**Appendix 1. Main assumptions for the calculation of the energy balances of Les Oluges in 1860, 1959 and 1999.**

The calculation of the energy balances of Les Oluges has been made following some of the main criteria and assumptions made in the previous study of Vallès (see the Supplementary Material in Marco, Padró, Cattaneo, Caravaca, & Tello, 2017) and the working papers of Aguilera et al., (2015) and Guzmán et al. (2014). We mainly followed this methodology for calculating by-products, livestock produce and human diets, applying the estimates to the original data we had about the main produce, livestock composition and population of Les Oluges in the different points of time. However, the agroecosystem of Les Oluges had its own distinctive features, which have been represented as faithfully as the availability of data allowed.

The main raw data from which we started to build the energy profile of Les Oluges comes, first, from the land uses detailed in the text, to which we added their productivity, obtained from the local records and surveys or from provincial records. Table 1 shows the production of farmland in Les Oluges in physical terms.

Additionally, we estimated the NPPact of the agroecosystem of Les Oluges considering not only the above-ground biomass, but also the below-ground biomass produced by the agroecosystem. Below-ground biomass was estimated following Guzmán et al. (2014) and refers to the roots of the trees and plants grown in the farmland. This is an important component of the phytomass produced, since it represents 48%, 35% and 20% of the NPPact of Les Oluges in 1860, 1959 and 1999 respectively.

Table 1: Farmland production in Les Oluges in 1860, 1959 and 1999; according to our estimations.

|  |  |  |  |
| --- | --- | --- | --- |
| **FARMLAND PRODUCTION**  | **1860** | **1959** | **1999** |
| **Yield (dry matter, kg/ha)** | **Vegetable garden** | Main produce | 825 | 922 | 3,873 |
| By-products | 1,006 | 1,401 | 3,170 |
| **Wheat (irrigated)** | Main produce |   | 2,064 |   |
| By-products |   | 3,654 |   |
| **Wheat** | Main produce | 550 | 1,032 | 2,536 |
| By-products | 1,145 | 1,939 | 2,593 |
| **Barley** | Main produce | 770 | 1,720 | 2,690 |
| By-products | 1,603 | 3,220 | 2,804 |
| **Rye** | Main produce | 467 |   |   |
| By-products | 973 |   |   |
| **Oat** | Main produce |   | 1,290 |   |
| By-products |   | 2,524 |   |
| **Fodder** | Main produce |   |  | 20,350 |
| By-products |   |   |   |
| **Vine** | Main produce | 98 | 132 |   |
| By-products | 1,285 | 1,697 |   |
| **Olive**  | Main produce | 77 | 320 | 1,167 |
| By-products | 1,027 | 3,189 | 13,824 |
| **Almond** | Main produce |   | 574 |   |
| By-products |   | 1,532 |   |
| **Woodland, schrubland & pastureland** **(dry matter, kg/ha)** | Woodland - timber & firewood | 1,579 | 813 | 813 |
| Grass | 1,002 | 1,002 | 1,002 |
| Acornds, mulch & others | 73 | 73 |   |
| Pinewood - timber & firewood |   | 875 |   |
| Riparian woods - timber &firewood |   | 162 |   |

The first adjustment we had to do in order to reflect the local specificities of Les Oluges involves the estimation of fallow land, which was traditionally widespread in Les Oluges. The historical records consulted, such as the *cartilla evaluatoria*, state that cropland sown with cereal was left uncultivated every other year. Therefore, we maintained half of the cereal cropland (for monoculture and associated crops) as fallow in our model for 1860. For 1959 we obtained local information by inquiry. Fallow was practiced every other year in most of the cereal cropland, except for the plots closer to the river, which were left fallow once every five years.

Secondly we had to estimate the amount and size of *formiguers* used in Les Oluges in 1860. We took as a reference the data available for a nearby village, Balaguer, and obtained a mean of 209 *formiguers* per hectare used in vegetable gardens and 102 *formiguers* per hectare in cereal cropland. Each *formiguer* would have been built with 20 kg of wood from woodland. According to the *cartilla evaluatoria* of Les Oluges, these were the only lands where *formiguers* were built. However, given the scarcity of manure that the historical records acknowledge for the Segarra County, and that in vineyard areas it was common to build *formiguers* with the pruned branches from the vines, we also added *formiguers* to the hectares were cereals and vineyard where intercropped.

The scarcity of manure and the widespread use of fallow were connected in Les Oluges. Scarcity of manure led to the need to keep cropland fallow in alternate years, but only the fallow land of monocultures was available for pasture since where cereals were sown between the vines, the strips left fallow could not be grazed because livestock could damage the vines. Thus livestock feeding required resources from the woodland to satisfy its needs, but this also meant that in 1860 a greater amount of manure was lost when animals were grazing.

For calculating the feed distribution among the livestock we followed these steps. For the energy balances of 1860 and 1959, first we calculated the feed available for livestock feeding, both from grains as barley, and from by-products, domestic residues and pastureland. Then we distributed it taking into consideration the suitability for each animal and the relevance of the animal for the sustenance and provision of the agroecosystem. For 1999, we did the same, but in this case we also include the feed imported from abroad and we included the embodied energy of this feed. Thus, in 1860 in order to fulfil the nutritional needs of the livestock, it was necessary to resort to woodland resources.

Grazing and *formiguers* are included in the resources extracted from woodland in 1860, but the total extraction of wood from the woodland was estimated using the data available for the nearby village of Balaguer. For 1959 and 1999 we used provincial data for the estimation of woodland biomass production and resources extracted from it.

When the agroecosystem of Les Oluges has been transformed into and industrial farm system, many local farming specificities have tended to disappear. Cropland was fertilised mainly with manure and synthetic fertilisers. The amount of manure available has been estimated according to the composition and management of the livestock-barnyard fund component of the agroecosystem. The information about the use of mineral fertilisers was obtained from local surveys that gave us the dose of synthetic fertilisers applied per hectare. By accounting a nutrient balance of the agroecosystem we obtained the total amount of synthetic fertilisers applied and the number of hectares fertilised (Table 2). For the nutrient balance we took into consideration the traditional cultural uses of cropland fertilisation–i.e. which crops were prioritised for fertilisation and which crops were seldom fertilised—and, for 1999, the limit set by the legislation which establishes a maximum of 170kg of nitrogen per hectare (Diari Oficial de la Generalitat de Catalunya DOGC, 2009).

Table 2. Manure and synthetic fertilisers applied in Les Oluges in 1860, 1959 and 1999; according to our estimations.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Total kg** | **Total hectares fertilised** | **Kg/ha** |
| **1860** | **1959** | **1999** | **1860** | **1959** | **1999** | **1860** | **1959** | **1999** |
| Manure (fresh matter) | 920,947 | 1,540,252 | 35,562,160 | 165 | 269 | 791 | 5,580 | 5,719 | 44,979 |
| Synthetic fertilisers |  | 155,590 | 4,039,000 |  | 389 | 696 |  | 400 | 5,805 |

Finally, in 1999 we had to estimate the flux that we considered waste. In our case, it includes only the burned biomass of pruning. The surplus of straw available after satisfying its possible uses inside the agroecosystem (livestock feeding and bedding), has been considered FP. In 1999 the surplus of straw was 43% of the FP. Including this by-product as waste would have increased the volume of this flow more than twelve times and the FEROI would have fall to 0.28.

References

 Aguilera, E., Guzmán, G. I., Infante-amate, J., García-ruiz, R., Herrera, A., & Villa, I. (2015). *Embodied Energy in Agricultural Inputs. Incorporating a historical perspective*. Retrieved from http://hdl.handle.net/10234/141278

Amate, J. I., Aguilera, E., & Molina, M. G. De. (2014). *Sociedad Española de Historia Agraria - Documentos de Trabajo* (Vol. 3).

Diari Oficial de la Generalitat de Catalunya DOGC. DR 136/2009\_Zones vulnerables en relació amb la contaminació de nitrats que procedeixen de fonts agràries i de gestió de les dejeccions ramaderes.

Guzmán, G. I., Aguilera, E., Soto, D., Cid, A., Infante, J., Garcia-Ruiz, R., … González de Molina, M. (2014). *Methodology and conversion factors to estimate the net primary productivity of historical and contemporary agroecosystems (I)* (No. 1407). Retrieved from http://repositori.uji.es/xmlui/handle/10234/91670

Marco, I., Padró, R., Cattaneo, C., Caravaca, J., & Tello, E. (2017). From vineyards to feedlots: A fund-flow scanning of sociometabolic transitions in the Vallès County (Catalonia) (1860-1956-1999). *Global Environmental Change*.