08 €**	53.190 €	33.402,92 €	460,89 €	32.942,03 €	6.588,41 €	26.353,63 €	26.814,51 €
5					2.792,30 €	1.287,20 €	461,69 €	4.541,18 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.053,43 €	**15.245,89 €**	**19.787,08 €**	53.190 €	33.402,92 €	422,48 €	32.980,44 €	6.596,09 €	26.384,35 €	26.806,83 €
6					2.792,30 €	1.287,20 €	461,69 €	4.541,18 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.053,43 €	**15.245,89 €**	**19.787,08 €**	53.190 €	33.402,92 €	384,07 €	33.018,85 €	6.603,77 €	26.415,08 €	26.799,15 €
7					2.792,30 €	1.287,20 €	461,69 €	4.541,18 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.053,43 €	**15.245,89 €**	**19.787,08 €**	53.190 €	33.402,92 €	345,67 €	33.057,26 €	6.611,45 €	26.445,80 €	26.791,47 €
8					2.792,30 €	1.287,20 €	461,69 €	4.541,18 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.053,43 €	**15.245,89 €**	**19.787,08 €**	53.190 €	33.402,92 €	307,26 €	33.095,66 €	6.619,13 €	26.476,53 €	26.783,79 €
9					2.792,30 €	1.287,20 €	461,69 €	4.541,18 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.053,43 €	**15.245,89 €**	**19.787,08 €**	53.190 €	33.402,92 €	268,85 €	33.134,07 €	6.626,81 €	26.507,26 €	26.776,11 €
10					2.792,30 €	1.287,20 €	461,69 €	4.541,18 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.053,43 €	**15.245,89 €**	**19.787,08 €**	53.190 €	33.402,92 €	230,44 €	33.172,48 €	6.634,50 €	26.537,98 €	26.768,43 €
11					2.792,30 €	1.287,20 €	461,69 €	4.541,18 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.053,43 €	**15.245,89 €**	**19.787,08 €**	53.190 €	33.402,92 €	192,04 €	33.210,88 €	6.642,18 €	26.568,71 €	26.760,74 €
12					2.792,30 €	1.287,20 €	461,69 €	4.541,18 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.053,43 €	**15.245,89 €**	**19.787,08 €**	53.190 €	33.402,92 €	153,63 €	33.249,29 €	6.649,86 €	26.599,43 €	26.753,06 €
13					2.792,30 €	1.287,20 €	461,69 €	4.541,18 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.053,43 €	**15.245,89 €**	**19.787,08 €**	53.190 €	33.402,92 €	115,22 €	33.287,70 €	6.657,54 €	26.630,16 €	26.745,38 €
14					2.792,30 €	1.287,20 €	461,69 €	4.541,18 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.053,43 €	**15.245,89 €**	**19.787,08 €**	53.190 €	33.402,92 €	76,81 €	33.326,11 €	6.665,22 €	26.660,88 €	26.737,70 €
15					2.792,30 €	1.287,20 €	461,69 €	4.541,18 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.053,43 €	**15.245,89 €**	**19.787,08 €**	53.190 €	33.402,92 €	38,41 €	33.364,51 €	6.672,90 €	26.691,61 €	26.730,02 €
																					NPV	197.236,08 €

Cash Flow Streams for NPV Calculation – Reference 4

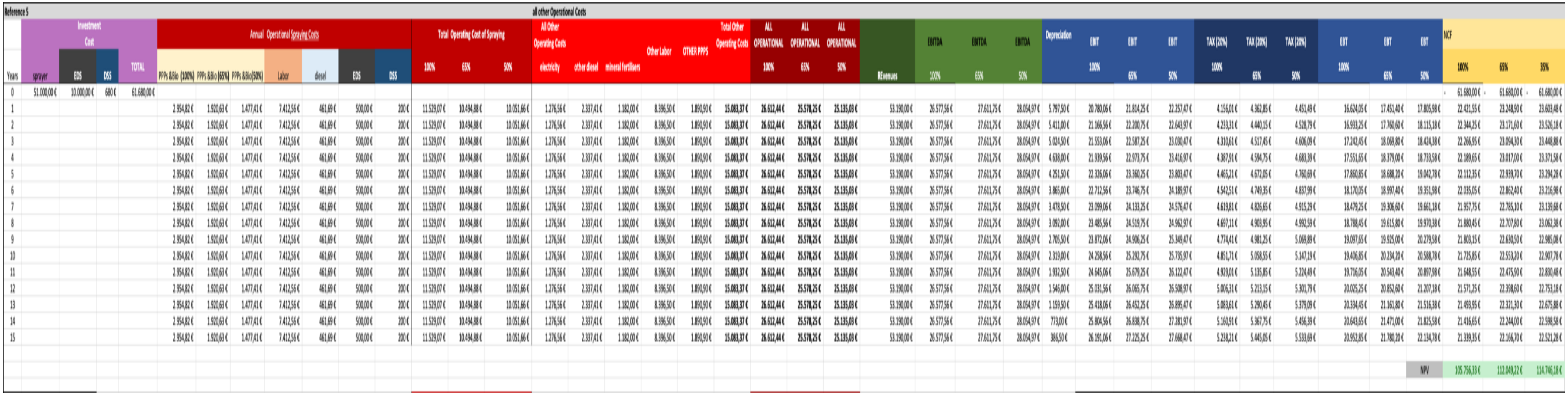


Reference 4

all other Operational Costs

	Investment Cost				Annual Operational Spraying Costs							Total Operating Cost of Spraying			All Other Operating Costs			Other Labor	OTHER PPPS	Total Other Operating Costs	ALL OPERATIONAL	ALL OPERATIONAL	ALL OPERATIONAL		EBITDA	EBITDA	EBITDA	Depreciation	EBIT	EBIT	EBIT	TAX (20%)	TAX (20%)	TAX (20%)	EBT	EBT	EBT	NOC		
Years	sprayer	EDS	DSS	TOTAL	PPPs (100%)	PPPs (60%)	PPPs (40%)	Labor	diesel	EDS	DSS	100%	60%	40%	electricity	other diesel	mineral fertilisers				100%	60%	40%	REvenues	100%	60%	40%		100%	60%	40%%	100%	60%	40%	100%	60%	40%	100%	60%	40%
0	51.000,00 €	10.000,00 €	680 €	61.680,00 €																																		- 61.680,00 €	- 61.680,00 €	- 61.680,00 €
1					1.978,25 €	1.186,95 €	791,30 €	7.412,56 €	461,69 €	500,00 €	200 €	10.552,50 €	9.761,20 €	9.365,55 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.849,10 €**	**25.057,80 €**	**24.662,15 €**	53.190,00 €	27.340,90 €	28.132,20 €	28.527,85 €	5.797,50 €	21.543,40 €	22.334,70 €	22.730,35 €	4.308,68 €	4.466,94 €	4.546,07 €	17.234,72 €	17.867,76 €	18.184,28 €	23.032,22 €	23.665,26 €	23.981,78 €
2					1.978,25 €	1.186,95 €	791,30 €	7.412,56 €	461,69 €	500,00 €	200 €	10.552,50 €	9.761,20 €	9.365,55 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.849,10 €**	**25.057,80 €**	**24.662,15 €**	53.190,00 €	27.340,90 €	28.132,20 €	28.527,85 €	5.411,00 €	21.929,90 €	22.721,20 €	23.116,85 €	4.385,98 €	4.544,24 €	4.623,37 €	17.543,92 €	18.176,96 €	18.493,48 €	22.954,92 €	23.587,96 €	23.904,48 €
3					1.978,25 €	1.186,95 €	791,30 €	7.412,56 €	461,69 €	500,00 €	200 €	10.552,50 €	9.761,20 €	9.365,55 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.849,10 €**	**25.057,80 €**	**24.662,15 €**	53.190,00 €	27.340,90 €	28.132,20 €	28.527,85 €	5.024,50 €	22.316,40 €	23.107,70 €	23.503,35 €	4.463,28 €	4.621,54 €	4.700,67 €	17.853,12 €	18.486,16 €	18.802,68 €	22.877,62 €	23.510,66 €	23.827,18 €
4					1.978,25 €	1.186,95 €	791,30 €	7.412,56 €	461,69 €	500,00 €	200 €	10.552,50 €	9.761,20 €	9.365,55 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.849,10 €**	**25.057,80 €**	**24.662,15 €**	53.190,00 €	27.340,90 €	28.132,20 €	28.527,85 €	4.638,00 €	22.702,90 €	23.494,20 €	23.889,85 €	4.540,58 €	4.698,84 €	4.777,97 €	18.162,32 €	18.795,36 €	19.111,88 €	22.800,32 €	23.433,36 €	23.749,88 €
5					1.978,25 €	1.186,95 €	791,30 €	7.412,56 €	461,69 €	500,00 €	200 €	10.552,50 €	9.761,20 €	9.365,55 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.849,10 €**	**25.057,80 €**	**24.662,15 €**	53.190,00 €	27.340,90 €	28.132,20 €	28.527,85 €	4.251,50 €	23.089,40 €	23.880,70 €	24.276,35 €	4.617,88 €	4.776,14 €	4.855,27 €	18.471,52 €	19.104,56 €	19.421,08 €	22.723,02 €	23.356,06 €	23.672,58 €
6					1.978,25 €	1.186,95 €	791,30 €	7.412,56 €	461,69 €	500,00 €	200 €	10.552,50 €	9.761,20 €	9.365,55 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.849,10 €**	**25.057,80 €**	**24.662,15 €**	53.190,00 €	27.340,90 €	28.132,20 €	28.527,85 €	3.865,00 €	23.475,90 €	24.267,20 €	24.662,85 €	4.695,18 €	4.853,44 €	4.932,57 €	18.780,72 €	19.413,76 €	19.730,28 €	22.645,72 €	23.278,76 €	23.595,28 €
7					1.978,25 €	1.186,95 €	791,30 €	7.412,56 €	461,69 €	500,00 €	200 €	10.552,50 €	9.761,20 €	9.365,55 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.849,10 €**	**25.057,80 €**	**24.662,15 €**	53.190,00 €	27.340,90 €	28.132,20 €	28.527,85 €	3.478,50 €	23.862,40 €	24.653,70 €	25.049,35 €	4.772,48 €	4.930,74 €	5.009,87 €	19.089,92 €	19.722,96 €	20.039,48 €	22.568,42 €	23.201,46 €	23.517,98 €
8					1.978,25 €	1.186,95 €	791,30 €	7.412,56 €	461,69 €	500,00 €	200 €	10.552,50 €	9.761,20 €	9.365,55 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.849,10 €**	**25.057,80 €**	**24.662,15 €**	53.190,00 €	27.340,90 €	28.132,20 €	28.527,85 €	3.092,00 €	24.248,90 €	25.040,20 €	25.435,85 €	4.849,78 €	5.008,04 €	5.087,17 €	19.399,12 €	20.032,16 €	20.348,68 €	22.491,12 €	23.124,16 €	23.440,68 €
9					1.978,25 €	1.186,95 €	791,30 €	7.412,56 €	461,69 €	500,00 €	200 €	10.552,50 €	9.761,20 €	9.365,55 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.849,10 €**	**25.057,80 €**	**24.662,15 €**	53.190,00 €	27.340,90 €	28.132,20 €	28.527,85 €	2.705,50 €	24.635,40 €	25.426,70 €	25.822,35 €	4.927,08 €	5.085,34 €	5.164,47 €	19.708,32 €	20.341,36 €	20.657,88 €	22.413,82 €	23.046,86 €	23.363,38 €
10					1.978,25 €	1.186,95 €	791,30 €	7.412,56 €	461,69 €	500,00 €	200 €	10.552,50 €	9.761,20 €	9.365,55 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.849,10 €**	**25.057,80 €**	**24.662,15 €**	53.190,00 €	27.340,90 €	28.132,20 €	28.527,85 €	2.319,00 €	25.021,90 €	25.813,20 €	26.208,85 €	5.004,38 €	5.162,64 €	5.241,77 €	20.017,52 €	20.650,56 €	20.967,08 €	22.336,52 €	22.969,56 €	23.286,08 €
11					1.978,25 €	1.186,95 €	791,30 €	7.412,56 €	461,69 €	500,00 €	200 €	10.552,50 €	9.761,20 €	9.365,55 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.849,10 €**	**25.057,80 €**	**24.662,15 €**	53.190,00 €	27.340,90 €	28.132,20 €	28.527,85 €	1.932,50 €	25.408,40 €	26.199,70 €	26.595,35 €	5.081,68 €	5.239,94 €	5.319,07 €	20.326,72 €	20.959,76 €	21.276,28 €	22.259,22 €	22.892,26 €	23.208,78 €
12					1.978,25 €	1.186,95 €	791,30 €	7.412,56 €	461,69 €	500,00 €	200 €	10.552,50 €	9.761,20 €	9.365,55 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.849,10 €**	**25.057,80 €**	**24.662,15 €**	53.190,00 €	27.340,90 €	28.132,20 €	28.527,85 €	1.546,00 €	25.794,90 €	26.586,20 €	26.981,85 €	5.158,98 €	5.317,24 €	5.396,37 €	20.635,92 €	21.268,96 €	21.585,48 €	22.181,92 €	22.814,96 €	23.131,48 €
13					1.978,25 €	1.186,95 €	791,30 €	7.412,56 €	461,69 €	500,00 €	200 €	10.552,50 €	9.761,20 €	9.365,55 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.849,10 €**	**25.057,80 €**	**24.662,15 €**	53.190,00 €	27.340,90 €	28.132,20 €	28.527,85 €	1.159,50 €	26.181,40 €	26.972,70 €	27.368,35 €	5.236,28 €	5.394,54 €	5.473,67 €	20.945,12 €	21.578,16 €	21.894,68 €	22.104,62 €	22.737,66 €	23.054,18 €
14					1.978,25 €	1.186,95 €	791,30 €	7.412,56 €	461,69 €	500,00 €	200 €	10.552,50 €	9.761,20 €	9.365,55 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.849,10 €**	**25.057,80 €**	**24.662,15 €**	53.190,00 €	27.340,90 €	28.132,20 €	28.527,85 €	773,00 €	26.567,90 €	27.359,20 €	27.754,85 €	5.313,58 €	5.471,84 €	5.550,97 €	21.254,32 €	21.887,36 €	22.203,88 €	22.027,32 €	22.660,36 €	22.976,88 €
15					1.978,25 €	1.186,95 €	791,30 €	7.412,56 €	461,69 €	500,00 €	200 €	10.552,50 €	9.761,20 €	9.365,55 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	2.104,14 €	**15.296,60 €**	**25.849,10 €**	**25.057,80 €**	**24.662,15 €**	53.190,00 €	27.340,90 €	28.132,20 €	28.527,85 €	386,50 €	26.954,40 €	27.745,70 €	28.141,35 €	5.390,88 €	5.549,14 €	5.628,27 €	21.563,52 €	22.196,56 €	22.513,08 €	21.950,02 €	22.583,06 €	22.899,58 €
																																					NPV	110.401,12 €	115.216,09 €	117.623,57 €

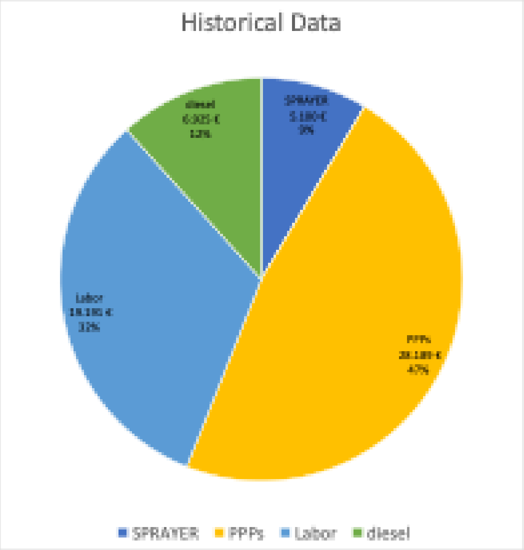
Cash Flow Streams for NPV Calculation – Reference 5

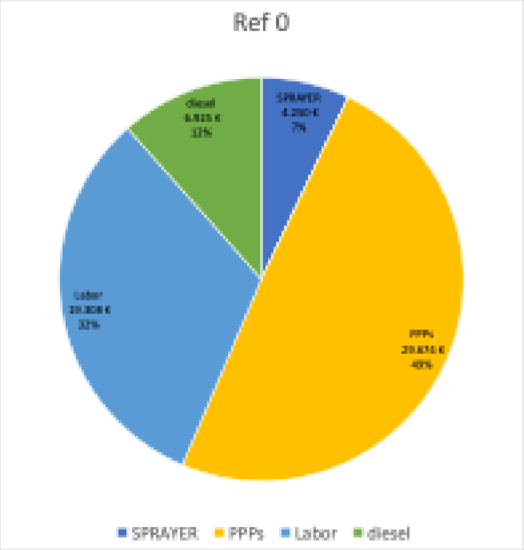


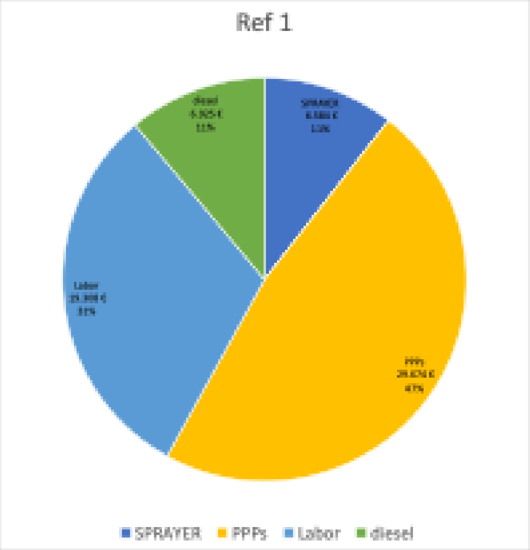
Reference 5															all other Operational Costs								
	Investment Cost				Annual Operational Spraying Costs							Total Operating Cost of Spraying			All Other Operating Costs					Total Other Operating Costs	ALL OPERATIONAL	ALL OPERATIONAL	ALL OPERATIONAL
Years	sprayer	EDS	DSS	TOTAL	PPPs &Bio (100%)	PPPs &Bio (65%)	PPPs &Bio(50%)	Labor	diesel	EDS	DSS	100%	65%	50%	electricity	other diesel	mineral fertilisers	Other Labor	OTHER PPPS		100%	65%	50%
0	51.000,00 €	10.000,00 €	680 €	61.680,00 €																			
1					2.954,82 €	1.920,63 €	1.477,41 €	7.412,56 €	461,69 €	500,00 €	200 €	11.529,07 €	10.494,88 €	10.051,66 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.890,90 €	**15.083,37 €**	**26.612,44 €**	**25.578,25 €**	**25.135,03 €**
2					2.954,82 €	1.920,63 €	1.477,41 €	7.412,56 €	461,69 €	500,00 €	200 €	11.529,07 €	10.494,88 €	10.051,66 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.890,90 €	**15.083,37 €**	**26.612,44 €**	**25.578,25 €**	**25.135,03 €**
3					2.954,82 €	1.920,63 €	1.477,41 €	7.412,56 €	461,69 €	500,00 €	200 €	11.529,07 €	10.494,88 €	10.051,66 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.890,90 €	**15.083,37 €**	**26.612,44 €**	**25.578,25 €**	**25.135,03 €**
4					2.954,82 €	1.920,63 €	1.477,41 €	7.412,56 €	461,69 €	500,00 €	200 €	11.529,07 €	10.494,88 €	10.051,66 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.890,90 €	**15.083,37 €**	**26.612,44 €**	**25.578,25 €**	**25.135,03 €**
5					2.954,82 €	1.920,63 €	1.477,41 €	7.412,56 €	461,69 €	500,00 €	200 €	11.529,07 €	10.494,88 €	10.051,66 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.890,90 €	**15.083,37 €**	**26.612,44 €**	**25.578,25 €**	**25.135,03 €**
6					2.954,82 €	1.920,63 €	1.477,41 €	7.412,56 €	461,69 €	500,00 €	200 €	11.529,07 €	10.494,88 €	10.051,66 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.890,90 €	**15.083,37 €**	**26.612,44 €**	**25.578,25 €**	**25.135,03 €**
7					2.954,82 €	1.920,63 €	1.477,41 €	7.412,56 €	461,69 €	500,00 €	200 €	11.529,07 €	10.494,88 €	10.051,66 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.890,90 €	**15.083,37 €**	**26.612,44 €**	**25.578,25 €**	**25.135,03 €**
8					2.954,82 €	1.920,63 €	1.477,41 €	7.412,56 €	461,69 €	500,00 €	200 €	11.529,07 €	10.494,88 €	10.051,66 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.890,90 €	**15.083,37 €**	**26.612,44 €**	**25.578,25 €**	**25.135,03 €**
9					2.954,82 €	1.920,63 €	1.477,41 €	7.412,56 €	461,69 €	500,00 €	200 €	11.529,07 €	10.494,88 €	10.051,66 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.890,90 €	**15.083,37 €**	**26.612,44 €**	**25.578,25 €**	**25.135,03 €**
10					2.954,82 €	1.920,63 €	1.477,41 €	7.412,56 €	461,69 €	500,00 €	200 €	11.529,07 €	10.494,88 €	10.051,66 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.890,90 €	**15.083,37 €**	**26.612,44 €**	**25.578,25 €**	**25.135,03 €**
11					2.954,82 €	1.920,63 €	1.477,41 €	7.412,56 €	461,69 €	500,00 €	200 €	11.529,07 €	10.494,88 €	10.051,66 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.890,90 €	**15.083,37 €**	**26.612,44 €**	**25.578,25 €**	**25.135,03 €**
12					2.954,82 €	1.920,63 €	1.477,41 €	7.412,56 €	461,69 €	500,00 €	200 €	11.529,07 €	10.494,88 €	10.051,66 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.890,90 €	**15.083,37 €**	**26.612,44 €**	**25.578,25 €**	**25.135,03 €**
13					2.954,82 €	1.920,63 €	1.477,41 €	7.412,56 €	461,69 €	500,00 €	200 €	11.529,07 €	10.494,88 €	10.051,66 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.890,90 €	**15.083,37 €**	**26.612,44 €**	**25.578,25 €**	**25.135,03 €**
14					2.954,82 €	1.920,63 €	1.477,41 €	7.412,56 €	461,69 €	500,00 €	200 €	11.529,07 €	10.494,88 €	10.051,66 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.890,90 €	**15.083,37 €**	**26.612,44 €**	**25.578,25 €**	**25.135,03 €**
15					2.954,82 €	1.920,63 €	1.477,41 €	7.412,56 €	461,69 €	500,00 €	200 €	11.529,07 €	10.494,88 €	10.051,66 €	1.276,56 €	2.337,41 €	1.182,00 €	8.396,50 €	1.890,90 €	**15.083,37 €**	**26.612,44 €**	**25.578,25 €**	**25.135,03 €**

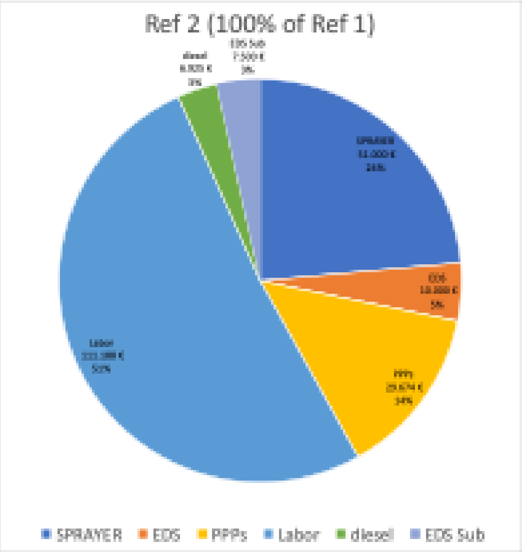
		EBITDA	EBITDA	EBITDA	Depreciation	EBIT	EBIT	EBIT	TAX (20%)	TAX (20%)	TAX (20%)	EBT	EBT	EBT	NCF		
Years	REvenues	100%	65%	50%		100%	65%	50%	100%	65%	50%	100%	65%	50%	100%	65%	35%
0															- 61.680,00 €	- 61.680,00 €	- 61.680,00 €
1	53.190,00 €	26.577,56 €	27.611,75 €	28.054,97 €	5.797,50 €	20.780,06 €	21.814,25 €	22.257,47 €	4.156,01 €	4.362,85 €	4.451,49 €	16.624,05 €	17.451,40 €	17.805,98 €	22.421,55 €	23.248,90 €	23.603,48 €
2	53.190,00 €	26.577,56 €	27.611,75 €	28.054,97 €	5.411,00 €	21.166,56 €	22.200,75 €	22.643,97 €	4.233,31 €	4.440,15 €	4.528,79 €	16.933,25 €	17.760,60 €	18.115,18 €	22.344,25 €	23.171,60 €	23.526,18 €
3	53.190,00 €	26.577,56 €	27.611,75 €	28.054,97 €	5.024,50 €	21.553,06 €	22.587,25 €	23.030,47 €	4.310,61 €	4.517,45 €	4.606,09 €	17.242,45 €	18.069,80 €	18.424,38 €	22.266,95 €	23.094,30 €	23.448,88 €
4	53.190,00 €	26.577,56 €	27.611,75 €	28.054,97 €	4.638,00 €	21.939,56 €	22.973,75 €	23.416,97 €	4.387,91 €	4.594,75 €	4.683,39 €	17.551,65 €	18.379,00 €	18.733,58 €	22.189,65 €	23.017,00 €	23.371,58 €
5	53.190,00 €	26.577,56 €	27.611,75 €	28.054,97 €	4.251,50 €	22.326,06 €	23.360,25 €	23.803,47 €	4.465,21 €	4.672,05 €	4.760,69 €	17.860,85 €	18.688,20 €	19.042,78 €	22.112,35 €	22.939,70 €	23.294,28 €
6	53.190,00 €	26.577,56 €	27.611,75 €	28.054,97 €	3.865,00 €	22.712,56 €	23.746,75 €	24.189,97 €	4.542,51 €	4.749,35 €	4.837,99 €	18.170,05 €	18.997,40 €	19.351,98 €	22.035,05 €	22.862,40 €	23.216,98 €
7	53.190,00 €	26.577,56 €	27.611,75 €	28.054,97 €	3.478,50 €	23.099,06 €	24.133,25 €	24.576,47 €	4.619,81 €	4.826,65 €	4.915,29 €	18.479,25 €	19.306,60 €	19.661,18 €	21.957,75 €	22.785,10 €	23.139,68 €
8	53.190,00 €	26.577,56 €	27.611,75 €	28.054,97 €	3.092,00 €	23.485,56 €	24.519,75 €	24.962,97 €	4.697,11 €	4.903,95 €	4.992,59 €	18.788,45 €	19.615,80 €	19.970,38 €	21.880,45 €	22.707,80 €	23.062,38 €
9	53.190,00 €	26.577,56 €	27.611,75 €	28.054,97 €	2.705,50 €	23.872,06 €	24.906,25 €	25.349,47 €	4.774,41 €	4.981,25 €	5.069,89 €	19.097,65 €	19.925,00 €	20.279,58 €	21.803,15 €	22.630,50 €	22.985,08 €
10	53.190,00 €	26.577,56 €	27.611,75 €	28.054,97 €	2.319,00 €	24.258,56 €	25.292,75 €	25.735,97 €	4.851,71 €	5.058,55 €	5.147,19 €	19.406,85 €	20.234,20 €	20.588,78 €	21.725,85 €	22.553,20 €	22.907,78 €
11	53.190,00 €	26.577,56 €	27.611,75 €	28.054,97 €	1.932,50 €	24.645,06 €	25.679,25 €	26.122,47 €	4.929,01 €	5.135,85 €	5.224,49 €	19.716,05 €	20.543,40 €	20.897,98 €	21.648,55 €	22.475,90 €	22.830,48 €
12	53.190,00 €	26.577,56 €	27.611,75 €	28.054,97 €	1.546,00 €	25.031,56 €	26.065,75 €	26.508,97 €	5.006,31 €	5.213,15 €	5.301,79 €	20.025,25 €	20.852,60 €	21.207,18 €	21.571,25 €	22.398,60 €	22.753,18 €
13	53.190,00 €	26.577,56 €	27.611,75 €	28.054,97 €	1.159,50 €	25.418,06 €	26.452,25 €	26.895,47 €	5.083,61 €	5.290,45 €	5.379,09 €	20.334,45 €	21.161,80 €	21.516,38 €	21.493,95 €	22.321,30 €	22.675,88 €
14	53.190,00 €	26.577,56 €	27.611,75 €	28.054,97 €	773,00 €	25.804,56 €	26.838,75 €	27.281,97 €	5.160,91 €	5.367,75 €	5.456,39 €	20.643,65 €	21.471,00 €	21.825,58 €	21.416,65 €	22.244,00 €	22.598,58 €
15	53.190,00 €	26.577,56 €	27.611,75 €	28.054,97 €	386,50 €	26.191,06 €	27.225,25 €	27.668,47 €	5.238,21 €	5.445,05 €	5.533,69 €	20.952,85 €	21.780,20 €	22.134,78 €	21.339,35 €	22.166,70 €	22.521,28 €
														NPV	105.756,33 €	112.049,22 €	114.746,18 €

Cost Structure of Spraying PPP- all References





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PPPs
Labor
diesel
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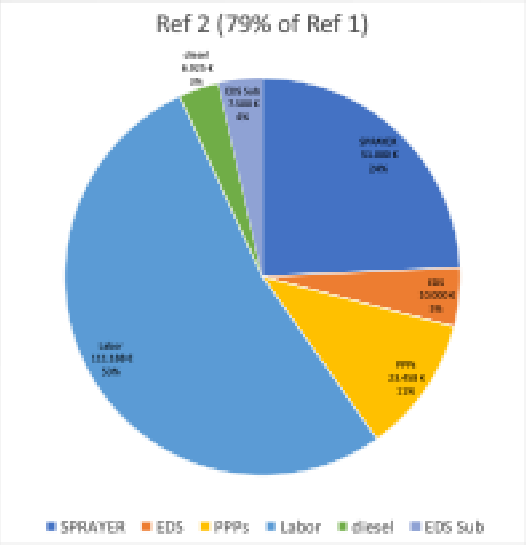
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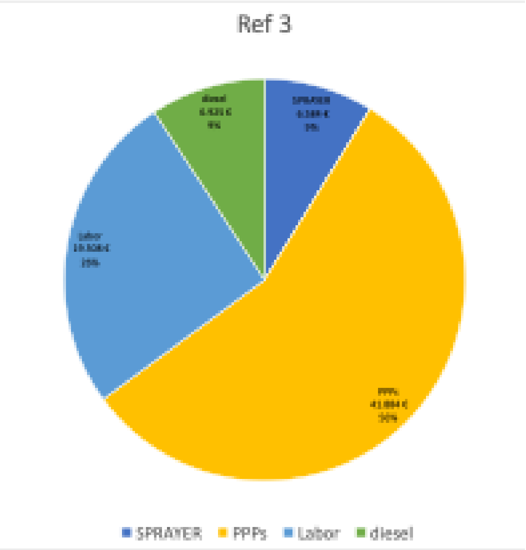
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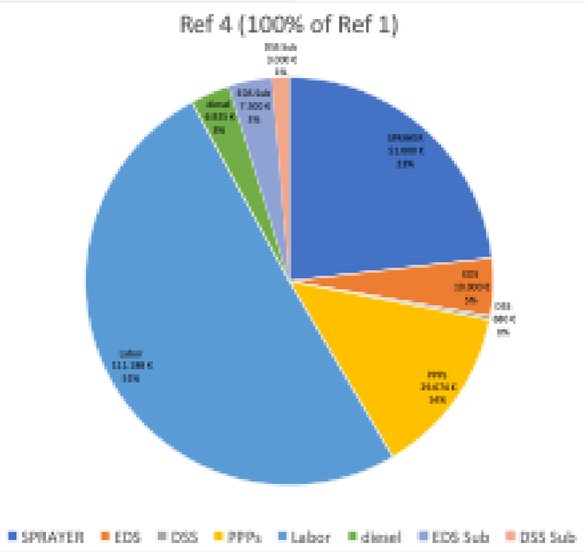
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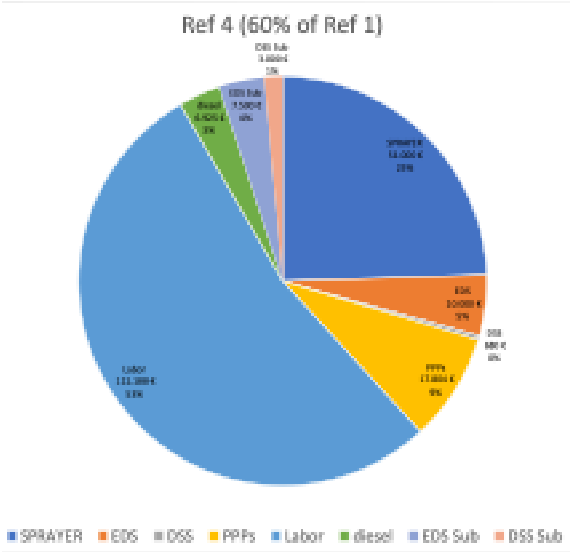
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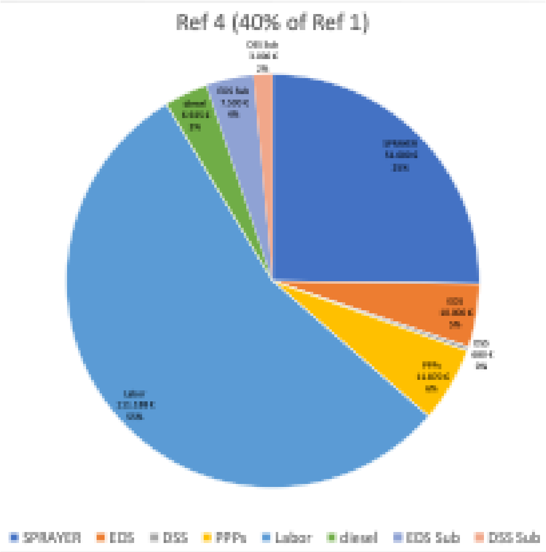
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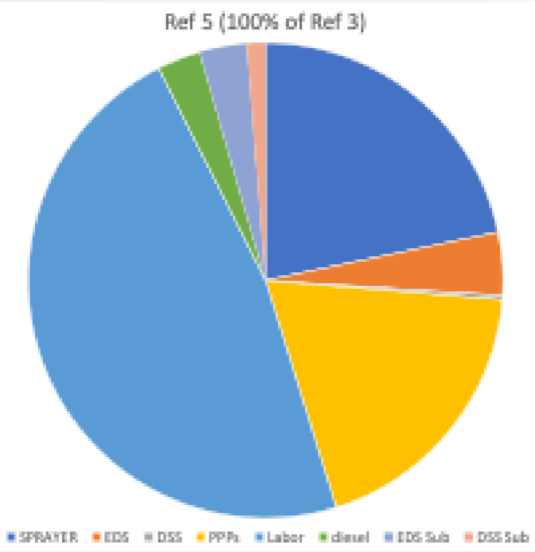
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DSS
PPPs
Labor
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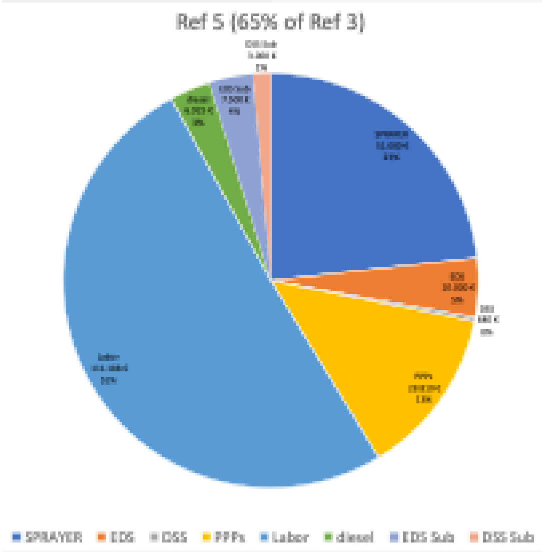
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DSS
PPPs
Labor
diesel
EDS Sub
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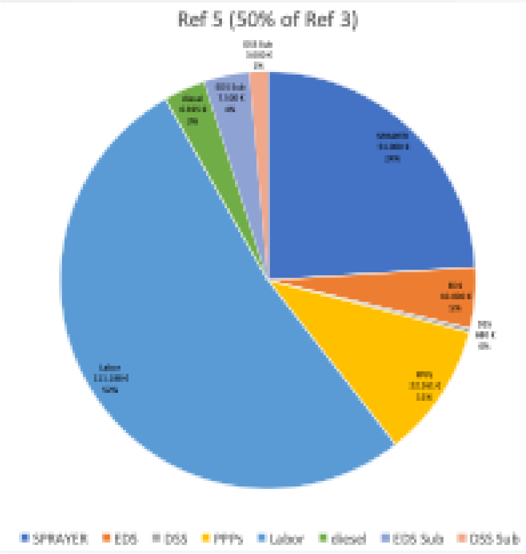
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EDS
DSS
PPPs
Labor
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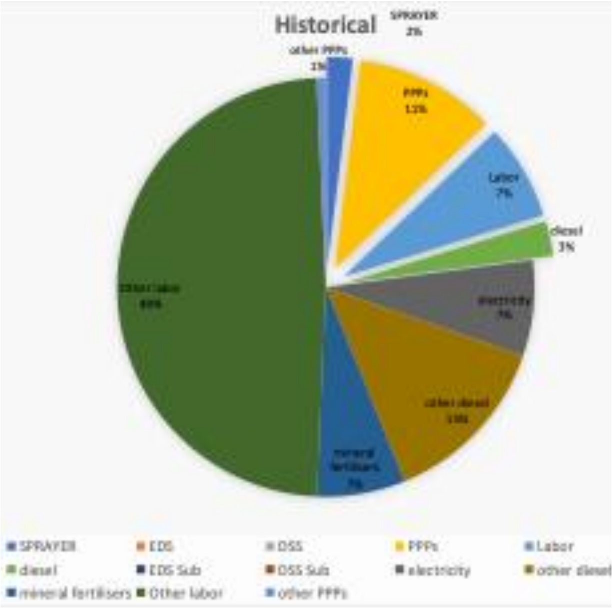
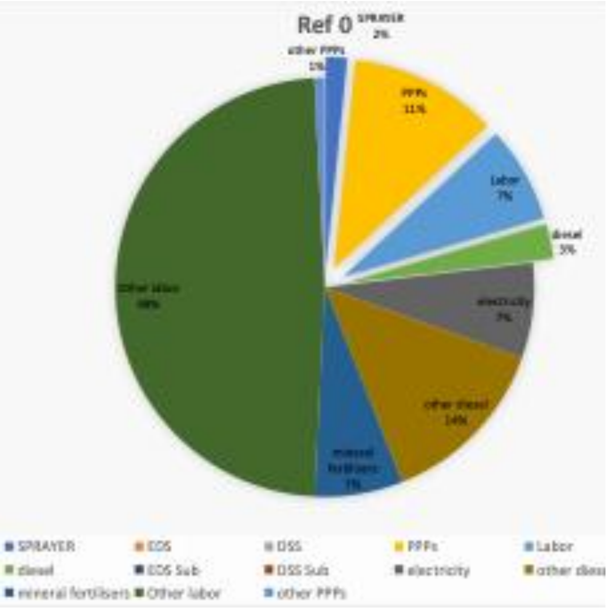
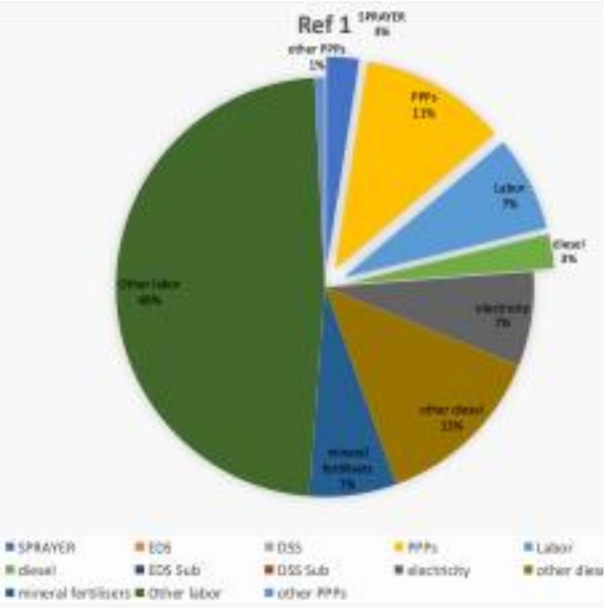
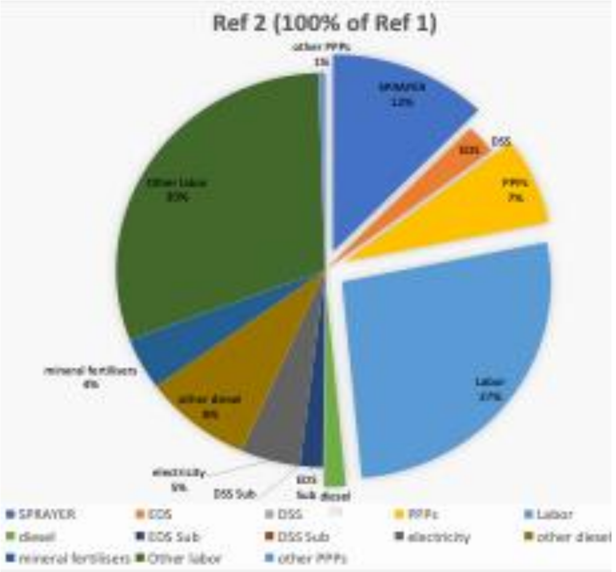
EDS Sub
DSS Sub

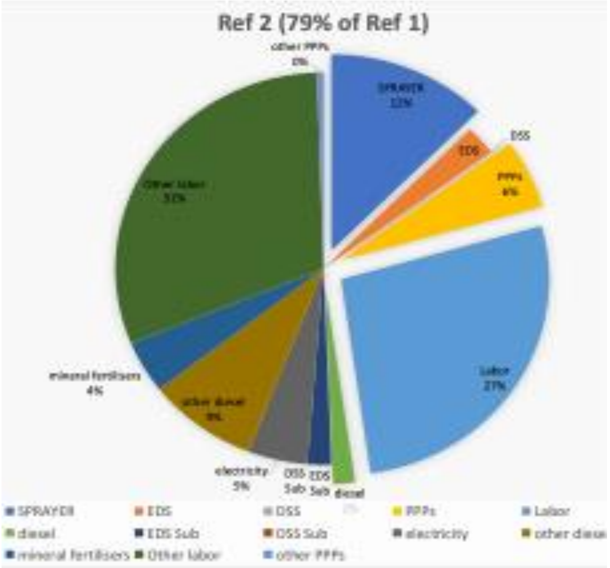
Total Vineyard Cost Structure of all References

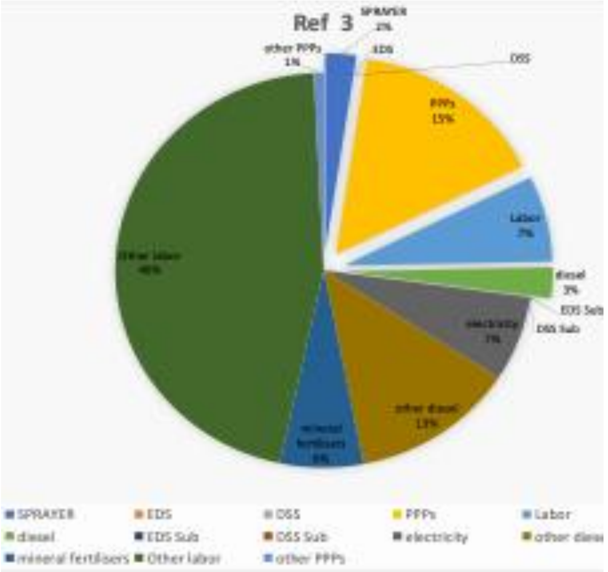


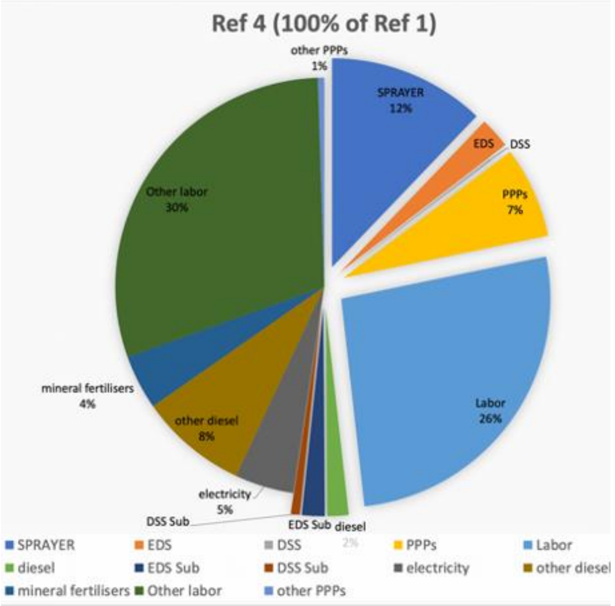


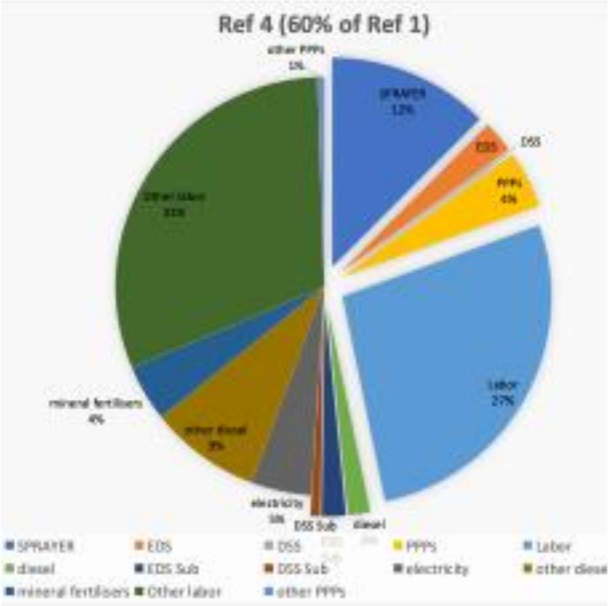


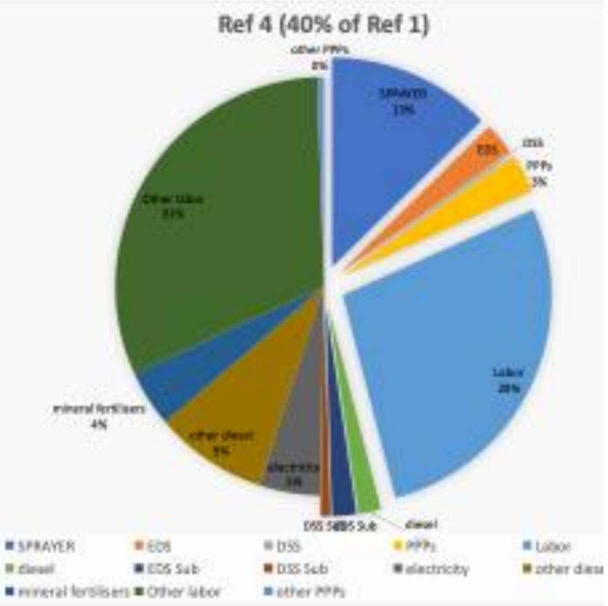

Ref 2 (100% of Ref 1)
other PPPs 1%
SPRAYER 12%
EDS
DSS
PPPs 7%
Labor 27%
Other Labor 33%
mineral fertilisers 4%
other diesel 8%
electricity 5%
DSS Sub
EDS Sub
diesel
SPRAYER
EDS
DSS
PPPs
Labor
diesel
EDS Sub
DSS Sub
electricity
other diesel
mineral fertilisers
Other labor
other PPPs

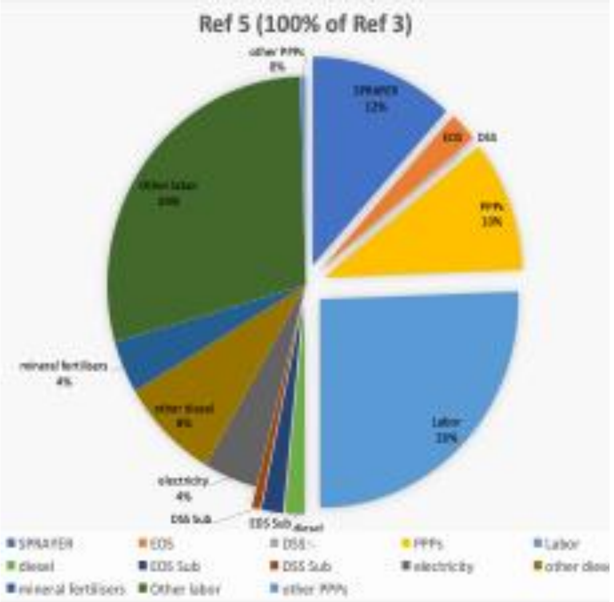

Ref 2 (79% of Ref 1)
other PPPs 0%
SPRAYER 12%
EDS
DSS
PPPs 6%
Labor 27%
Other Labor 32%
mineral fertilisers 4%
other diesel 9%
electricity 5%
DSS Sub
EDS Sub
diesel
SPRAYER
EDS
DSS
PPPs
Labor
diesel
EDS Sub
DSS Sub
electricity
other diese
mineral fertilisers
Other labor
other PPPs

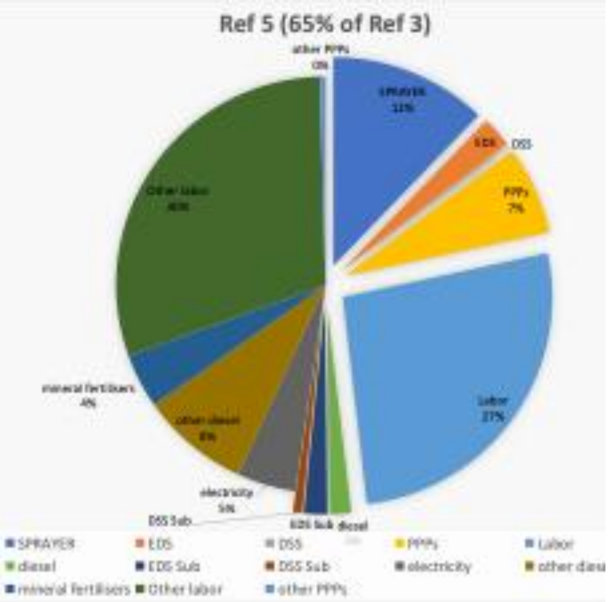

Ref 3
SPRAYER 2%
other PPPs 1%
EDS
DSS
PPPs 15%
Labor 7%
diesel 3%
EDS Sub
DSS Sub
electricity 7%
other diesel 13%
mineral fertilisers 6%
Other labor 46%
SPRAYER
EDS
DSS
PPPs
Labor
diesel
EDS Sub
DSS Sub
electricity
other diese
mineral fertilisers
Other labor
other PPPs

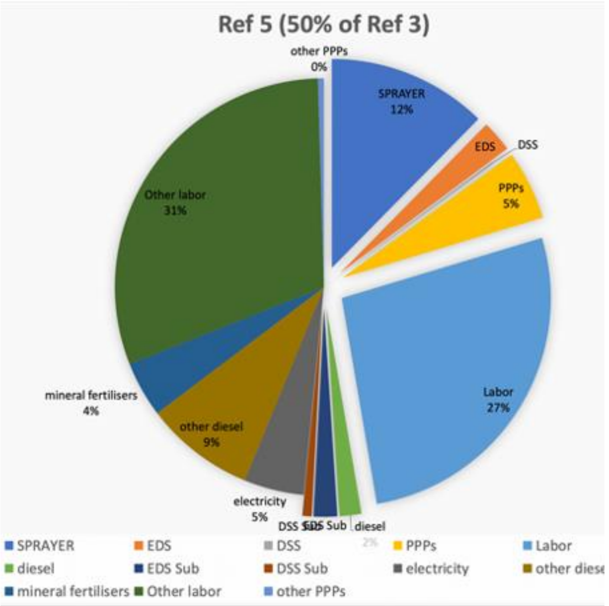

Ref 4 (100% of Ref 1)


Ref 4 (60% of Ref 1)


Ref 4 (40% of Ref 1)


Ref 5 (100% of Ref 3)


Ref 5 (65% of Ref 3)


Ref 5 (50% of Ref 3)