From integration to abandonment. Forest management in the Mediterranean agro-ecosystems before and after the "green revolution" (The Vallès County, Catalonia, Spain, 1860-1999)

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Abstract

We are seeking to analyze the role played by forest and territorial management in the economic and ecological functioning of the agrarian ecosystem in a West-Mediterranean advanced organic economy towards 1860, and compare it with the one prevailing at the end of the 20th century. In order to highlight the link between energy and land use, we have reconstructed the agrarian energy balances in five Catalan municipalities towards 1860 and at present, to relate them with the landscape evolution of this territory reconstructed by GIS from cadastral maps and aerial photographs. Working together with landscape ecologists we have applied to these land-use maps some indices of eco-landscape structure and connectivity to understand their ecological functioning. We have found that in 1860 the energy return on energy input was 1.67, despite its unavoidable dependence on the inefficient livestock bioconversion to obtain manure and traction. In 1999, on the contrary, the return was only 0.21, meaning a consumption of five energy units for each one offered to the consumer society. A key feature that allowed to maintain the high energy performance in the 1860 agrarian system was its *territorial efficiency*, mainly achieved trough a sound integrated management of agricultural, pasture and forest land. The energy inefficiency of the agrarian system brought about by the so-called green revolution mainly owes its existence to the unsound disconnection between livestock breeding, crop production and forest management.

1. Research approach

Using the Energy and Material Flow Analysis (EFA, MFA) we are studying the agrarian landscape as an ecological footprint of the social metabolism that any society maintains with the natural systems that sustain them. Our approach combines the study of this energy balances of different agrarian systems with the land mosaics they produce, through a GIS analysis of land cover patterns. In order to understand this Land Cover-Land Use Change (LUCC), we consider that social metabolism is the main driving force behind the long term changes in land uses. Working together with forest and landscape ecologists, we have applied some Landscape Ecology Indices of ecological structure and connectivity to measure the environmental impact of those territorial changes.

Energy flow analysis may help to highlight some key features that lay in the historical anatomy of cultural landscapes. Most of this cultural landscapes were shaped by agrarian economies that attained high population densities while remaining organic. According to Ester Boserup, 64 inhabit./ Km^2 or 1.5 hectares per person seems to have been an upper frontier (Boserup, 1981). When an organic agrarian system achieved such a high density, rural societies had to face and solve two main problems related with energy efficiency: 1) The big energy losses through the conversion into manure, draught power, and cattle products of biomass eaten by livestock as pasture or fodder; and 2)

The decreasing availability of firewood and other forestry products when cultivated land increased its share within the useful agrarian area. In past organic rural economies the only way to maintain a high energy performance in a high intensive land use system was to keep a sound integrated territorial management of the three main sides of the agro-ecosystem: cultivated, pasture and forest lands. The creativity we can now discover in many territorial features of these cultural landscapes can be seen as innovative responses to this challenge.

2. Study area

Our case study comprises five Catalan municipalities of the Vallès county with a common extent of 13,488 hectares: Castellar del Vallès, Caldes de Montbui, Palau-Solità i Plegamans, Polinyà and Sentmenat. They are located in a small plain situated in a tectonic basin between Catalonia's littoral and pre-littoral mountain ranges, whose diversity of geological substrata have led to the development of a considerable variety of soils. Both the surface streams and groundwater springs are relatively more abundant in the fault zone between the tectonic basin and the mountains, where the oldest nucleated settlements were located. Although the poorest share of population used to live in those small towns or villages, the most apparent feature of human settlement in that mid-northeast of Catalonia was a network of scattered poly-cultural farms, called *masies* in Catalan, structured into compact units around an isolated rural dwelling. Starting from the end of the late medieval agrarian struggles, the landowners who held the *masies*, gradually gained control of the rights of access to land, over a complex and conflictive transition from feudalism to agrarian capitalism (Garrabou, Planas and Saguer, 2000; Garrabou and Tello, 2004).

The closeness to Barcelona –between 5 to 12 hours on horseback according to a timetable map of 1808-1809– meant that the Vallès was connected very early on with the commercial dynamics of Catalonia's demographic and urban centre of gravity. Population growth, increasing peasant inequality, and market incentives increase the extension of cultivated lands, mainly through the plantation of vineyards in former woodland areas. Vines were planted in poor soils, and no manure was applied on them except at the time of initial planting. This meant that a partial wine-growing specialisation allowed the poly-cultural owners of the *masies* to concentrate the scarce manure on the better soils devoted to vegetable gardens, cereals, legumes or hemp. Vineyard pruning and green shoots even went towards fertilising other crops, either directly as compost or indirectly as fodder

Table 1. Population density in the Catalan study area (inhabitants/km^2 1718-1999)

	1718	*1787*	*1860*	*1900*	*1930*	*1960*	*1999*
Vallčs Study Area	20.8	29.4	65.8	71.0	91.7	110.7	278.0
mean in Catalonia	13.7	29.7	54.5	64.1	92.6	132.1	194.7

Available hectares per inhabitant in the Catalan study area (1718-1999)

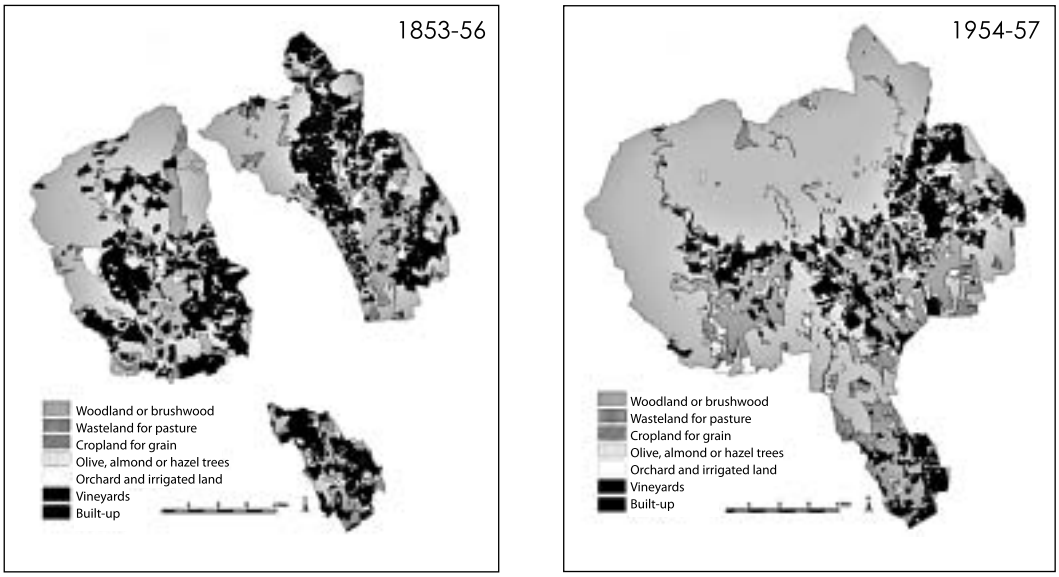
	number of inhabitants	*total available land in hectares per inhabitant*	*arable available land in hectares per inhabitant*	*available land apt to cereal sowing in hects. per inhabitant*
1718	2,804	4.83	3.74	3.12
1787	3,972	3.41	2.64	2.20
1860	8,880	1.53	1.18	0.99
1900	9,575	1.41	1.10	0.91
1930	12,375	1.09	0.85	0.71
1990	14,933	0.91	0.70	0.59
1999	37,504	0.36	0.28	0.23

Source: Garrabou and Tello, 2004.

and manure. All of these were responses to the challenge of feeding a population that had tripled between 1787 and 1860, and attained 66 inhabitants/Km^2. This meant that only 1,5 hectares per person were available to feed the local population with an organically-based intensive agriculture in a Mediterranean bioregion subject to water stress, where keeping livestock and obtaining fertilisers became severely limiting factors (Wrigley, 2004).

Several waves of increases in the relative prices of wine encouraged vineyard planting, from the 17th to the beginning of the 18th century, added to the oidium plague in 1840-50. The result was the cultural landscape mosaic shown in Map 2, that in 1853-56 still combined different Mediterranean crops.

Map 2. Land use cover in the Catalan study area (Vallès county) in 1853-56 and 1954-57



Source: made with GIS by Oscar Miralles, from the cadastral maps in the historical archive of the Institut Cartogràfic de Catalunya (ICC), and the Spanish Provincial Cadastral Office, for our research project SEC03-08449-C04. We thank the ICC for giving us permission to publish this 1853-56 maps.

A very different wave of vine planting started in 1867 when the phylloxera plague hit French vineyards, causing relative prices for Catalan wine to soar. This grapevine fever suddenly displaced polycultivation, provoking the first episode of environmental and economic globalisation that linked the fate of that area to the international value of a single export product. This ended suddenly with the arrival of the disease to the Vallès in 1883. By 1890 it had killed all vines, and the region's agriculture swung towards the production of fresh milk, vegetables, potatoes and legumes for daily delivery to the nearby cities. The new model was consolidated circa 1930, when the available land had been reduced to a single agrarian hectare per inhabitant. In spite of the abandonment of many terraces previously planted with vines, and the growing of woodland in sloping soils, at least in the Vallès tectonic plane the agrarian landscape remained in 1954-57 a poly-cultural one, with a mosaic of diverse patches (Map 2). But after the 1960s the fast spreading of the so called "green revolution" put a sudden end to the old rural culture and society.

3. Energy efficiency trough territorial efficiency

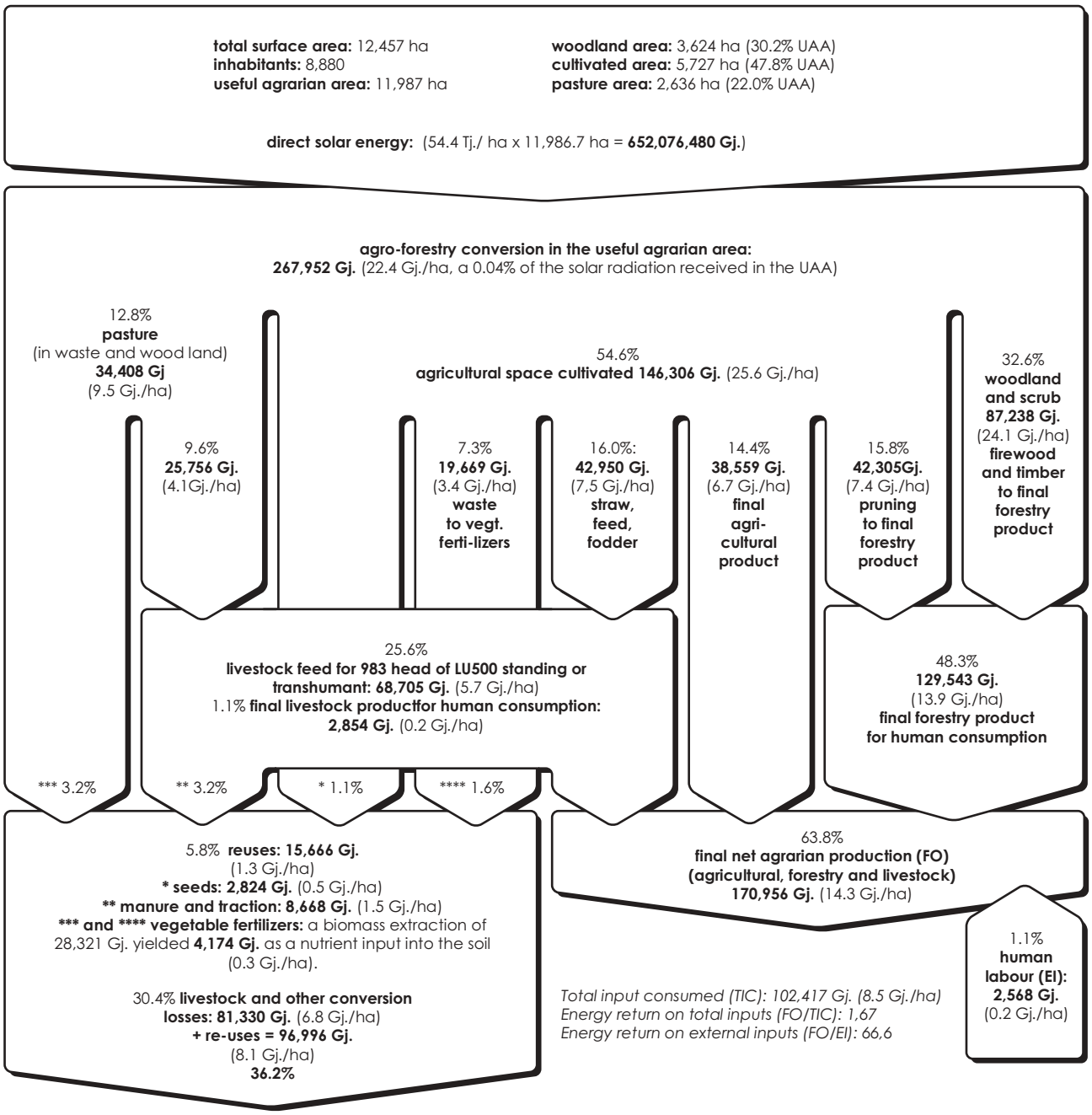
Despite the high intensive Mediterranean organic agriculture then practiced, the energy balance of the prevailing agrarian system in the study area towards 1860 reveals that the energy return on energy input (EROI) was 1.67. The energy content of the final net agrarian output amounted to 64% of the primary solar energy fixed by photosynthesis, while conversion losses were only 36%. The key feature to attain such a high energy performance was a close integration between the three main agrarian spaces: cultivated, pasture and wood lands. The existing unavoidable dependence on livestock bioconversion, in order to obtain manure and traction, was highly inefficient: 26% of the available vegetable biomass was transformed by livestock into traction power, manure and cattle products, while the final livestock output only accounted for 1% of that primary energy derived towards animal bio-converters. This supposed a big problem for any traditional organic agrarian system. But the integration between cropping, livestock feeding and forestry offered an efficient response to that challenge. Together with an intense reuse of almost any biomass by-product, that meant a negligible amount of external inputs other than human labour, it explains why the energy content of the final agrarian product still represented 64% of the primary solar energy (Table 3.).

The intensive cropping caused lack of wood, a big challenge that was faced with an innovative response: the *cropping of trees and shrubs*. Due to the high proportion of cropped land, the availability of wood and firewood was only 1.8 Kg. per inhabitant a day, or 9.8 Gj./inhab./year (less than the mean consumption in the Mediterranean Europe towards 1750-1850 according to Malamina, 2001). Vine and olive tree pruning or shoots became a partial substitute for firewood or charcoal when they became increasingly scarce as a consequence of turning woods and brushwood into vineyards or other woody crops. In that sense, as the Spanish landscape ecologist Fernando González Bernáldez stressed, shrubbery or woody crops became in the Mediterranean a sort of "forestry transition" between natural and cultivated rings or patches. It also meant a sound solution to the dilemma between exploitation and conservation, locating in the space an intermediate degree of agro-ecosystem maturity (González Bernáldez, 1995). Thanks to that "forestry transition" cropped lands filled the fuel gap with the pruning of vineyards and olive or almond trees, that raised the available firewood to 14.6 Gj./inhab./year (2.7 Kg. per head a day).

4. Landscape results of an unhinged social metabolism

The energy inefficiency of the present agrarian system, brought about by the so-called green revolution could mainly be caused by the unsound disconnection between livestock breeding, crop production and forest management. In 1999 the agrarian return on total inputs was only 0.21, meaning a consumption of five energy units for each one obtained. Cropped land holds only 32% of the useful agrarian area, and captures 47% of solar energy, due to the doubling of the energy output in each cropped hectare. Forests fill a 61% of land, but most of them remain abandoned and wasted. Livestock weight is 22 times the existing one in 1860. It is fed with imported fodder and remains disconnected from the surrounding territory except for the polluting dung. The old agrarian mosaic has disappeared and a lot of the best agricultural soils have been built-up. The main energy flows of this unhinged social metabolism go across the territory as if it were only an inert base. Once again energy inefficiency is closely related to an inefficient and unsound land use that entails unsustainable ecological consequences (Map 4 and Table 5.).

Table 3. Annual flows in five Catalan municipalities towards 1860 (Spain)

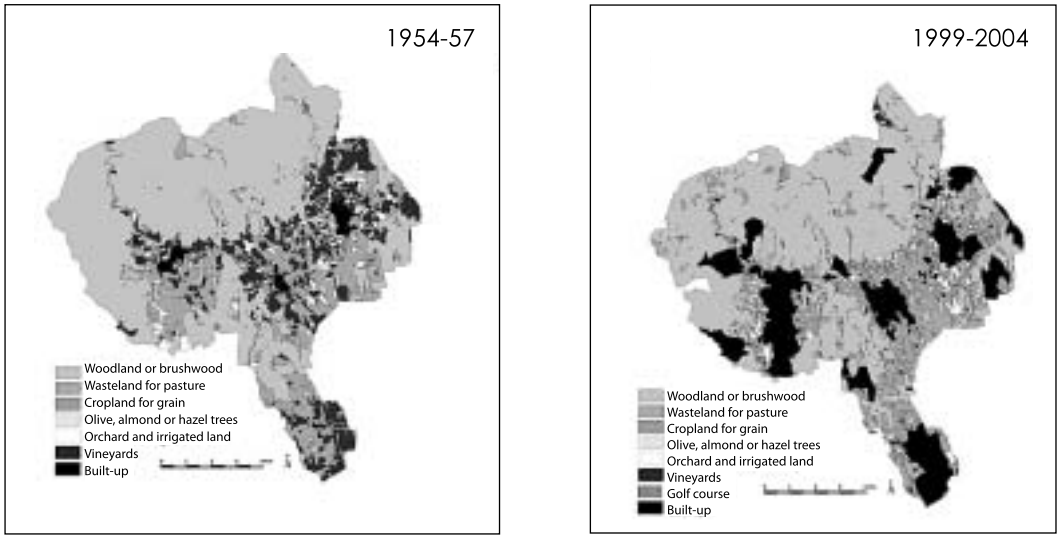


Source: made with GIS by Oscar Miralles, from the Spanish Provincial Cadastral Office, for our research project SEC03-08449-C04.

The end of this old Mediterranean agrarian mosaic has impoverished the ecological structure of landscape, and its biodiversity. A team of ecologists have applied to our land use historical maps two landscape ecology indices based on theoretical grounds and field work expertise (Marull, Pino, Tello, Mallarach, 2006). The Landscape Structure Index evaluates through GIS analysis the territorial capacity to shelter different organisms and ecological processes, according to the intensity of human land uses. The Ecological Connectivity Index is based on a computerized model of travel cost distances between different classes of ecologically functional areas, and the impedance effects of different soil uses or anthropogenic barriers. The indices adopt values between 1 and 10, and the maps do show a clear impoverishment of the ecologically functional areas and its ecological connectivity (Map 6.).

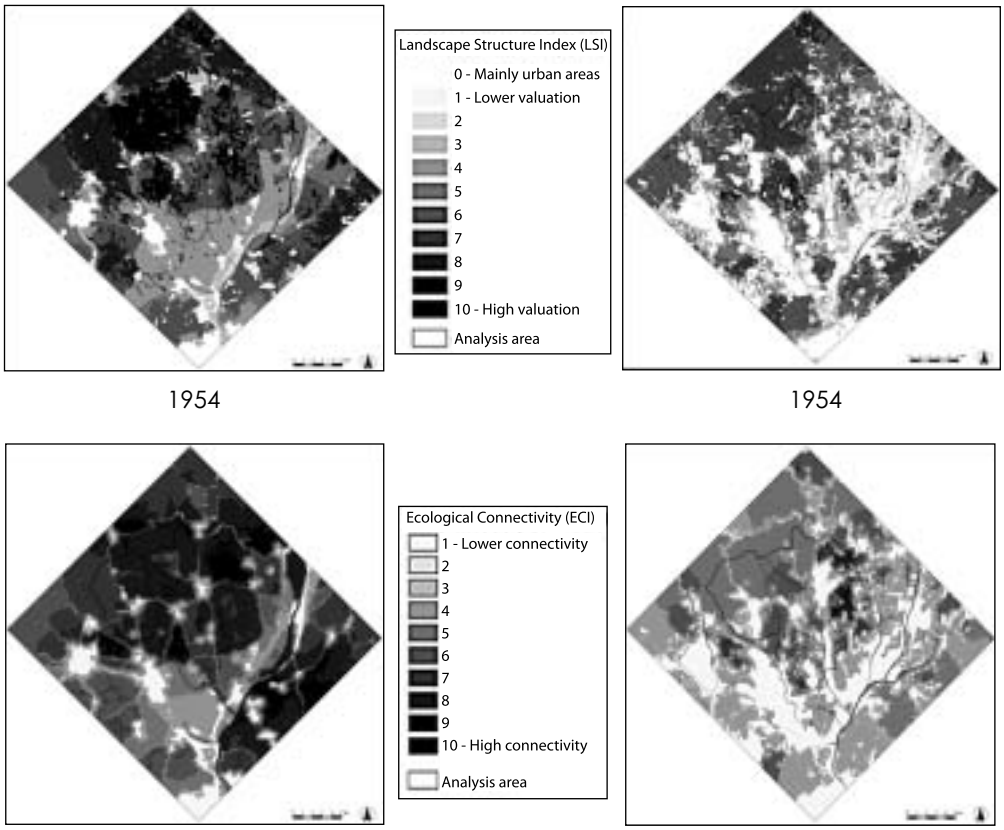
Past organic economies maintained an integrated management of territory not on account of its ecological virtues, but because the prevailing energy poverty made it necessary. Later the consumption of fossil fuels rendered the integrated use of land no longer *necessary*. But had the end of a necessity borne the end of its ecological *virtues*? The answer is important, because now we need the overcome the dysfunctional and ecologically unsound land use that is causing serious environmental pathologies.

Map 4. Land use cover in the Catalan study area in 1954-57 and 1999-2004



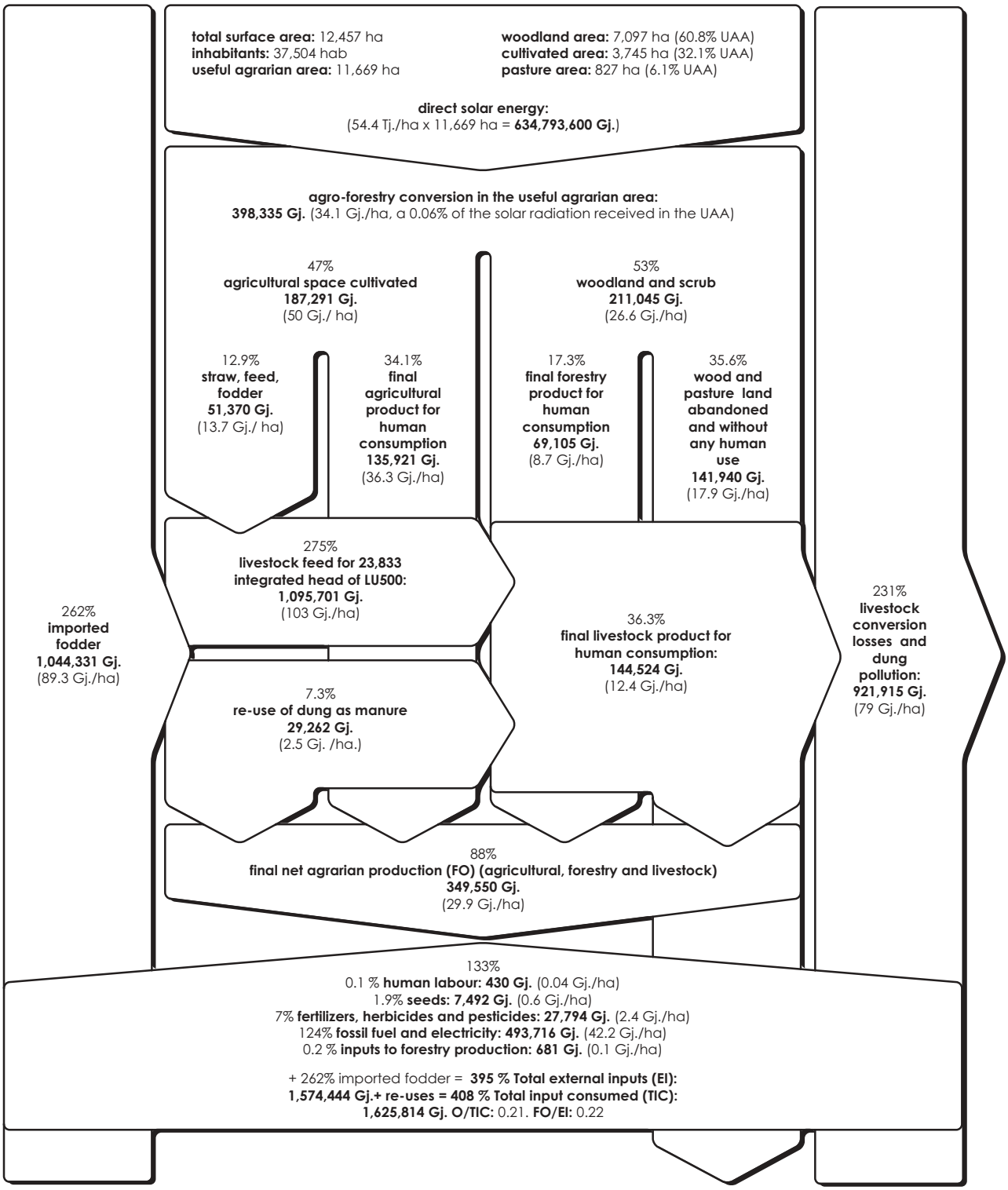
Source: Marull, Pino, Tello, Mallarach, 2006.

Map 6. Landscape Structure and Connectivity Indices of the Catalan study area (Vallès county) in 1954-57 and 1999-2004



Source: Marull, Pino, Tello, Mallarach, 2006.

Table 5. Annual flows in the same Catalan municipalities in 1999 (Spain)



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