The biological balance and ecological infrastructure of the vineyard landscape

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Abstract. The vineyard landscapes that are known today, almost everywhere, result fundamentally from the technical requirements of consumption and markets, and therefore production factors. This condition, corresponding to the productive function of the landscape, must be reconciled with its other functions - conservation of resources and recreation. This article aims to reflect on the principles of design, planning and management associated with this productive system, considering strategies to increase the landscape's biodiversity and ecological infrastructure, which contributes to greater environmental sustainability. It considers problems linked to climate change, and valuation of the landscape where the economic, social, ecological, and affective dimensions are integrated. The main features and concepts associated with sustainable wine production are integrated production or biologic production. The geomorphological, soil and microclimate features – expressed in the *terroir* - and the plant species most suitable for sustainable production and protection of these landscapes include systems, infrastructures, and patterns in each landscape. The reflection is supported by one case-study in the *Alentejo* region of Portugal – the Borba wine sub-region.

1 Introduction

Intensive agriculture is linked to damage to ecosystems, loss of biodiversity and homogenization of the landscape worldwide [1]. Thus, Sustainable Agriculture, Integrated Production or Organic Production are basic concepts and practices to raise the biological balance, conserve biodiversity and respect and/or value ecological infrastructure in agricultural landscapes.

Agricultural production depends on landscape characteristics, as well as on biodiversity and the ecological system. The articulation between natural and cultural systems determines complex dynamics. Agriculture can lead to major simplification and disruption of both systems.

Today's wine landscapes are based on technical consumption and market requirements, as well as on production factors. This productive function of the landscape must be reconciled with the conservation of resources and recreation (where affective feelings and sensory specificities are involved, as well as tourist dynamics). All of them are functions linked to the landscape - production, protection, and recreation.

The purpose of this article is to reflect on the design, planning and management principles associated with this productive system, considering strategies to increase biodiversity, respect and intensify the ecological system and value other landscape structures and infrastructure in the landscape, as well as historical and cultural aspects.

Such strategies and principles will naturally also contribute to greater environmental sustainability, to solving problems linked to climate change, and enhancement of the landscape - where economic, historical-cultural, social, ecological, and affective dimensions come together.

Integrated Production is defined as an *"(...) agricultural system for the production of food and other quality food products" based on the "rational management of natural resources" and which privileges "the use of regulatory mechanisms*" of production [2].

Thus, Integrated Production includes Integrated Protection, from the perspective of protecting plants and mitigating derivative effects (preservation of natural resources and safeguarding animals) [2,3].

The reflection is based on a case study in the south of Portugal, in the *Alentejo* region, the Borba wine sub-region.

2 Landscape of Borba wine sub-region of *Alentejo*, Portugal

2.1 Alentejo region

Portugal is a Mediterranean country, according to some cultural and natural attributes and/or influences: varied relief and soils, long summers, warm, dry and mild winters, low rainfall with high temperatures, intense light, settlements concentrated in the south of the country, significant depopulation, predominantly aging population, where extensive agricultural exploitation is dominant [4-6].

In these conditions, human needs dictated primarily a rural agricultural economy.

Alentejo is in the south of Portugal (Fig. 1). It is characterized by extensive plains, only interrupted by small hills or exceptionally by small mountains. It has extensive areas, with open cereal fields or pastures, cork oak forests (*montado*), woods and forests, vineyards, and olive groves. Smaller units are situated next to settlements, where there is diversified land use - market gardens and orchards, pastures, vineyards, and olive groves [5-7].

Alentejo is one of the largest wine regions in Portugal (22,000 hectares) (Fig. 1). It is a very sunny region and in the summer, temperatures are very high, allowing the perfect ripening of grapes [8].

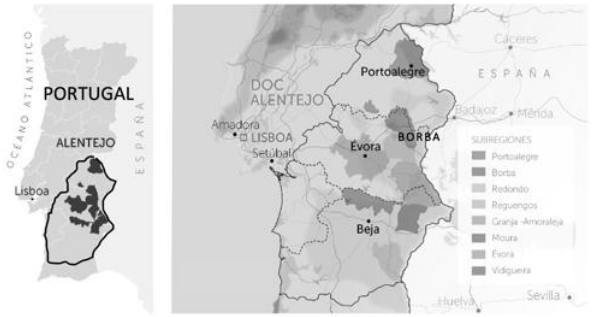


Figure 1. Portugal, *Alentejo* and wine sub-regions [9].

2.1.1 Borba sub-region

The Borba wine sub-region covers several administrative municipalities - Estremoz, Borba and Vila Viçosa being the largest (Fig. 2).

This territory is located between two large hydrographic basins - Tagus and Guadiana. Thus, the watercourses are mainly in the initial position, with a torrential regime. However, some have a permanent presence of water. This area has a large aquifer, which is an important support for agriculture, where intensive agriculture is carried out, requiring the use of water in plants which until recently was not needed (as in the case of vineyards).

In the Guadiana basin, the geological substrate is predominantly limestone and marble (*Anticline de Estremoz*), and consequently, we have mostly mediterranean soils, and in the Tagus basin, schist soils.

Urban areas are small and concentrated, with a mostly elderly population.

The *montado*, woods and forests are found mainly in higher topography, away from the agglomerations.

Vineyards and olive groves are the most common land use in the *Borba* wine sub-region, not only around the villages and towns, but also in the *Montes* and *Herdades* landscapes - small or large properties, the basis of the agricultural economy. Here we find the owner's house and other buildings supporting agricultural activity.

Thus, a diversified and complex landscape pattern is evident, with a narrower, more irregular, and diverse matrix close to settlements, and a broader, more homogeneous matrix in distant areas [10].

Figure 2. Administrative municipalities (white) and the limit of Borba wine sub-region (black) [10].

2.2 *Borba* vineyard landscape

The Borba vineyard landscape includes different areas, essentially related to the geomorphological situation: the hydrographic basins and the position within them, the geological substratum, and consequently, the soils and different microclimatic conditions.

In the south, the vineyards are closer to the mountain (*Serra D'Ossa*) and at a higher altitude (in between the Tagus and Guadiana basins). They are found on plateaux, in the valley and in the middle of the mountain slope, in schist soils, in large properties and in large areas. We can see that here the presence of vineyards is not significant when compared with other classes of land use (Figs. 3a, b).

On the central axis, the vineyards are on good soils (calcareous and deep), in small properties, close to settlements. Here vineyards and olive groves are the most significant land use (Fig. 3c).

In the north, the vineyards are in the Tagus basin, in a flat area, with poor soils (yellow schist) and in huge properties. The dominant land use is vineyards, with *montado* and meadows also being significant (Fig 3d).

The main grape varieties are the original ones (*Alicante Bouchet, Trincadeira, Aragonês, Siria, Arinto*, among others) and now most of the vineyards are irrigated. They are in flat and undulating areas and at the base of the slope. Farmers in this region are generally old (aged over 60). Part of the production is carried out by *Adega de Borba* and the rest by private producers.

(a)

(b)

(c)

(d)

Figure 3. *Borba* wine sub-region – examples of south (a,b), central axis (c), and north (d) vineyard landscapes.

3 Vineyard landscape: Increasing biodiversity and ecological potential

The sustainable implementation and management of productive ecosystems is increasingly prominent on the agendas of governments, some institutions (European or global), academics and individual communities.

The aim to increase biodiversity and agricultural production based on ecological foundations – defended since the middle of last century by Landscape Architects, and in Portugal by the first generation of these professionals - has increasingly become incorporated in laws, agendas, and technical procedures.

The biophysical feature of landscape is linked to its biological and physical systems. This ecological interest is reflected in several aspects of the natural and cultural use of land:

- areas with endemic or well-adapted vegetation (forests, woods, groves, protected trees, monumental trees, hedges, borders, riparian gallery);
- water courses, natural drainage lines, ponds, wetlands;
- poor soils, rock surfaces with endemic vegetation;
- rotational areas;
- areas without melliferous plants;
- stone walls, public paths, archaeological sites, and others.

In Portugal, in the context of Sustainable Agriculture and Integrated Production, the government is approving new procedures contained in books such as ‘Sustainable Agriculture’ (2022) [11] or ‘Technical Norms for the Exercise of Integrated Production’ (2023) [12]. Here we can see new requirements, including biodiversity rules and enforcement of an ecological system and infrastructure.

Consequently, there must be plans for properties [12], as well as for sub-regional and regional production, involving strategies and procedures for nature conservation centred on Landscape Planning, Landscape Design and Management.

For existing or potential vineyards, we must [12, 13]:

- Make an evaluation of the vineyard’s (or sub-region or region of vineyards) suitability within the context.
- Make an Exploration Plan.
- Define actions to conserve natural resources: improve the soil, water, vegetation, and topoclimate.
- Ensure the flow of water in accordance with the relief.
- Protect against the risk of soil loss.
- Define and keep areas of ecological interest, as well as others that are relevant from a historic, archaeological, cultural, social, memorial and affective/aesthetic point of view.
- Protect main water courses and adjacent strips of 10 m on each side (protected by law), as well as water courses with a torrential regime. Thus only the protective function must be maintained or reinforced.
- Recover riverside corridors and corridors associated with torrential water lines; natural curves cannot be altered.

- On the banks of watercourses, as well as on torrential drainage watercourses, native vegetation must be planted (suitable for each soil and the humidity present).
- Avoid using wetlands and areas with poor drainage for production functions; promote the preservation of temporary ponds.
- Adopt practices that allow the conservation of pollinating species in their habitats.
- Plant honey species, rich in pollen and nectar.
- Use biodiverse bushes and meadows with greater diversity of species.
- Use hedges with a variety of endemic or well-adapted vegetation: inside large plots, on the edge of vineyards, between different land uses, on property boundaries.
- Plant and/or maintain endemic species (trees, shrubs and grasses).
- Maintain and protect protected trees; and protect monumental trees (even if not classified).
- Practice in the plot must respect nesting periods and consider fauna and flora, including pollinating insects.

4 Designing vineyards with high biological balance and with valorising ecological infrastructure

To fulfill the integrated vision associated with the notion of landscape, strategies must be developed to promote a landscape pattern that values the biological balance, the fertility base, the ecological infrastructure, and cultural aspects that can be achieved through landscape design and management.

The ecological infrastructure should be identified at three levels [13] and must include natural and cultural elements: field or plot; property/farm, the landscape in general.

At the field level (field edges, torrential drainage lines, alleyways, stone walls; ridge areas with rocky substrate very close to the surface).

At the property level (the agro-ecosystem or protected areas should be defined mostly based on the soil suitability and relief conditions - dry and wet system – and existing vegetation).

At the global level (the main decisions on land use and ecological protection should be influenced by the fundamental infrastructure of the landscape (drainage basin, relief conditions - dry and wet system, soil properties and existing vegetation).

A vineyard designed with a high biological balance and ecological potential was the case in the past in the Borba landscape. The complex agro-ecosystem in the first ring around the urban areas was characterized by small properties and mixed land use.

The multifunctional landscape was there: market gardens, vineyards, olive groves, vineyards combined with olive groves, wheat fields, orange groves, annual crops, hedges (low hedges or shrub hedgerows; edges with trees, hedges, grass strips and small woodland patches (*montado*). Further from this first ring, pastures for cattle and *montado* prevailed.

Today's design follows the fundaments of the old system.

The principle is to transform the monoculture vineyards, mostly present in the south and north of Borba wine sub-region, into a more complex agro-ecosystem using several green cover strategies. These can be used inside or outside the plot, in the property, or in planning municipalities or the sub-region's vineyard area.

Wild spontaneous flora is potentially interesting - in hedgerows and field fences, paths, and roads, between rows of vines, rotating lands, and meadows. In all these situations, this increases floristic biodiversity and can do away with the need to subject the vines to certain treatments: some are clearly not desirable, but many are, because they ward off pests or attract auxiliary insects [14]. This spontaneous flora is also important because it stimulates pollination [13, 14].

For example, permanent green cover, with preference for spontaneous colonization by local flora, protects the soil (erosion, compaction and reduces water requirements). In these areas, the fauna occurs almost automatically and is of economic interest, because it includes the natural enemies of the arthropod pest [13].

In addition, the shrub species used in the hedges are important for the pest predator insect population (e.g *Rubus fruticosus, Cornus sanguinea, Prunus spinosa, Lonicera xylosteum, Rosa canina, Crataegus monogyna, Celtis australis, Acer spp, Viburnum lantana*, among others [13].

All these areas - of wild flora or bushy plants - are significant corridors for faunal species, increase biodiversity, the diversity of the landscape pattern and create more emotional and affective landscapes.

5 Case-study: Herdade de Mata Cães

This property of 200 hectares is in the north of Borba wine sub-region and has 7 hectares devoted to vineyards. The exploration plan is based on increasing biodiversity combined with sustainable agriculture. There is some biological agriculture, as in the vineyard.

The vineyard was planted in 2017, the strategy being expressed in selecting the place for vineyards and their design. Currently, after 6 years, the vineyard and the solutions adopted to increase biodiversity and the ecological infrastructure are clear.

Now, we will see in more detail the steps taken in these three different approaches.

From the point of view of planning, the strategy was based on the type of soil as well as the biophysical infrastructure present in the landscape, which determined the agricultural areas and the definition of plots (Figs. 4 and 5).

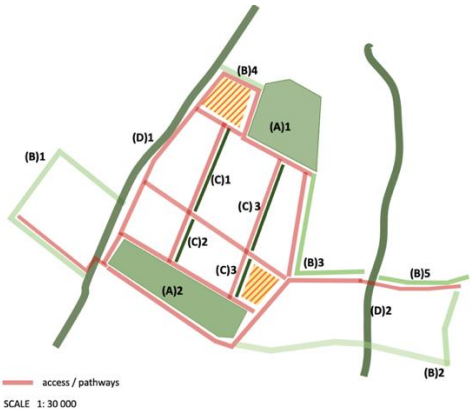
Figure 4. Field limits (orange) and the main ecological systems (dry and wet) and existing vegetation | Mata Cães vineyards, 2016.

Figure 5. Field limits (orange) | Mata Cães vineyards, 2023.

Concerning the design of landscape infrastructure, this ensured biophysical requirements and nature conservation, including: nature conservation areas in the wettest and driest areas, protection of drainage areas, planting hedges surrounding routes and paths, planting hedges between some vineyard lines and plots, seeding biodiverse meadows between lines, saving stone walls.

The aim was to protect water, soil, and vegetation, increase useful organisms against pests and diseases, and increase biodiversity, among others (Figs. 6 and 7).

Planting diverse species aims to improve the natural habitat and avoid predators (Fig. 6).



DRY SYSTEM AND *ECOLOGICAL CORRIDORS*

A(1) Trees: *Quercus rotundifólia*, *Pyrus bourgaeana* and *Cercis siliquastrum*. **Shrubs:** *Ulex minor*, *Cytisus scopariu*, *Phillyrea angustifolia*, *Crataegus monogyna* and *Quercus coccifera*.

A(2) Trees: *Quercus rotundifólia*, *Pyrus bourgaeana* and *Celtis australis*. **Shrubs:** *Retama sphaeroscarpa, Cytisus multiflorus, Quercus coccifera, Crataegus monogyna, Rhamnus lycioides, Phillyrea angustifolia* and *Teucrium fruticans*.

B(1): Shrubs: *Cytisus multiflorus, Retama sphaeroscarpa* and *Crataegus monogyna*.

B(2): **Shrubs:** *Crataegus monogyna, Nerium oleander* and *Cytisus scoparius*.

B(3): **Shrubs:** *Lavandula stoechas, Lonicera caprina*, *Rosa sempervirens*.

B(4): **Shrubs:** *Crataegus monogyna*.

B(5): **Shrubs:** *Laurus nobilis* and *Rosa sempervirens*. **Tree:** *Cupressus sempervirens*.

C(1): **Shrubs:** *Teucrium fruticans*, *Lavandula stoechas*, *Thymus citriodorus*, *Ruscus aculeatus*, *Myrthus communis*, *Lonicera caprina*, *Rosmarinus officinalis* and *Rosmarinus officinalis prostratus*.

C(2): Shrubs: *Retama sphaeroscarpa*, *Cytisus multiflorus, Cytisus scoparius, Lavandula stoechas* and *Thymus citriodorus*.

C(3): **Shrubs:** *Genista tracantos, Cistus salviifolius*, *Cistus ladanifer*, *Myrthus communis*, *Rhamnus lycioides*, *Cistus crispus* and *Thymus mastichina.*

(D) WET SYSTEM: riparian gallery

D(1) Trees: *Fraxinus angustifolia*, *Salix salviifolia*, *Sambucus nigra, Tamarix africana*. Shrubs: *Rosa sempervirens*.

D(2) Trees: *Celtis australis, Salix salviifolia* and *Fraxinus angustifolia*. Shrubs: *Rosa sempervirens*, *Viburnum tinus, Lonicera caprina* and *Nerium oleander*.

(A) ORCHARDS

Trees: *Prunus dulcis, Citrus sinensis, Citrus limon and Juglans regia.* **Shrubs:** *Punica granatum*, Cydonia oblonga, *Arbutus unedo and Rubus idaeus*.

Figure 6. Planting plan | Mata Cães vineyards, 2015.

Figure 7. Master Plan (conceptual ecological infrastructure) | Mata Cães vineyards, 2015.

The management followed the strategy used in the implementation. Some plants used in the hedges and between the lines have been pruned and tended, and species which died have been replaced by others that are better adapted.

In alternating lines, leguminous and grassy species were sown, keeping species of the local flora in the others between lines (Fig. 8).

We underline the importance of the hedge on the south periphery of the property, which also aimed to protect against the spread of pollution from the neighboring property (resulting from traditional practices in the olive grove). This situation could affect recognition of the Mata Cães vineyard as organic.

Figure 8. Shrub lines in between other lines of vineyard biodiverse meadows | Mata Cães vineyards, 2023.

Pruning and meadow cuttings between vineyard lines are shredded and left on the ground (Fig. 9).

In the higher areas and where there is rocky substrate at the surface, where endemic species (trees and shrubs) were planted, natural regeneration can be observed, which is already beginning to be significant (Fig. 10). Along the watercourses, the plantings are maintained and increased to develop a denser riparian gallery.

Figure 9. Shredded material between lines | Mata Cães vineyards, 2023.

Figure 10. Endemic species (trees and shrubs) dry systems | Mata Cães vineyards, 2023.

5 Conclusions

This article reflects on some contributions, based on traditional agricultural practice and scientific knowledge which has existed for decades, associated with agriculture and landscape.

Certainly, the intensive production of vineyards and large homogeneous areas will be maintained, due to consumption, market, and production factors. This leads to major simplification and disruption of landscape systems.

As stated before, agricultural production depends on the characteristics of the landscape, but also on biodiversity and the ecological system. These are the elements to consider and work with, right now, aiming to re-naturalize and protect the landscape's basic natural resources (soil, water, vegetation, and climate).

Thus, increasing biodiversity and protecting or reinforcing the landscape's ecological infrastructure contributes to environmental sustainability, reduces problems linked to climate change, and values the landscape as a dynamic, complex system - where economic, social, ecological, and affective dimensions are integrated.

Solutions for sustainable agriculture involve work in different areas - planning, design, and management. The case study of *Herdade de Mata* Cães vineyards aimed to illustrate these practices and requirements.

The production of quality and quantity wine involves the conservation and/or re-naturalization of nature in

existing and future vineyards and in maintenance actions. This perspective - nothing new, because it was linked to traditional production - was broken and ignored for decades, due to inadequate and/or fragmented policies and laws, or non-supervision of others (linked to integrated production, ecological domains, sustainable agriculture, and landscape improvement).

Given the new dynamics and visibility associated with climate change and increased biodiversity, it is the moment to take this opportunity to act in a different direction. We have now a great opportunity to move towards real sustainable agriculture and integrated production. It is necessary to provide information and training actions for landowners, bring about a new literacy in agricultural practice. This movement needs financial support to transform agricultural areas and the landscape. It must involve everyone - governments, institutional organizations, local authorities, associations, academics, property-owners, and those who run the property.

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