Pucha Preta Agroforestry Complex
Almost null balance eco farms

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Abstract

The management of planetary resources is far from reaching the equity and sustainability needed to achieve effective worldwide well-being. It's essential to promote a strong sense of individual action, a stronghold of responsibility for mankind and the planet. This dissertation is, therefore, a contribution in the form of a preliminary study for the installation of an agroforestry complex, so users can live more ecologically and with greater independence of general supply chains.

To make it possible, the national agroforestry sector is characterized: a country whose soil and ecosystems are diminished, governed by strategies that poorly prepared us to face changes in the climate. Benefits of the sector are listed. The natural park and the property where the complex is to be installed are characterized, for its correct integration in the natural dynamics of its surroundings. The reforestation plan is drafted, with a tree mesh that promotes the requalification of soil and local ecosystems. Difficulties in establishing new trees in the degraded soil, under severe climate and lacking an adequate vegetative protection, are resolved through irrigation and a water distribution photovoltaic powered system. Also, in order to provide the means to live in the property, the requalification of existing structures is studied, and a photovoltaic system is designed to meet the domestic consumption and thermal comfort needs - the latter supported by biomass. The investment is accounted for and a comment is made available based on relevance and viability.

***Keywords*:** agroforestry complex; operational sustainability; ecosystem rehabilitation; forestry synergy.

1 Introduction

In 1987 the United Nations World Commission on Environment and Development published *Our Common Future,* a report which synthesized the environmental debate into a single sentence: "Humanity has the capacity to create sustainable development to ensure that it meets its present needs without compromising that possibility for future generations." The same commission pointed out the need to address the problem of poverty – considered to significantly increase pressures on the environment – and the need for a less materialistic and more equitable economy – so that essential human needs for food, energy, housing, water and health can be met. Also, that development cannot be considered sustainable if it is not equitable [1].

It turns out that, despite the numerous objectives set, proposed and voted, such a problem as a more just and altruistic distribution of planetary wealth remains to be solved [2] [3]. However, because it's fundamental to regard the universal ethical principles that exalts us as a species as the ones that should prevail, the best is to act the ones that have a vision beyond materiality, and understand that we should not consider our needs first than the others [4] [5]. Taking this into consideration, and because the author values, on the one hand, an altruistic and proactive stance capable of acting in order to make an individual contribution, and on the other hand, the well-being and peace of mind that nature can provide, it's settle as of being of essential value the development of projects that guarantee us quality of life and a protected stability – to the maximum possible extent – from the general supply chains that move our present society.

In this sense, a study for the implementing an agroforestry complex is developed, representing a personal contribution in the sense of the sustainability of our presence on Earth. The complex should be energetically independent, producer of wealth, sustainable and integrated in its natural surroundings, whose intervention doesn't compromise the sanity and biodiversity of the ecosystems it explores. On the contrary, the selected property, subjected to several fires, is ecologically quite weakened, and this complex aims to support the restructuring and strengthening of affected ecosystems.

1.1 Northeast geologic characterization and soil uses

Our identity, strategies as a society, property structures and uses of natural resources are strongly influenced by the diversity of our territory – the crossing of Atlantic, Mediterranean and Iberian Continental climatic influences over a complex soil pattern that covers almost all geological time. In the Northeast of Portugal, where the complex is to be install, *Leptosols* – thinner soils form from difficult weathering of sedimentary shales – dominate, and *Cambisols* – deeper, sand-textured, granite based – occupy half of the remaining area. As a result, the region soils are often thin and with high stoniness. The latter constitutes an unavoidable pedological and geomorphological feature, which limit the soil uses and practices: 77% of the territorial area corresponds to moderate and high stoniness, and that 34% is covered by rock [6] [7] [8] [9].

Due to its significant agroclimatic duality, this region may be divided into two topological sub-regions, shaped by different topography and climate: *Terra Fria* and *Terra Quente*. The second one, where the complex is to be install, is marked by the presence of the Mediterranean climate, the middle course of Douro river and vineyards terraces. The olive tree is characteristic, and cherry and almond trees colour the sage green landscapes [6] [10] [11]. A Land Suitability Chart establishes the domain of soil with significant limitations: reduced thickness – limits the rooting of the plants [7]; lack of water in the soil – its thickness doesn't allow water storage [12] [13]; the stoniness and sharp and irregular slopes – obstacle to cultural practices [7] [14]. Only 1% of this sub-region has a high agricultural suitability, compared to 7% not suitable for any agroforest purpose. The comparison between the areas used for agriculture, forestry and pasture, and its aptitude for these uses, reveals serious imbalances (Figure 1.1 and Table 1.1). Whether due to limitations or to uses not suited, current use does not meet the potential of the land, which corroborates the low productivity, and contribute to the further degradation of already weakened soils [7] [12] [14].

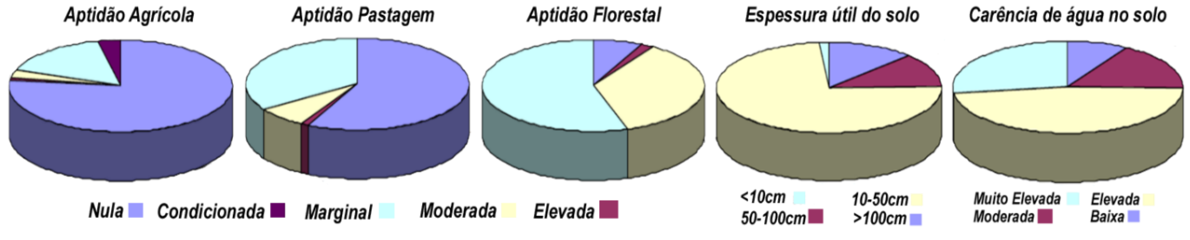

Figure 1.1 - The soils of the northeast of Portugal: aptitude and limitations to the land use. Image adapted for a qualitative view using student software version Adobe Photoshop [7].

Legend, up: Agricultural Aptitude; Pasture Aptitude, Forest Aptitude; Soil thickness; Soil water shortage. Legend, down left: Null; Conditional; Residual; Moderate; High. Legend, down right: Very High; High; Moderate; Low.

Table 1.1 - Northeastern land use and suitability [15].

Aptitude	*High + Moderate*	*Not Null*	*Current Usage*
Agricultural	4%	23%	47%
Pasture	8%	42%	5%
Forest	38%	93%	18%

1.2 The forest option

We, as a species, always benefit greatly from interacting with forests. This remains a subject of interest, especially in our urban landscapes where most of the word population can be found. Forests act as heat waves attenuators – refresh the surrounding areas, reflect radiation and provide shade, which lowers temperatures. They clean the air, water and soil, and conduct water infiltration. They provide useful recurses and food. Also, there are innumerable benefits in health care, such as encouraging physical activity, reducing stress levels and improvements in mental health, lower violence and crime levels, and increasing social interactions, which results in an higher life expectancy, and fewer health problems [12] [13] [16] [17].

If we characterize the state of the Portuguese forest, we find that half of its area was completely destroyed by fires over the last 30 years; the main extension is of eucalyptus – a non-autochthonous species distributed in large monospecies industrial extensions, highly propitious to fires and source of destruction of ecosystems and soils; the govern includes the latter, and areas completely burned or in early regeneration – all quite distant from what a balanced ecosystem is – so forest may be kept as the official dominant land use – 35.4%, 2010; and the forest area, if trends maintain, is steadily declining to the equivalent to 28 deforested football fields per day. The majority of this area passed to the class "wastelands and pasture" [18].

Nevertheless, rehabilitation, maintenance and expansion of healthy forest ecosystems constitutes a solution for all the predispositions to soil deterioration listed, promoting productive potential of the soil and of biodiversity [7]. This may be achieved through planned reforestation, based on autochthonous species and balances found in nature, to accelerate its regeneration and expansion. Multifunctionality for the forest spaces is therefore advocated, where income is sought through the synergistic use of surplus products, which is often intrinsic to its necessary maintenance. This protects and improves national soil, and it profitable in a sustainable way, with all the innumerable benefits associated with forests [12] [13] [19] [20].

It's also primordial to consider the challenges faced by the forestry sector – cyclical climate changes, a strong rural depopulation, constant and organized forest fire crimes, lack of political courage in create effective means on forest management, and spreading of pests, diseases and invasive species – which have a favourable scenario in the weakened national ecosystems. Responsible and effective strategies are essential for the maintenance and strengthening of our forest heritage [21] [22] [23] [24].

1.3 The Tua valley and the property under intervention

The property under intervention is located within the Regional Natural Park of the Tua Valley, a protected perimeter with characteristic climate and diversified ecosystems: 700 species of vascular flora, 400 of cryptogamic flora, 943 of fauna, as well as an undetermined number of aquatic invertebrate species grouped in 72 families. The landscape and the geomorphology are diverse and marked by hills, slopes, rocky outcrops, plateaus and valleys, namely the ones of the rivers Douro, Tua and Tinhela [11] [25].

The property where the complex is to be install, like most of the rural properties of this region – where there is no up-to-date land registry system – has no known official limits defined. So, following a procedure to officially new ones, a first step was taken by settle a temporary delimitation for the property, through the few known information available in the financial services and in the land registry services. The property is situated on a hillside, average slope of 25-30%, from the banks of the Tua River, to the beginning of the Serra do Faro peak. Field visits were made to understand the property potential for investment. A riverine 4ha area, and a 32ha submontane area were distinguished, divided by the national road. The absence of significant arboreal stratum was confirmed. Four covered structures, a well, a water collection structure, a small vegetable garden, fruit trees, and many watering hoses, once in daily operation, were identified. Only partial areas of vineyard crops for Port wine, and olive groves for own consumption olive oil are kept in operation.

2 Agroforest complex design

2.1 Reforestation mesh design and specimen selection

In order to be able to carry out the requalification of the submontane area, which will be the one that will be intervened with a reforestation plan, it was divided in topical areas by the type of present culture, the altitude and the humidity. For the area to be reforested – which corresponds to the majority of wastelands and burned areas, with the exception of ecological refuge – a principal mesh with an 8m compass was defined, after some alternative strategies designed, with the maximum adaptability to the level curves of the property to guarantee the levelling of the forest functional lines, to facilitate future maintenance operations and harvesting. A complementary mesh with an 4m compass was also defined, to the areas that also should be replanted but where no irrigation system is planned. From within the state listing of plants that are authorized and advised to be used in reforestation, those that are best adapted to the climate conditions and relief of the property, and to the strategic vision defined for the vegetal cover in creation, were chosen. For the 8m compass mesh, that is planned to be fully equipped with irrigation means, Quercus faginea (Portuguese oak), Quercus pyrenaica (Pyrenean oak), Pinus pinea (stone pine), Castanea sativa (chestnut), Quercus rotundifolia (holm oak), and Quercus suber (cork oak). For the 4m compass mesh, to the areas of the higher stoniness, Buxus sempervirens (boxwood), Juniperus oxycedrus (juniper), Olea europaea sylvestris (oleaster), Quercus coccifera (kermes oak); to the forest riverside, Acer monspessulanum (maple), Alnus glutinosa (alder), Betula pubescens (birch), Fagus sylvatica (beech), Fraxinus angustifolia (common ash), Sambucus nigra (elderberry); to the resto f the property with no planned irrigation system rest, like lining the paths and roads, Arbutus unedo (strawberry tree), Celtis australis (nettle tree), Prunus insititia (damson), Prunus spinosa (blackthorn), Laurus nobilis (laurel), a Prunus avium (cherry tree).

2.2 Water supply and storage system

Irrigation areas were defined so they have similar dimensions, which is reflected in similar quantities of water to be supplied to each one of them. It was also intended the continuity of the level lines. The water deposits were implanted at a higher elevation point than each irrigation area. Assumptions: **(i)** the irrigation needs of the forest species selected were defined accounting for the average annual rainfall – the property is included in areas of 524-701mm and 702-878mm [26] – of the region, the water requirements of each species – a minimal of 400-600mm for all species was considered [12] [27] [28] [29] – and a previous irrigation project considered as a valid reference [30] – due to the which resulted in the definition of an average value of 2500 m3/ha/year; **(ii)** it was a strategic conservative decision this water would have to be available in an period of six consecutive months (e.g. the driest); **(iii)** all the irrigation areas (AR) extension is considered irrigable; **(iv)** 8 meters diameter deposits integrated in the forestal mesh, with a minimum 8m water column; **(v)** water circulation is ensured by pumps, powered by photovoltaic panels mounted upon the deposits, with a 6 hours of nominal operation, daily – which is a conservative approach for the summer, where the demand will be at its highest; **(vi)** a minimum autonomy of 5 days – nominal irrigation values – for each irrigation area, considering either equipment faults or impossibility of water collection; **(vii)** pipe water velocities exceeding 1.5m/s are not advised to avoid eventual dangers inherent in water-hammer effects [31] [32].

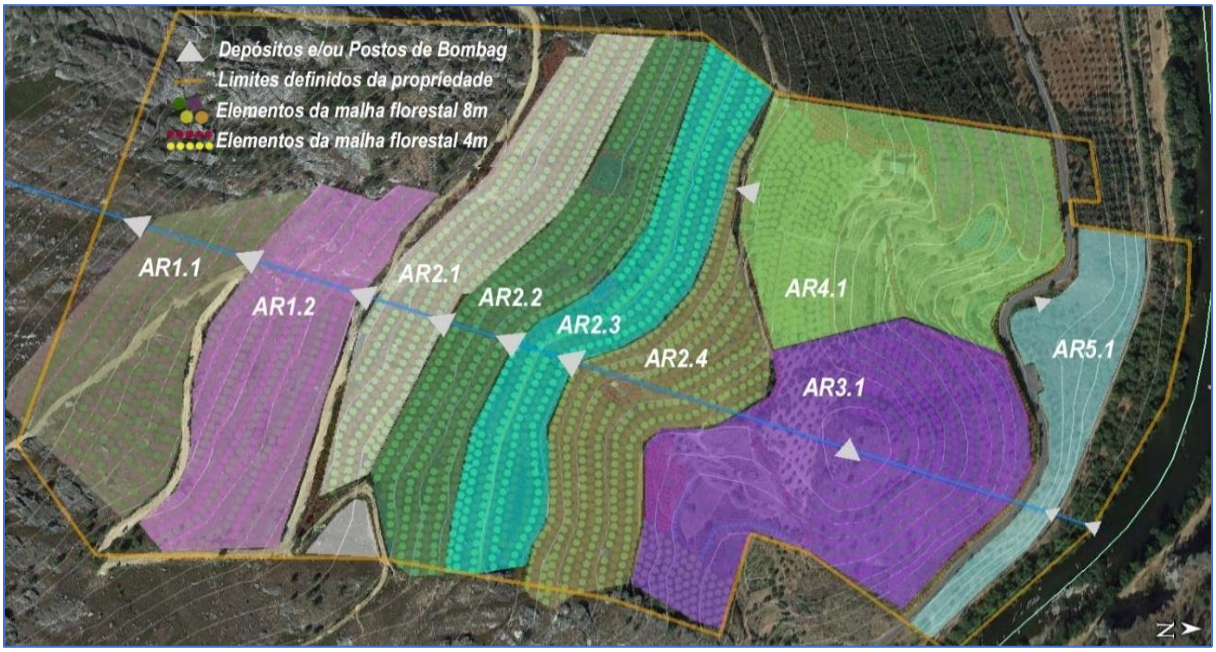

Figure 2.1 - Irrigation scheme on the reforestation mesh, over an aerial photography.

Table 2.1 - Planning of the gradual installation and cost of Deposits and Pumping Points.

	Tubagem	V_h [m^3/h]	D_{Need} [cm]	D_{Norm} [cm]	V_{Tub} [m/s]	Δh [m]	ΔL_{recta} [m]	ΔL_{est}* [m]	HP_1** [m]	HP_2*** [m]
1	*TUA/AR5.1*	7.0	5.0	20	0.06	29	240	291	47	33
2	*TUA/AR3.1*	63.3	15.0	20	0.56	93	215	262	109	97
3	*AR3.1/AR2.3*	38.4	11.7	20	0.34	35	335	400	59	40
4	*AR2.3/AR2.1*	25.3	9.5	20	0.22	40	155	193	52	43
5	*AR2.1/AR1.1*	12.3	6.6	20	0.11	80	240	291	98	-23
6	*AR2.3/AR4.1*	13.3	6.9	20	0.12	-27	310	371	-4	84
7	*Op: 1+2->5*	*70.2*	*1*	*15.8*	*0.62*	*248*	*945*	*1101*	*315*	*257*

$$*\Delta L_{est} = 1.15\Delta L_{recta} + 15,\ **HP_1 = 0.06\Delta L_{est},\ ***HP_2 = 0.037\Delta L_{est} + 1.75 + \Delta h$$

The head required is difference in heights between the initial tank base and the final tank top, plus the friction losses. The latter are estimated by two methods: (i) Through an irrigation diagram, using the inner diameter and the circulating flow, and a value of 6m/100m was estimated. (ii) Through Hazen-Williams equation tables considering: a distributed loss of 2m/100m; a loss of 0.17m per junction, one every 10m of piping – which is rather conservative, but provides room for future repairs; a localized loss of 0.35m per suction valve – five equivalent elements were considered per section [29] [33]. These values apply to 115% of the estimated pipe length – considering readjustment pipe needs – plus 15m to the rising of 12m in each tank. A third more conservative value of 10m/100m was considered. Results available in Table 2.1. Irrigation needs of the smaller trees aren't the same as the referenced values, so a coefficient of proportionality was defined.

Table 2.2 - Pump Station Planning with 6:00 nominal operation, e HP >200.

#ano	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
PSK2-40												1			
PSK2-100	1														
TUA/AR5.1															
TUA/AR3.1												1	1	1	1
AR3.1/AR2.3	1	1	1	1	1	1	1	1	1	1	1				
AR2.3/AR2.1												1	1	1	1
AR2.1/AR1.1															
AR2.3/AR4.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

2.3 Photovoltaic system simulation and design

In order to provide the means to live in the property, the requalification of structures is studied, and a photovoltaic system is designed to meet the domestic consumption and thermal needs - the latter supported by biomass. A consumption curve was defined considering characteristic of a family of four people, Figure 2.2. The climatization needs were estimated for predefined model characteristics [34]. A south facing typical system with panels, batteries, an Inverter + MPPT + Charge controller, and the connection cables was design through MATLAB simulation [90]. It was established that a set of 36 panels and 10 batteries, considering the coldest and warmest months in 2018, and that winter heating needs are supplied but a wood burned until 10kW. Equipment specifications and main mathematical considerations [35]. The developed simulation allowed to define consisting of 32 photovoltaic panels A typical current salamander was also considered [36].

3 Investment initial study

Costs were estimated for **reforestation operations**: Clearing 4 meters width functional lines and paths between them at €300/ha, a total of 12 ha, amounts to (i) €3600. Opening of pits, 800 pits/€750, for 4450 trees, amounts to (ii) €4170. Plantation at 200 units/€60, protective tubes at €0.35/unit, fertilization at €0.20/unit, which corresponds to a total of (iii) €3780 [19]. Considering Cork Oak at €1.75/unit, Oak trees at €1.25/unit; Tender pine at €1.75/unit; Chestnut tree at €2.25/unit; Holm oak at €1.75/unit [37], this amounts to (iv) €8110. Assuming (v) a mortality rate of 30%[38], it is estimated a total of **€25000**, (i+ii+iii+iv)[1+(v)] [39].

Costs were estimated for **pumping equipment and water tanks**: deposits are estimated around €15000 according to a manufacturer's information [40]. Regarding the pumping equipment [41], the supplier offered guideline prices between €8000 and €30000. Detailed prices are only available thought dedicated projects. In order to have a base price available for the pumping system, prices for the various models were assumed, and control and photovoltaic equipment was accounted as 50% of the pumps' value. Also, 1800 meters of piping was considered at 2 € / m [42], to which 40% in joints and other assessments are added, to a total of €5000.

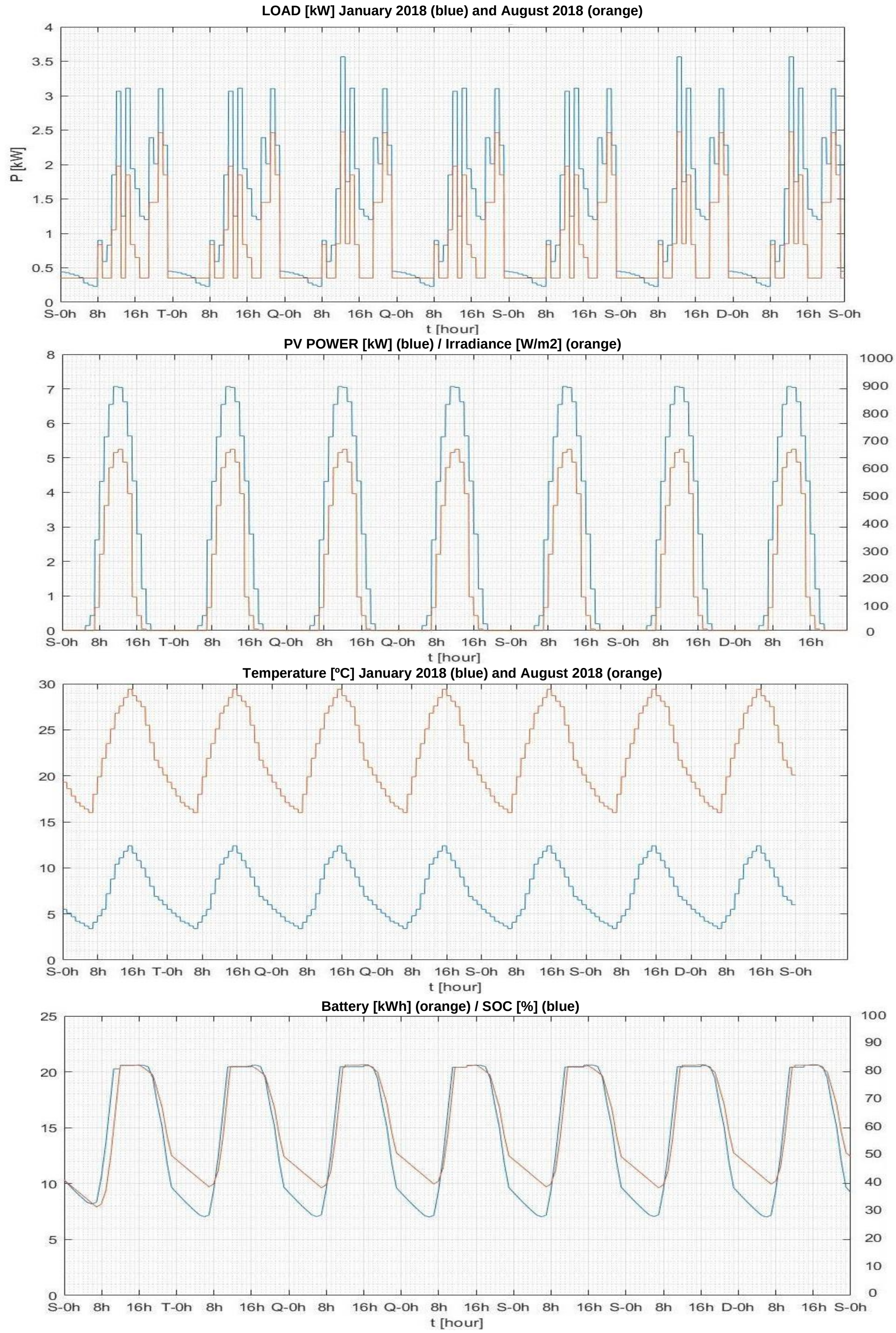

Figure 2.2 - Simulated behavior of the projected PV system. Images produced by simulation using the MATLAB student version software.

Table 3.1 - Planning of the Gradual Installation and Cost of Deposits and Pumping Points..

ano	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
AR1.1,1.2															
AR2.1, 2.2	1														
AR2.3,2.4					1				1						
AR3.1, 4.1, 5.1	1						1				1				
PSK2-40												1			
PSK2-100	1														
Piping	5														
Custo [k€]	80				15		15		15		15	30			

The investment in the **photovoltaic system's equipment** is estimated to be €6400 in the 32 photovoltaic panels, €3000 in the 10 batteries, € 2125 in the Inverter+MPPT+Charge controller, €500 in cable, and €100 in 6 protections [35]. Also €1700 in a wood burner [36]. This account for a total cost of **€13825**. Through the load curve, it is estimated a weekly electricity consumption of 176.4 kWh, annual average. Considering the price for sales tariff to final customers in BTN (<= 20.7 kVA and> 2.3 kVA), of €10.44/month for the contracted power of 6.9 kVA, and €0.1326/kWh for active energy [43], it's estimated a consumption of €1345/year. However, there is no electrical installation; considering an example of a 150m connection costing €1300 [44], and that 60% of the cost is proportional to the distance, it's estimated a cost of €2600. Costs for the support structures for the connection are arbitrated at €1000. This corresponds to a simple payback time of (1), or, if, from an academic point of view, this is calculated by considering an associated discount rate of 5%:

$$PBT = \frac{C_0}{C_i} = \frac{13819-3600}{1345} \approx 7{,}6 \qquad (1)$$

$$PBT = \ln\left[\left(1-\frac{C_0}{C_1}\right)^{-1}\right]/ln(1+r) \approx 10 \qquad (2)$$

4 Conclusions and future developments

The reality of our national forest and the relations between suitability and use of our land are conclusive indicators of, on one hand, the poor state of our ecosystems, and of significant opportunities to reduce expenses thought investment in solutions of low maintenance costs, independent of the supply outside foreign chains, and, on the other hand, the undisturbed progressive degradation of our soil potential. The expansion of forest areas, represents, in this sense, a cheaper solution for significant upgrades in the individual and in the society's quality of live, heath, and economical independence. It's essential the promotion of independent and responsible measures by governments.

Immediately, without being dependent on political decisions, strong individual measures are essential to defend the sustainability of our presence on Earth, the independence of the centralized supply chains on which we depend so much, and our quality of life. In this sense, the current dissertation seeks to be a first organized contribute to set in motion an implementation project for the mentioned agroforest complex, to achieve these objectives in an individual contribution scale. The estimates made here are first engineering reference values, to be iteratively adjusted with subsequent works and developments. Since there are no known local references on this subject, they can serve as iterative initial values.

Of all the investments, the reforestation is the one that covers the greater area intervened. It is expected that a good GPS location service, with high precision, will be a useful tool in marking the functional lines, for further soil preparing and reforestation work. It will be also necessary to carry out a dedicated study of local individuals of the selected species so that reproductive strategies can be chosen to create the collection of plants used, or to find someone able to provide this service. This is because local species generally have more adaptative capacities. Conceptually, the soil preparation and reforestation procedures are quite simple. Studies for characterization of the local soil are necessary for a better adaptation of soil preparation techniques, nutritional supplementation, adaptation of natural soil restoration practices, and adjustment of irrigation needs.

The water supply system, with the pumping equipment and the water tanks, are the most delicate investments in this project. The estimated costs are too high to be put into practice in the known context in which this study is set on. Even with the established gradual implementation strategies the individual costs must be reviewed with national suppliers, and alternatives studied in subsequent studies. Otherwise, additional multifunctional sectors that depend on the water supply must be considered so a financial analysis of the investment can be realised. It is also recognized that this first analysis was carried out, purposely, in a very conservative way. With the current project, more than twice the water required is available annually, with a minimum system autonomy of one week. Subsequent less conservative readjustment analysis and the exploration of less costly logistics alternatives will make investment more appealing.

The photovoltaic project, with the wood burner for winter heating, although it is possible to improve the energy model of the space (e.g. adapt the simulation parameters to the reality of the construction project), is conclusive and can be compared with proposals from suppliers, and subsequently adjusted for the other structures and implemented. For the structure where the minimum distance to the electrical network corresponds to a payback time of 7.6 years - and the equipment has all the guarantee period superior to that - the viability of the investment is guaranteed. Also, a conservative analysis was also made, since the peak of the energy needs occur in the summer, when only 6 hours of nominal panel operation were considered – value that is considered below the real energy available. Also, given the availability of circulating water, it would be of interest to study options for additional cooling of solar panels for additional increments in their performance.

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