AN APPLICATION OF ECOLOGICAL FOOTPRINT: JOKKMOKK MUNICIPALITY (Sweden)

AND COMPARISON WITH MONTECHIARUGOLO MUNICIPALTY (ITALY)

Chiara Buratti, Leonardo Da Vinci trainee, Jokkmokk

April 2009

"There is one measure, and one measure only, describing the capacity and relationship between human society and living systems: Ecological Footprinting. It is the only standard by which we may calibrate our collective impact upon the planet, and assess the viability of our future. (…) no report about the environment is complete without it."

Paul Hawken, Executive Director, Natural Capital Institute

"The great thing about the Footprint concept is that it captures a lot of disparate information and brings it together in a rather simple concept."

Bruce Sampson, former Vice President Sustainability, BC Hydro, Canada

"*The calculations of Ecological Footprints will impress the world community and help politicians, business, engineers, and the public-at-large to find new and exciting paths towards sustainable development."*

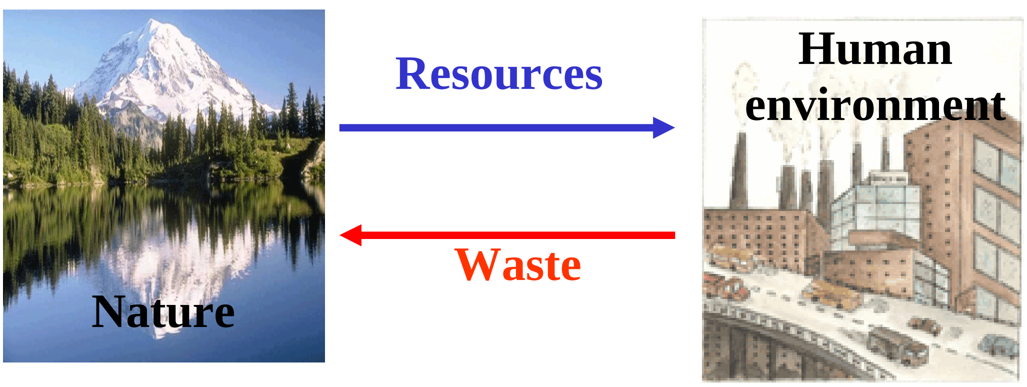
Prof. Ernst Ulrich von Weizsaecker, MP, Founder and Former President of the Wuppertal Institute, and Member of the German Bundestag

Index

1 The Ecological Footprint

1.1 Definitions

The Ecological Footprint is a synthetic indicator of sustainability that measures the amount of land and water area a human population requires to produce the resources it consumes and to absorb its wastes.
This concept developed in 1990 with the studies of Mathis Wackernagel and William Reese, researchers of University of British Columbia, Vancouver (Canada).
An example to explain the concept of ecological footprint: we can imagine a city contained in a glass dome that lets the light enter but does not permit to any material to enter or exit. So the question is: how big should the dome be to enable the city to support itself indefinitely only thanks to the ecosystems and to their resources? The total ecosystem surface necessary for the inhabitant's life is its *Ecological Footprint*. So the scientific concept of *carrying capacity* is upset, we do not want to know how many inhabitants a specific environment can support, but how many hectares of land are necessary for providing the area with materials and energetic resources and for absorbing the produced waste.
It is then possible to compare the measured unit of Ecological Footprint with the actual area where the population lives, so it will be possible to understand if and how much the local *carrying capacity* is exceeded. In this way it is possible to assess the weakness associated to specific environmental matrixes.
It is important to remember that the Ecological Footprint does not give a comprehensive analysis of the environment, but it should be associated to other social and economical indicators to have a more complete outline of the impacts.



1.2 Calculation method

The basic concept of the Ecological Footprint is that for each quantity of materials and energy consumed there is a land area that satisfies this request, guaranteeing the necessary resources and the absorption of the waste.

The conversion into areas of consumptions is based on some fundamentals rules:

- definition of population's yearly consumption of raw materials and energy and of the quantity of waste produced: the values are classified between *consumption categories* (services, mobility…);
- conversion of the resources and waste consumption data in the corresponding biological productive areas (*footprint land types*), necessary for the maintenance of the matter and energy flows; so it is possible to calculate the territorial surface necessary for generating resources, supplying with services and absorbing waste;
- conversion of the footprint land types in a common unit of measurement, using two different types of parameters: the *equivalence factors,* that describe the ratio between the productivity of each type of land and the biologically productive land and water area on the Earth, and the *yield factors*, representing the productivity of the footprint land types across different nations compared with the world average production of the same land type. So the hectares relative to each category are converted in an equivalent area that describes their world average productivity (*global hectare*), and consent to compare different countries with very different characteristics (for climate, geography, economy, technology…);
- the areas (global hectares) for the different categories can be added in a final value representing the total biological capacity demand from a specific population;
- that value (Ecological Footprint) can be compared with the Biocapacity available in the area (expressed in global hectares); Biocapacity is the capacity of the ecosystem to produce "useful biological materials"[1] and to absorb waste materials generated by humans using current management schemes and extraction technologies.

1.3 Equivalence Factors and Yield Factors

Equivalence Factors and Yield Factors are used to convert hectares into the equivalent number of global hectares. They are applied to both Footprint and Biocapacity calculations.

[1] "Useful biological materials" are defined as those used by the human economy (Kitzes et al., 2007).

The *Equivalence factor* is the key factor that allows lands of different types to be converted into the common unit of global hectares; it is a productivity-based scaling factor that converts a specific land type into universal unit of biological productive area, a global hectare.
In this way it is possible to determine how many global hectares are contained in one hectare of world-average land of cropland, grazing land, forest, infrastructure etc., for a specific year.
For instance, to convert an average hectare of cropland to global hectares, it must be multiplied by the cropland equivalence factor of 2.64, indicating that cropland productivity is more than twice and a half productive than a hectare of land with world average productivity. Grazing land, which has a lower productivity than the world average one, has an equivalence factor of 0.49. Equivalence factors are the same for every country.

The *Yield factor* is an index representing the difference in production of a specific land type across different nations. This difference may due to natural factors, such as precipitations or soil quality, or management practices: for example one hectare of pasture in New Zealand produces on average more meat than a hectare of pasture in Jordan.
To measure these differences, the yield factor compares the production of one hectare of a specific land type in a specific nation to the world average hectare production of the same land type. Each country has its own set of yield factors.

1.4 Ecological Footprint Accounting methods

Two distinct methods are available for the calculation of Ecological Footprint: compound and component-based.

Compound method is based on a top-down approach and it is used in particular for the calculation of the Footprint of the Nations and of the citizen. It is based on the possibility to determine the yearly consumptions of the population analyzing the inbound and outbound flows of materials and energy concerning the territory. The consumptions are estimated adding imports (inbound flows) and subtracting the exports (outbound flows) to the internal productions, without knowing the relative single-end-use. The result is significant in proportion to the data completeness and to the accuracy of the conversion values about energy. The compound method is the one used to assess the national Ecological Footprint published in the WWF Living Planet Network.

The *component-based method* is based on a bottom-up approach, and is useful to determine the Footprint of productive activities and services, because it refers to a procedure similar to LCA (Life cycle assessment).
Most of data are mainly on a local level, even if this can cause problems because it is often difficult to find information and statistics on a small scale; it is also difficult to compare the results with others case studies.

The two methods represent two different kinds of interpretations of the Ecological Footprint, they can be alternative or complementary, one does not substitute the other. In the Ecological Footprint calculation we often have "hybrid" situations, where we have to consider our objectives and the data availability. Both the final data are expressed in global hectares.

1.5 Sub-National Ecological Footprint

The sub-national Ecological Footprint has as study object sub-national areas, as Regions, Counties, Municipalities, industrial sites etc.
Assessing the Ecological Footprint for sub-national geographic level is not as immediate as for the national level, nevertheless it is often used because it is a measure that policy makers can easily use to communicate to many types of audience.
For the calculation of the Footprint as an instrument for planning and territory management, it is useful to divide it in two separated forms: Footprint of the citizens and Footprint of the Territory.

The *Footprint of the citizen* is related to the population consumptions in a specific area; this instrument is particularly useful in the environmental education field, it permits to focus on the actions more impacting the environment, and to understand on which sectors we can operate to change the situation acting on the lifestyle of every single person. The consumption categories for the citizen Footprint are:

- food;
- housing;
- mobility;
- goods;
- services;
- waste.

The *Territory Footprint* analyses the different activities in the investigated area; the objective is to build a simplified balance for productive activities, mobility and waste. In this case the choices of the single citizens have only a partial influence on the final value. The considered consumption categories are:

- productive activities (agriculture, industry and craft, services);
- mobility;
- waste.

Every consumption category has an impact on different land types: for both Footprint of the citizen and Footprint of the territory these are the same:

- *Croplands*: growing crops for food, animal feed, fibre and oil;
- *Grazing areas*: raising animals for meat, hides, wool and milk;
- *Fishing grounds*: harvesting fish and other marine products;
- *Forests*: harvesting timber products and fuelwood;
- *Build-up area*: construction of infrastructure for housing, transportation and industrial production. Occupation of areas by hydroelectric dams and reservoir used for the hydropower production;
- *Carbon land*: absorption of the carbon dioxide not sequestered by the oceans using the carbon absorption potential of the world average forest.

It is also to consider the land for the conservation of biodiversity, estimated as the 12% of the Biocapacity, although many scientists state that this percentage is too small.

The referring model used to calculate the Footprint of the citizen and the Footprint of the territory are represented in Table 1.1 and 1.2.

Table 1.1 Distribution of the impacts of the consumptions categories on the territory categories for the Footprint of the citizen.

	Footprint land types						
Consumption categories	Carbon land (gha)	Cropland (gha)	Grazing land (gha)	Fishing ground (gha)	Forest (gha)	Build-up area (gha)	**TOTAL**
Food	X	X	X	X			X
Housing	X					X	X
Mobility	X					X	X
Goods	X	X	X		X		X
Services	X					X	X
Waste	X					X	X
TOTAL	X	X	X	X	X	X	**X**

Table 1.2 Distribution of the impacts of the consumptions categories on the territory categories for the Footprint of the territory.

	Footprint land types						
Consumption categories	Carbon land (gha)	Cropland (gha)	Grazing land (gha)	Fishing ground (gha)	Forest (gha)	Build-up area (gha)	**TOTAL**
Productive activities	X	X	X			X	X
Mobility	X					X	X
Waste	X						X
TOTAL	X	X	X			X	X

2 Jokkmokk Municipality Ecological Footprint

In this work I want to estimate the Ecological Footprint of Jokkmokk territory.
As described in the previous chapter, the Ecological Footprint of the territory is based on the impacts on the following consumption categories:

- productive activities (agriculture, industry and craft, services);
- mobility;
- waste.

The “Productive activities” category, composed by agriculture, industry and services, is based on impacts related to energy consumption in the different sectors and to the land area occupied by the infrastructures.
Since I do not want to calculate the Footprint of the citizen, in this work I will introduce a new consumption category, “Residential areas”, that includes the energy consumptions of the citizens and the area occupied by the residential buildings.
The categories “Mobility” and “Waste” give us some information more about “Productive activities” and “Residential areas”: in fact, the mobility inside of the territory concerns in particular the mobility of the citizens (associated to “Residential areas”) and of the goods (associated to “Productive activities”), and the production of waste includes urban waste (associated to “Residential areas”) and industrial waste (associated to “Productive activities”). This concept is represented in Figure 2.1.

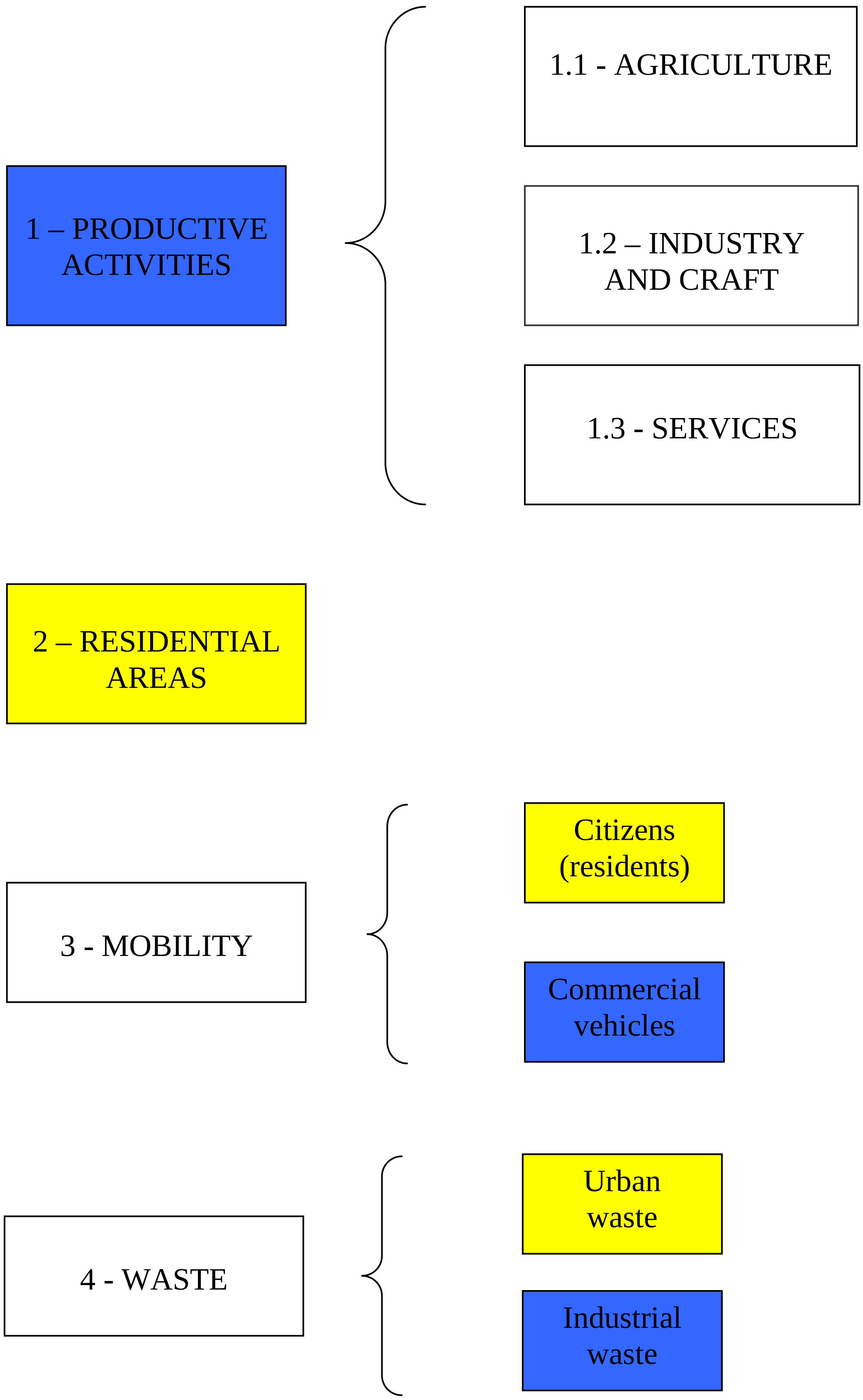


Figure 2.1 Consumptions categories in the Footprint of the territory of Jokkmokk Municipality.

The method used is intermediate between Component based method and Compound method: in fact I use the principles of Compounds method, but at the same time the activities are analyzed in a way typical of the Component based method.

In the calculation I have given the priority to the use of local data: only when it was not possible to get them, they have been estimated from larger scale data.

2.1 Jokkmokk Municipality

Jokkmokk Municipality ("Jokkmokks Kommun" in Swedish) is located in Northern Sweden, in Norbotten County (Figure 2.2), 7 km over the Polar Arctic Circle. The Municipality is the second largest size of all Swedish municipalities, with an area of 19,477 km^2, and is the less populated in Sweden, with 5,305 inhabitants (December 2008), and a density of about 0.3 inhabitants/km^2.

The municipality is situated in the Scandinavian Mountains in Swedish Lapland; a large part of the area has been the habitat of reindeer herding Sami people and has been protected as a UNESCO World Heritage Site under the name Laponia area.

In the Municipality there are four national parks: Sarek, Muddus, Padjelanta and Stora Sjöfallet, and several nature reserves.

Jokkmokk Municipality has a diverse economy including tourism, small and medium sized companies, service industries and the Sami culture and associated business.

The Municipality is part of the organization "Sverige Ekokommuner" ("The National Association of Swedish Eco-municipalities", www.sekom.nu).

Moreover the Municipality is now arranging an Energy Plan, as required by the Government, containing information about the consumption of energy and projects in energy field; in this contest the data collected for the calculation of the Ecological Footprint (in particular the Carbon Footprint) can be a good help, giving an idea about the energy consumption in the area.

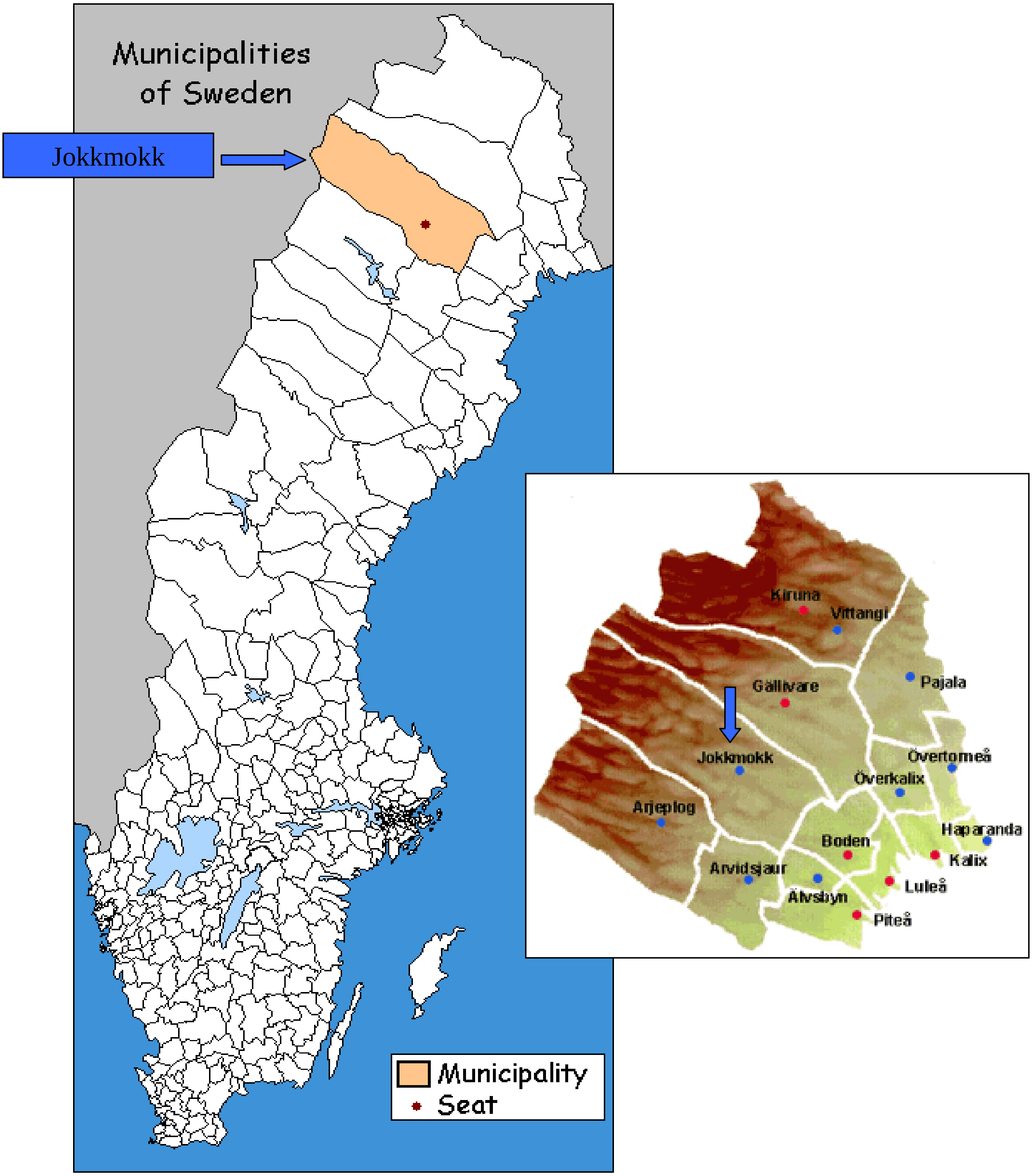


Figure 2.2 Localization of Jokkmokk Municipality in Sweden and in Norbotten County.

2.2 Data and formulas

The data used for the calculation are described in Table 2.1, divided between consumption categories and their impact on footprint land types.

Table 2.1 Data necessaries for the calculation of the Footprint of the territory

Consumption categories	**Footprint land types**			
	Carbon land	Cropland	Grazing area	Build-up area
Productive activities	Energy consumptions in productive activities (electricity, fuels, wood)	Area occupied by lands for crop production	Area occupied by graze land	Area occupied by structures used for productive activities
Residential area	Energy consumption of habitations (electricity, fuels, wood)			Area occupied by residential area
Mobility	Fuel used by means of transport			Area occupied by the streets
Waste	Energy necessary to burn the waste produced			

Every datum is then converted in global hectares, using the following formulas (for Carbon land, Cropland, Grazing area and Build-up area)[2]:

$$E.F._{\text{Carbon land}} = \{[P_C * (1 - S_{oceans})] / Y_C\} * EQF$$

Where:

P_c = annual emission (production) of carbon;

S_{oceans} = percentage of anthropogenic emissions sequestered by oceans in a given year (0.35%);

Y_c = annual rate of carbon uptake per hectare of world average forest land (0.095 kg CO_2/m^2 * year);

EQF = equivalence factor.

[2] Reference: "Calculation methodology for the National Footprint Accounts 2008 Edition", Global Footprint Network (California).

$$E.F._{Cropland} = A * YF * EQF$$

$$E.F._{Grazing\ area} = A * YF * EQF$$

$$E.F._{Build\text{-}up\ area} = A * YF * EQF$$

Where:

A = area available;

YF = yield factor;

EQF = equivalence factor.

The Equivalence Factors and the Yield Factors for Sweden for year 2005 (Table 2.2) have been provided from Global Footprint Network (California), "National Footprint Accounts 2008 Edition".

Table 2.2 Yield factors and equivalence factors for Sweden, year 2005.

	Yield factor (-)	**Equivalence factor (gha/ha)**
Cropland	1.796	2.644
Grazing land	1.681	0.497
Inland water	1.000	0.397
Forest	1.328	1.333
Build-up area	1.796	2.644
Carbon	-	1.333

2.2.1 Productive activities: agriculture

The Productive activity Agriculture has an impact on the Footprint land types Carbon land, Cropland, Grazing land and Build-up area.

Concerning Carbon land, the data source about energy consumption in agriculture has been Statistics Sweden website (www.scb.se), from where it has been possible to find the total quantity of energy used in agriculture in the year 2006, corresponding to 4,683 MWh.

The agriculture in Jokkmokk Municipality is practised on a very small scale, just for providing food for the animals in the farms, so we enclose petrol, diesel and burning oil consumption in the Consumption category Mobility, and we do not have to count the consumption of seeds and fertilizers, because they are not used; so we consider the datum found about energy consumption just as electricity consumption.

The emission factor for electricity in Sweden is 375 kg CO_2/MWh[3], so we can apply the formula for the Carbon Footprint:

$$E.F._{\text{Carbon land}} = \{[4{,}683 * 375 * 0.65)] / 0.095\} * 1.333 = \mathbf{1{,}601.6\ gha}$$

About the impact on Grazing land, the area occupied by them is estimated from the data about Norbotten[4], where it corresponds to 1,999 hectares; making a proportion with the two areas[5], we have 393.3 hectares of Grazing land in Jokkmokk Municipality. Then it is possible to apply the formula:

$$E.F._{\text{Grazing area}} = 393.3 * 1.681 * 0.497 = \mathbf{328.6\ gha}$$

It is important to remember that the grazing area does not include the graze of the reindeers, considered as a part of the forest area during the winter, and a part of the area occupied by National Parks in the summer.

The area occupied by Cropland has been found from Statistics Sweden website (area occupied by arable land) and corresponds to 248 hectares for Jokkmokk Municipality.

---

[3] Reference: http://energihandbok.se/x/a/i/10214/Berakning-av-koldioxidutslapp-for-olika-energislag.html.

[4] Reference: website of Swedish Board of Agricolture (Jordbruks Verket) (www.sjv.se).

[5] Jokkmokk Municipality area corresponds to 1,947,720 hectares, Norbotten area corresponds to 9,903,000 hectares.

$E.F._{Cropland} = 248 * 1.796 * 2.644 =$ **1,177.6 gha**

As the agriculture is practiced on a small scale, we will consider the area occupied by the buildings used in agriculture (impact on Build-up area) as enclosed in the Consumption category Residential area.
The final diagram for Agriculture is represented in Table 2.3.

Table 2.3 Summarizing diagram about Agriculture Footprint

	Datum	Ecological Footprint
Carbon land	Electricity consumption	**1,601.6 gha**
Grazing area		**328.6 gha**
Cropland		**1,177.6 gha**
TOTAL		**3,107.8 gha**

2.2.3 Productive activities: Industry

The Productive activity Industry has an impact on the Footprint land types Carbon land and Build-up area.
About the impact on Carbon land, we have to consider the consumption of electricity, LPG, diesel and burning oil. The data we have, from Statistics Sweden website, is about the energy consumption in the industrial sector for the year 2007, corresponding to 13,737.6 MWh.
From this value, the 49% is from electricity (6,731.4 MWh), the 6% is from burning oil (824.2 MWh), the 1.5% is from diesel (206 MWh) and the rest is from LPG (5,944.6 MWh).
In Sweden the emission factor for LPG is 234.5 kg CO_2/MWh, for burning oil is 274 kg CO_2/MWh and for diesel it corresponds to 259 kg CO_2/MWh (all the data have been found from Statistics Sweden website).
So we can apply the following formulas:

$E.F._{Carbon\ land} = \{[6,731.4 * 375 * 0.65)] / 0.095\} * 1.333 =$ **2,302.2 gha** *(electricity)*

$E.F._{Carbon\ land} = \{[5,944.6 * 234.5 * 0.65)] / 0.095\} * 1.333 =$ **1,271.4 gha** *(LPG)*

$E.F._{Carbon\ land} = \{[206 * 259 * 0.65)] / 0.095\} * 1.333 =$ **48.7 gha** *(diesel)*

$E.F._{Carbon\ land} = \{[824.2 * 267.5 * 0.65)] / 0.095\} * 1.333 = \mathbf{201\ gha}$ *(burning oil)*

About the impact on the category Build-up area, the area occupied by the industrial area has been measured by hands from the map and it corresponds to 61.1 hectares. The formula is the following one:

$E.F._{Build\text{-}up\ area} = 61.1 * 2.644 * 1.796 = \mathbf{290.1\ gha}$

The final diagram about the Ecological Footprint of the industrial sector is represented in Table 2.4.

Table 2.4 Summarizing diagram about Industry Footprint

	Datum	Ecological Footprint	**TOTAL**
Carbon land	Electricity consumption	2,302.3 gha	**3,283.4 gha**
	LPG consumption	1,271.4 gha	
	Diesel consumption	48.7 gha	
	Burning oil consumption	201 gha	
Build-up area		290.1 gha	**290.1 gha**
TOTAL			**3,573.5 gha**

2.2.3 Productive activities: Services

The Productive activity Services has an impact on the Footprint land types Carbon land and Build-up area.

Concerning Carbon land, we consider the consumption of electricity, burning oil and wood. The data, from Statistics Sweden website, are about the energy consumption in the services sector for the year 2006, corresponding to 18,409 MWh.

From this value, the 57% is from wood (10,493.1 MWh), the 40 % is from electricity (7,363.6 MWh) and the 3% is from burning oil (552.3 MWh). The emission factor for wood corresponds to zero, because it is a renewable source of energy, so the Footprint of wood consumption is zero[6].

[6] Reference: UNFCCC, United Nations Framework Convention on Climate Change.

The formulas used are the following ones:

$E.F._{Carbon\ land}$ = {[7,363.6 * 375 * 0.65)] / 0.095} * 1.333 = **2,518.5 gha** *(electricity)*

$E.F._{Carbon\ land}$ = {[552.3 * 267.5 * 0.65)] / 0.095} * 1.333 = **134.7 gha** *(burning oil)*

About the impact on Build-up area, the area occupied by services has been measured directly by hands from the map and it corresponds to 31.8 hectares, so we apply the formula:

$E.F._{Build\text{-}up\ area}$ = 31.8 * 2.644 * 1.796 = **151 gha**

The final data are summarized in Table 2.5.

Table 2.5 Summarizing diagram about Services Footprint

	Datum	Ecological Footprint	**TOTAL**
Carbon land	Electricity consumption	2,518.5 gha	**2.653.2 gha**
	Burning oil consumption	134.7 gha	
	Wood consumption	0 gha	
Build-up area		151 gha	**151 gha**
TOTAL			**3,400.9 gha**

The total Footprint for the Productive activities is summarized in Table 2.6.

Table 2.6 Summarizing diagram about Productive Activities Footprint

	Sector	Ecological Footprint	**TOTAL**
Carbon land	Agriculture	1,601.6 gha	**7,538.2 gha**
	Industry	3,283.4 gha	
	Services	2.653.2 gha	
Grazing land	Agriculture	328.6 gha	**328.6 gha**
Cropland	Agriculture	1,177.6 gha	**1,177.6 gha**
Build-up area	Industry	290.1 gha	**441.1 gha**
	Services	151 gha	
TOTAL			**9,485.5 gha**

2.2.4 Residential area

The Consumption category Residential area has an impact on the Footprint land types Carbon land and Build-up area.

Concerning Carbon land, we consider the consumption of electricity, burning oil and wood. The datum we have, from Statistics Sweden website, is about the energy consumption in Residential area for the year 2006, 55,057 MWh.

The 37% of this value is from wood (20,371 MWh), the 58% is from electricity (31,933 MWh) and the 5% is from burning oil (2,752.8 MWh). As we know the emission factor for wood correspond to zero, se we can apply the formula for electricity and burning oil:

$E.F._{\text{Carbon land}} = \{[31,933 * 375 * 0.65)] / 0.095\} * 1.333 =$ **10,921.7 gha** *(electricity)*

$E.F._{\text{Carbon land}} = \{[2,752.8 * 267.5 * 0.65)] / 0.095\} * 1.333 =$ **671.6 gha** *(burning oil)*

About the impact on Build-up area, the area occupied by residential building has been measured by hands from the map, and corresponds to 157.4 hectares. Then it is possible to use the formula:

$E.F._{\text{Build-up area}} = 157.4 * 2.644 * 1.796 =$ **747.4 gha**

The final data are summarized in Table 2.7.

Table 2.7 Summarizing data about Residential area Footprint

	Datum	**Ecological Footprint**	**TOTAL**
Carbon land	Electricity consumption	10,921.7 gha	**11,593.3 gha**
	Burning oil consumption	671.6 gha	
	Wood consumption	0 gha	
Build-up area		747.4 gha	**747.4 gha**
TOTAL			**12,340.7gha**

2.2.5 Mobility

The Consumption category Mobility has an impact on the Footprint land types Carbon land and Build-up area.

About Carbon land, I considered the consumption of petrol and diesel as fuels for vehicles. From Statistics Sweden website it has been possible to find the total consumption of petrol in the Municipality for the year 2006, corresponding to 38,050 MWh, and the total consumption of diesel, 58,584 MWh, and we have to subtract to this value 206 MWh, due to the industrial sector (see Chapter 2.2.3), so we get a result of 58,377.9 MWh for the Mobility sector. The emission factor for petrol corresponds to 261.5 kg CO_2/MWh (datum from Statistics Sweden). Then we can apply the formula:

$E.F._{\text{Carbon land}} = \{[38{,}050 * 261.5 * 0.65)] / 0.095\} * 1.333 =$ **9,075 gha** *(petrol)*

$E.F._{\text{Carbon land}} = \{[58{,}378 * 259 * 0.65)] / 0.095\} * 1.333 =$ **13,790.1 gha** *(diesel)*

Concerning the impact on the Build-up area, we have to consider the area occupied by the streets. The length of the streets into the towns of Jokkmokk, Vuollerim and Porjus has been provided from Göte Grahn (Jokkmokk Municipality) and it corresponds totally to 41 km. Then I have found the data about the length of the main streets from the website www.resrobot.se, the values are the following ones:

- Vuollerim – Murjek 18 km;
- Jokkmokk – Stora Sjöfallen 142 km (Jokkmokk – Porjus 46 km, Porjus – Stora Sjöfallen 96 km);
- Jokkmokk – Knikkjok 120 km;
- Jokkmokk – Karats 55 km;
- Jokkmokk – Vuollerim 41 km;
- Jokkmokk – Kåbdalis 58 km.

It is important to remember that the total is underestimated because it has been not possible to find the length of all the streets in the Municipality, but just of the ones in the biggest town and the main streets connecting one town to the other.

The width of the streets has been found from the website of the Road Department (Vägverket, www.vv.se) and it corresponds to 8 m into the towns, 9 m for the roads from Jokkmokk to

Porjus and from Jokkmokk to Vuollerim, and 6.5 m for all the rest of the roads. In total we have 3,360,000 m^2 of roads (336 hectares), so we can use the formula:

E.F.$_{\text{Build-up area}}$ = 336 * 2.644 * 1.796 = **1,595.5 gha**

In Table 2.8 we can see the final data.

Table 2.8 Summary of the data about Mobility Footprint.

	Datum	**Ecological Footprint**	**TOTAL**
Carbon land	Petrol consumption	9,075 gha	**22,865.1 gha**
	Diesel consumption	13,790.1 gha	
Build-up area		1,595.5 gha	**1,595.5 gha**
TOTAL			**24,460.6 gha**

2.2.6 Waste

The Consumption category Waste has an impact on the Footprint land type Carbon land.
The datum about the production of waste in Jokkmokk Municipality has been provided by Göte Grahn from Recycling Department, and represents the quantity of waste sent to Kiruna to be burned, corresponding to 17,736 ton for year 2008. The emission factor for waste is 0.25 kg CO_2/kg waste (from Swedish Environment Protection Agency, Naturvårdsverket), so we can use the formula:

E.F.$_{\text{Carbon land}}$ = {[17,736,000 * 0.25 * 0.65)] / 0.095} * 1.333 = **4,044 gha**

2.3 Ecological Footprint: results

After finding the contributes due to the different Footprint land types, it is possible to assess the total Ecological Footprint of the Municipality, adding the partial contribution of the Footprint land types or of the consumptions categories:

$$\mathbf{E.F._{TOT}} = E.F._{TOT\ carbon\ land} + E.F._{TOT\ cropland} + E.F._{TOT\ grazing\ area} + E.F._{TOT\ build\text{-}up\ area}$$

or

$$\mathbf{E.F._{TOT}} = E.F._{TOT\ productive\ activities} + E.F._{TOT\ mobility} + E.F._{TOT\ waste} + E.F._{TOT\ residential\ area}$$

We can see the final data in Table 2.9, the diagram is the same seen of Table 1.2.

Table 2.9 Distribution of the impacts of the consumptions categories on the territory categories for the Footprint of the territory for Jokkmokk Municipality.

	Footprint land types						
Consumption categories	Carbon land (gha)	Cropland (gha)	Grazing land (gha)	Fishing ground (gha)	Forest (gha)	Build-up area (gha)	**TOTAL**
Productive activities	7,538.2	1,177.6	328.6			441.1	9,485.5
Residential Area	11,593.3					747.4	12,340.7
Mobility	22,865.1					1,595.5	24,460.6
Waste	4,044						4,044
TOTAL	46,040.6	1,177.6	328.6			2,834	**50,330.8**

Figures 2.3 and 2.4 describe graphically Table 2.9: in Figure 2.3 we can see the percentage division of the Ecological Footprint of the Territory divided between the different Footprint land types, and in Figure 2.4 we can see the incidence of the consumption categories on the final value.

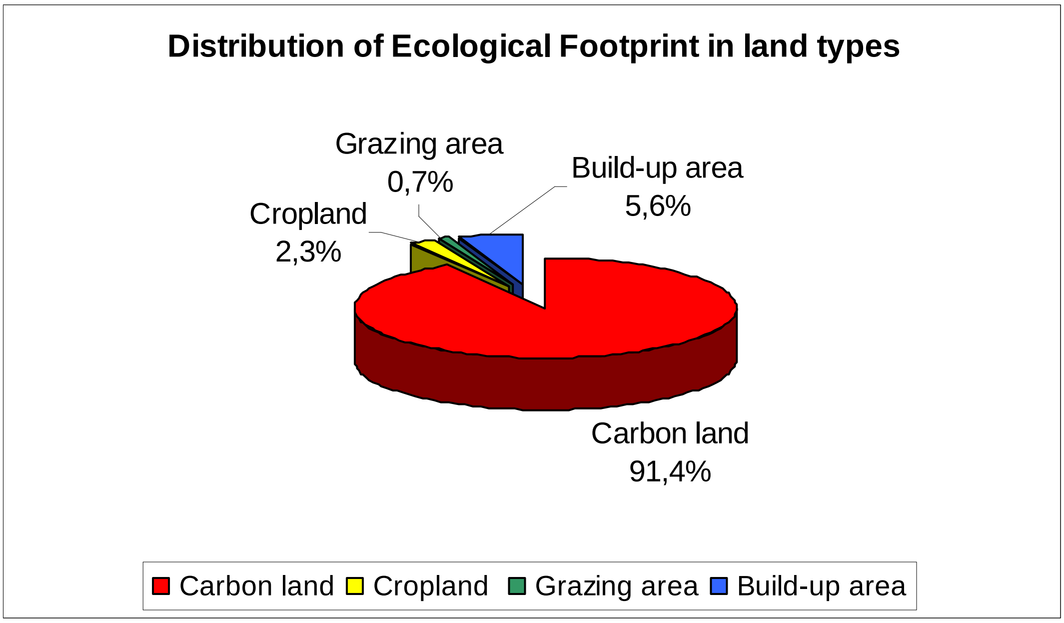


Figure 2.3 Percentage distribution of Ecological Footprint in Footprint land types for the Footprint of the Territory in Jokkmokk Municipality.

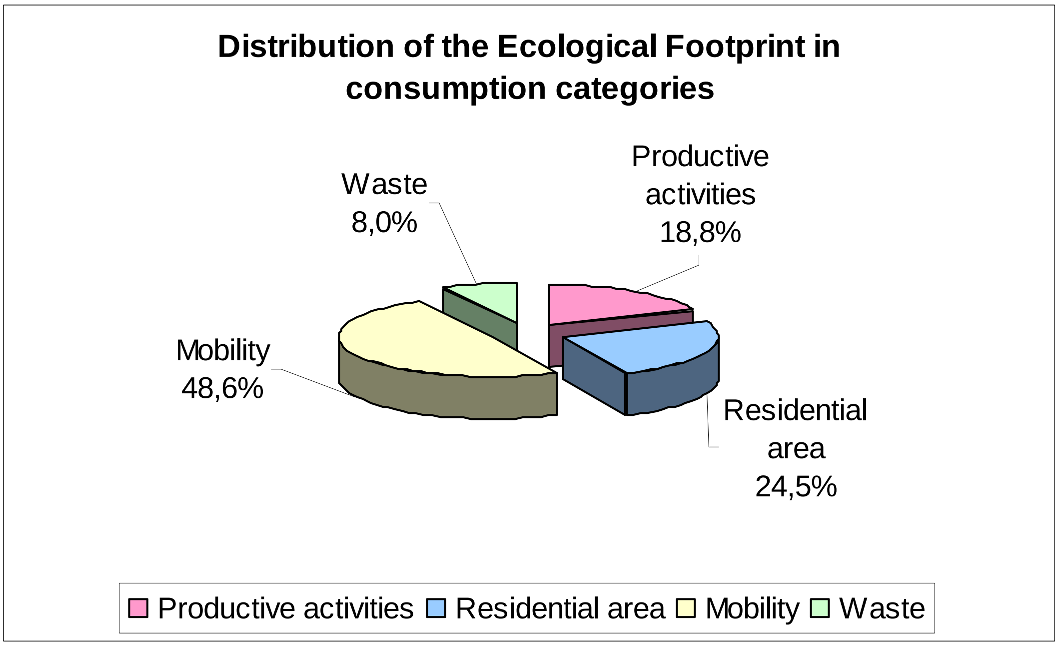


Figure 2.4 Percentage distribution of Ecological Footprint in consumptions categories in Jokkmokk Municipality.

The land type with the biggest Footprint is Carbon land (91.4%), followed by Build-up area (5.6%), Cropland (2.3%) and Grazing area (0.7%).

The consumption category with the higher Footprint is Mobility (48.6%), followed by Residential area (24.5), Productive activities (18.8%) and Waste (8%).

We can also consider just the Carbon Footprint of Jokkmokk Municipality: measuring the Carbon Ecological Footprint means measuring how much area is required to absorb human CO_2 emissions due to energy consumption.

Figure 2.5 shows the percentage components of the different CO_2 emissions source sectors on the Carbon Ecological Footprint. It shows that the Mobility sector is the most pollutant one (49.7%), this is due to the extension of the area of the municipality, since people have to cover a lot of kilometers for going from one place to the other. The Mobility sector is followed by the Residential area (25.2%), Waste (8.8%), Industry (7.1%), Services (5.8%) and Agriculture (3.4%).

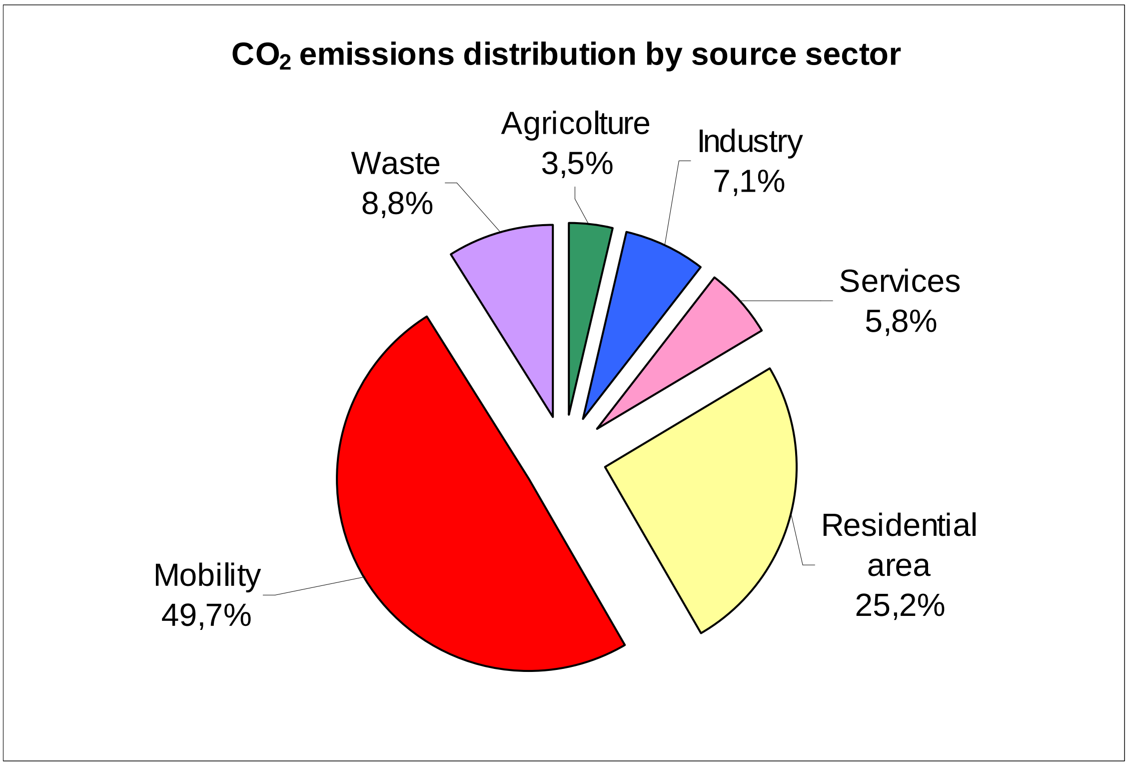


Figure 2.5 CO_2 emissions distribution by source sectors in Jokkmokk Municipality.

3 Jokkmokk Municipality Biocapacity

The Ecological Footprint then must be divided for the local available Biocapacity, and the ratio between the two values can tell us if the territory is in deficit (ratio > 1) or in reserve (ratio < 1).

As already said in the first chapter, the Biocapacity is the capacity of the ecosystem to produce “useful biological materials” and to absorb waste materials generated by humans using current management schemes and extraction technologies. To calculate the Biocapacity is necessary to collect the land use data in the territory, as the area occupied by croplands, grazing lands, forests, productive area etc. Then we have to convert this data in global hectares, using the equivalence factors and the yield factors for Sweden, with the following formula:

Global hectares = hectares * EQF * YF

In Table 3.1 is possible to see Jokkmokk land use data, then converted in global hectares; the available Biocapacity represents the 88% of the total (the 12% is considered as the land necessary for the conservation of the ecosystems). The datum about the area occupied by the forests (year 2003) has been found from the website of Swedish Forest Agency (Skogsstyrelsen, www.skogsstyrelsen.se); the one about the area occupied by Inland water (year 2008) has been found from Statistics Sweden website. The rest of the data has been previously found for the calculation of the Ecological Footprint.

Table 3.1 Jokkmokk land use area, Biocapacity and available Biocapacity.

Territory categories	Land use area (hectares)	Biocapacity (global hectares)	Available Biocapacity (global hectares)
Cropland	248	1,177.6	1,036.3
Grazing land	393.3	328.6	289.2
Forest	528,986	936,423.7	824,052.8
Inland water	174,190	69,153.4	60,855
Build-up area	586.3	2,771.3	2,438.7
TOTAL	**704,403.6** 1,947,720[7]	**1,009,854.6**	**888,672**

[7] Effective area of Jokkmokk Municipality.

It's very important to remember that the effective area of Jokkmokk Municipality, 1,947,403.6 hectares, is bigger compared to the total value found (704,403 hectares). In fact the area doesn't include the natural parks (with a total of 572.540 hectares), the numerous protected area, rock surfaces and high mountains, the last two not considered in the Ecological Footprint calculation. So the total available Biocapacity is underestimated.
In Figure 3.1 is represented the available Biocapacity divided between Footprint land types.

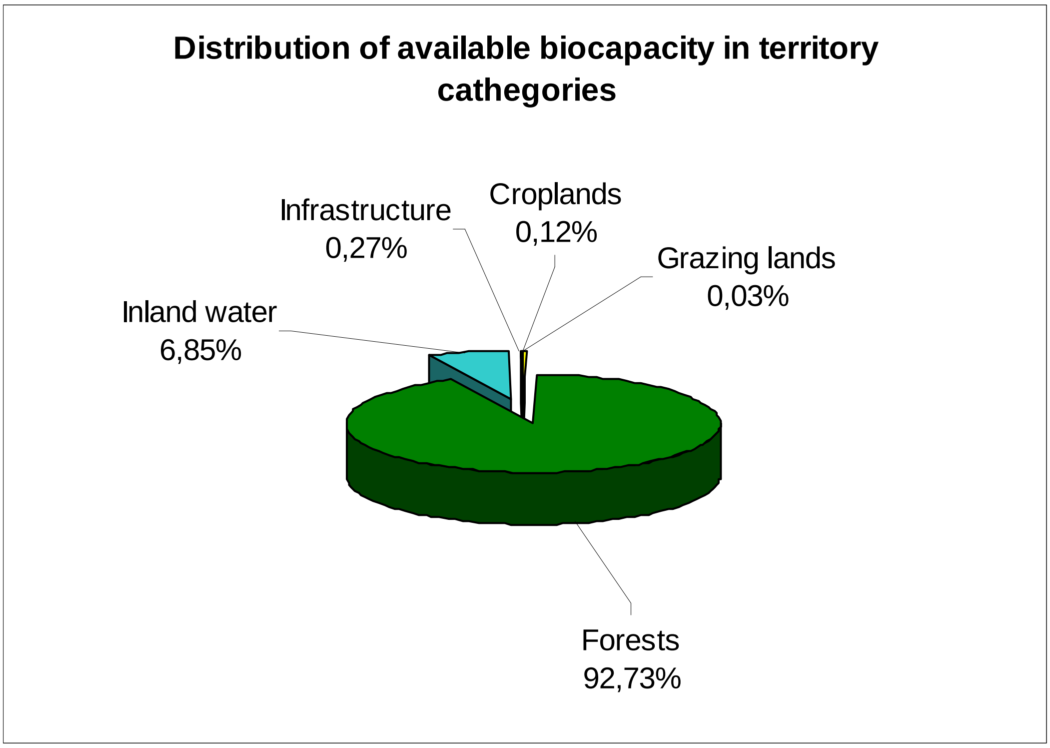


Figure 3.1 Distribution of available Biocapacity in Footprint land types in Jokkmokk Municipality.

The mayor part of the available Biocapacity is taken by the forests (92.73%), representing one of the main features of Jokkmokk territory. They are followed by the inland water (6.85%) and in very small parts by infrastructures (0.27%), croplands (0.12%) and grazing lands (0.03%).
So if we divide the Ecological Footprint for the available Biocapacity we get the following result:

E.F. / a. Biocapacity = 50,330.8 gha / 888,672 gha = **0.06**

This means that the ratio between Ecological Footprint and Biocapacity for Jokkmokk Municipality is less then 1, so the Municipality is in reserve, in particular it is using about the 6% of its “useful biological material”.

It is important to remember that this result is due in particular to the presence of the forests and to the small number of inhabitants: it is possible to see it better if we compare the Biocapacity per capita in Jokkmokk with the data about Sweden for 2005[8], as described in Table 3.2 and in Figure 3.2.

Table 3.2 Biocapacity per capita in Jokkmokk Municipality compared with the values for Sweden (year 2005).

Territory categories	Biocapacity Jokkmokk	Biocapacity per capita Jokkmokk	Biocapacity per capita Sweden
Cropland	1,036.3	0.19	1.42
Grazing land	289.2	0.05	0.34
Forest	824,052.8	155.33	5.39
Inland water	60,855	11.47	2.63
Build-up area	2,438.7	0.45	0.20
TOTAL	**888,672**	**167.5**	**10**

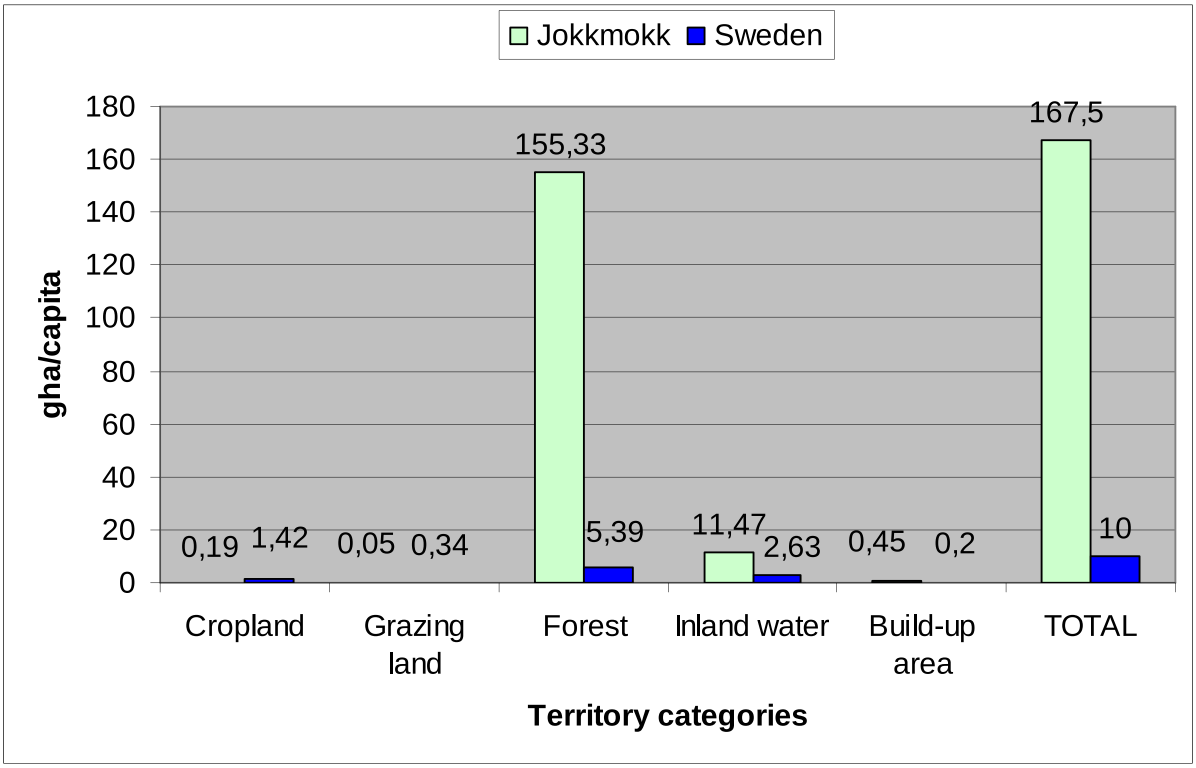


Figure 3.2 Biocapacity per capita in Jokkmokk Municipality compared with the values for Sweden (year 2005).

[8] Reference: “Ecological Footprint and Biocapacity, 2005 – Data Updated, based on National Footprint Accounts 2008 edition”, www.footprintnetwork.com.

4 Comparisons with Montechiarugolo Municipality (Italy)

The method I have used to calculate Jokkmokk Municipality Ecological Footprint is the same I used in my master thesis in 2007 for calculating Montechiarugolo Municipality Ecological Footprint, so it can be interesting to compare the results, considering that the two municipalities are very different each other, for climate, extension, density of inhabitants and economy.

Montechiarugolo Municipality is located in Northern Italy, in Emilia Romagna Region, in Parma Province (Figure 4.1 and 4.2). The area of the Municipality is 48 km^2, and the number of inhabitants in 2007 was 9,951.

The economy is mainly agricultural, with a large number of cheese factories (producing Parmigiano Reggiano cheese), two big industries (producing respectively tomato sauce and steel pipes), a thermal resort and several craft industries.

Figure 4.1 Localization of Emilia Romagna Region in Italy; the area highlighted with the red circle represents Parma Province.

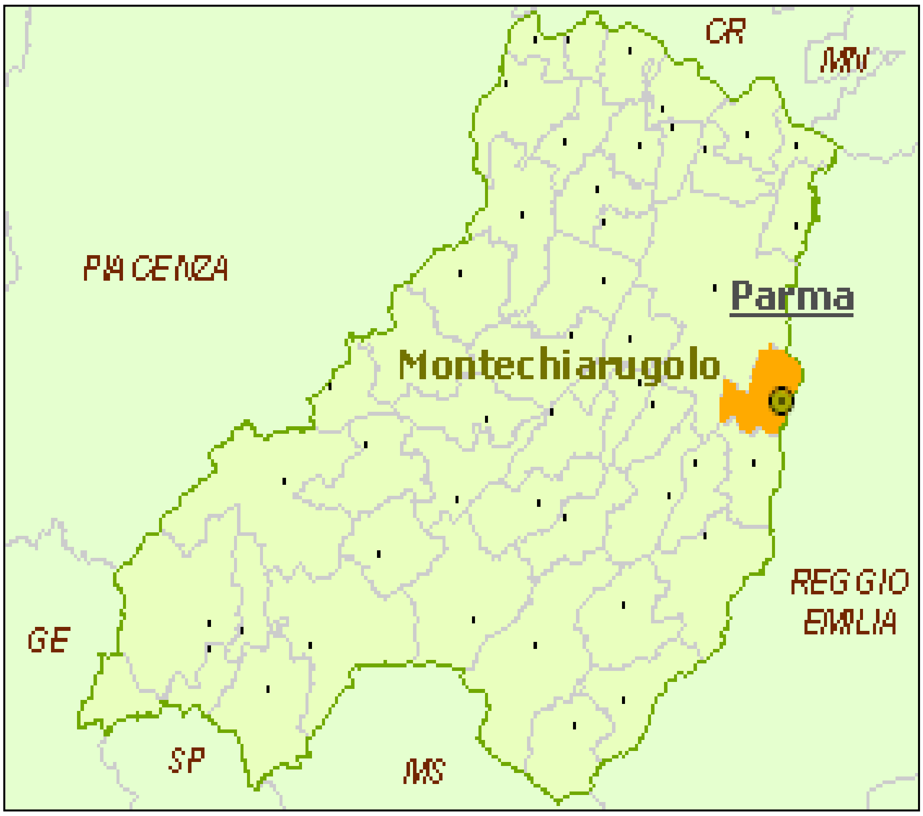


Figure 4.2 Localization of Montechiarugolo Municipality in Parma Province.

The Ecological Footprint of Montechiarugolo Municipality (year 2007) is 98,950 gha, and the Biocapacity is 10,795 gha, so the ratio between the two values is 9.1, that mean that Montechiarugolo is in deficit (we should need an area more that nine times bigger to supply to our consumptions and waste production). In Tables 4.1 and 4.2 it is possible to see the final data about Montechiarugolo Ecological Footprint, and about the land use area and Biocapacity.

Table 4.1 Distribution of the impacts of the consumptions categories on the territory categories for the Footprint of the territory for Montechiarugolo Municipality.

	Footprint land types (gha)						
Consumption categories	Carbon land	Cropland	Grazing land	Inland water	Forests	Build-up area	**TOTAL**
Productive activities	44.172	8.593	1.630			1.130	55.525
Mobility	20.289					259	20.547
Waste	6.952						6.952
Residential area	15.312					614	15.926
TOTAL	86.725	8.593	1.630			2.002	**98.950**

Table 4.2 Montechiarugolo land use area, Biocapacity and available Biocapacity.

Territory categories	Land use area (hectares)	Biocapacity (gha)	Available Biocapacity (gha)
Cropland	2.604	8.593	7.562
Grazing land	795	1.630	1.434
Forests	23	41,8	36,8
Inland water	0	0	0
Build-up area	686.8	2.003	1.762
TOTAL		**12.267**	**10.795**

It is then possible to compare with Jokkmokk the Footprint divided between Footprint land types and Consumption categories (Tables 4.3 and 4.4).

Table 4.3 Comparisons between Jokkmokk and Montechiarugolo distribution of the Ecological Footprint in Footprint land types.

Footprint land type	Jokkmokk Municipality	Montechiarugolo Municipality
Carbon land	91.4 %	86 %
Cropland	2.3 %	8.7 %
Grazing land	0.7 %	1.6 %
Build-up area	5.6 %	2 %

Table 4.4 Comparisons between Jokkmokk and Montechiarugolo distribution of the Ecological Footprint in Consumption categories.

Consumption categories	Jokkmokk Municipality	Montechiarugolo Municipality
Productive activities	18.8 %	56.1 %
Residential area	24.5 %	16.1 %
Mobility	48.6%	20.8 %
Waste	8 %	7 %

It is interesting to see from Table 4.3 that Footprint percentage for Carbon land is not so different between Jokkmokk and Montechiarugolo (91.4% and 86%), that mean that the average consumptions of energy are not so different. We have also to consider that in the calculation of the carbon Footprint for Jokkmokk we did not count the wood consumption for distant heating plant, as the wood emission factor is considered as zero.

The Footprint percentage about Cropland is bigger in Montechiarugolo, obvious result because of the agricultural economy in the Municipality.

About the consumption categories, we can see that in Jokkmokk the main part of the Footprint is taken by the Mobility (48.6 %), after that there are the residential area (24.5 %), the productive activities (18.8 %) and the waste (8%).

In Montechiarugolo on the other hand we have the Productive activities as the biggest consumption category (56.1%), followed by the Mobility (20.8%), the residential area (16.1%) and the waste (7%).

It is finally possible to compare the Biocapacity per capita of Montechiarugolo with Jokkmokk, as we can see in Table 4.5 and in Figure 4.3. There is an evident difference between the area occupied by the forests in Jokkmokk and in Montechiarugolo: this is mainly why Jokkmokk is in reserve and Montechiarugolo is in deficit; we saw, for example, that the percentage of the Footprint (taking the biggest part of the total Footprint) due to carbon land is not so different between the two municipalities.

Table 4.5 Comparisons between Jokkmokk and Montechiarugolo Biocapacity per capita.

Territory categories	Biocapacity per capita Montechiarugolo (gha)	Biocapacity per capita Jokkmokk (gha)
Cropland	0.76	0.19
Grazing land	0.14	0.05
Forest	0.003	155.3
Inland water	0	11.47
Build-up area	0.18	0.45
TOTAL	**1.08**	**167.5**

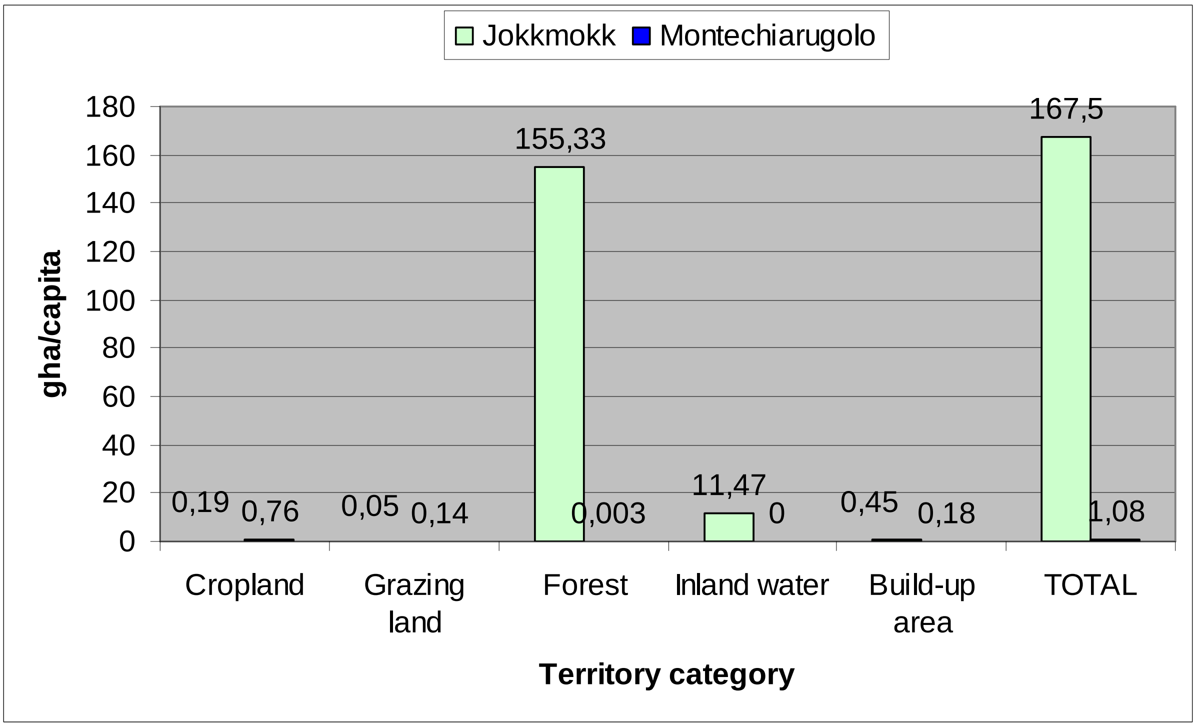


Figure 4.3 Comparisons between Jokkmokk and Montechiarugolo Biocapacity per capita.

5 Conclusions

This work, a part of my traineeship tasks during my Leonardo Da Vinci Program in Jokkmokk Municipality, has as objective the calculation of the Ecological Footprint of the territory of Jokkmokk Municipality. The method is the same I used in my master thesis for Montechiarugolo Municipality, elaborated from the original one developed by the Global Footprint Network, adapted to sub-national contests.

The calculation has been preceded by the data collection, after that the data have been converted in the correspondent territory area, obtaining a final value reflecting as best as possible the local situation; that can be a good help for understanding better the critic aspects of the territory analysed, and to give information about the resource metabolism in the area.

Analysing the results, it is evident that the Footprint of Jokkmokk is due mainly to the energy consumption, in particular from the Mobility, taking almost the 50% of the total Footprint, and representing the most critic aspect on the territory.

On the other hand it is very good that Jokkmokk is using the distant heating plant for the heating of the houses, since wood is a renewable source of energy, without impact on the total Ecological Footprint.

In Jokkmokk Municipality there are also a lot of forests compensating the consumptions of CO_2, so that at the end the ratio between Footprint and Biocapacity is widely less than 1 (0.06), and the Municipality is definitely in reserve. Moreover, the Biocapacity for Jokkmokk Municipality is underestimated, because it has not been considered the area occupied by the national parks and the protected area.

So this work can be considered as a starting point for monitoring the situation of the Municipality about environment, energy consumption and territorial planning.

After that, it has been interesting to compare the results for Jokkmokk with the ones for Montechiarugolo (Italy): from them it is possible to understand better some of the differences due to the climate, to the different extension of the two territories, and to the type of economy. For example, it is has been interesting to note that the Carbon Footprint percentage, that in both cases represents the main part of the Footprint, is not so different from Montechiarugolo to Jokkmokk. But at the end, as we know, the ratio between Footprint and Biocapacity is completely different (9.1 and 0.06), because Jokkmokk has a very big Biocapacity due to the forest area (528,986 hectares), and on the other hand Montechiarugolo has just 23 hectares of forests.

So this work can be considered also as a good example of application of the Ecological Footprint method to two situations completely different, almost extreme the one to the other, that in this way can be compared.

References

Buratti, C., 2007. *L'impronta Ecologica del Comune di Montechiarugolo (PR)*. Master Thesis in Environmental Sciences, Parma University.

Ewing, B., Reed, A., Rizk, S., Galli, A., Wackernagel, M., Kitzes, J., 2008. *Calculation Methodology for the National Footprint Accounts, 2008 Edition*. Global Footprint Network (California).

Giardinà, C., 2002. *Calcolo dell'Impronta Ecologica del Comune di Piacenza.* Master Thesis in Environmental Sciences, Parma University.

Giordano, F., 2004. *Calcolo dell'Impronta Ecologica del Comune di Savona.* Master Thesis in Environmental Sciences, Parma University.

Pearce, D.W., Turner, R.K., 1991. *Economia delle risorse naturali e dell'ambiente.* Edizioni Il Mulino, Bologna, Italy.

Scotti, M., 2003. *Linee guida per il calcolo delle Impronte Ecologiche locali.* Master Thesis in Environmental Sciences, Parma University.

Silvestri., F., 2007. *New Sustainable Development Instruments and Methodologies*. PhD Dissertation in Environmental Sciences, Milano Bicocca University.

Wackernagel, M., Rees, W., 2000. *L'Impronta Ecologica. Come ridurre l'impatto dell'uomo sulla terra.* Edizioni Ambiente, Milano, Italy

Wackernagel, M., Chambers, N., Simmons, C., 2002. *Manuale delle Impronte Ecologiche. Principi, applicazioni, esempi.* Edizioni Ambiente, Milano, Italy.

Web-page references

Global Footprint Network: www.footprintnetwork.com;

Jokkmokk Municipality (Jokkmokks Kommun): www.jokkmokk.se;

Montechiarugolo Municipality: www.comune.montechiarugolo.pr.it;

Resrobot: www.resrobot.se;

Statistics Sweden (Statistika Centralbyrån): www.scb.se;

Swedish Board of Agricolture (Jordbruks Verket): www.sjv.se;

Swedish Environmental Protection Agency (Naturvårdsverket): www.naturvardsverket.se;

Swedish Forest Agency (Skogsstyrelsen): www.skogsstyrelsen.se;

Swedish Road Department (Vägverket): www.vv.se;

The National Association of Swedish Eco-municipalities (Sverige Ekokommuner): www.sekom.nu.

Thanks to…

First of all a big “thank you!” to my tutor Elisabeth Hammarberg (Jokkmokk Municipality), the person who gave me the possibility to spend five months in Jokkmokk with Leonardo Da Vinci Programme and to develop the project about Ecological Footprint: thank you very much Elisabeth, for believing in me and for your great help.

Thank you very much to my “second tutor” Jennifer Forssell (Jokkmokk Municipality), for your essential help in the research of the data and the emission factors, and for the precious translations from Swedish to English…I don’t know what I would have done without you!

Thanks to Göte Grahn (Jokkmokk Municipality), for your help in the research of the data about the streets and the waste.

Thanks a lot to Francesca Silvestri from Milano Bicocca University, for your great help every time I had some doubt about the Footprint Method and for your English corrections, you have been really nice!

Thanks to Anders Reed and Bree Barbeau from Footprint Network (California, U.S.A.), for giving me the equivalence factors and yield factors for Sweden: thank you so much, without your help this work would not have been possible.

Thanks to Silvia Bossi, my favourite interpreter, for your English corrections.

Thanks to Samuel Roturier for your help in preparing the power point presentation about the Footprint.

Thank you to Jennifer, Elisabet and Maria, for being good friends during this time and for the evenings we spent together watching movies and making weird food experiments! :-)

Thank you so much to Samuel, for being a good friend and neighbour, and for teaching me how to cook a crêpe (even if I will never learn the right pronunciation)! :-)

A very big thank to Linnea, for all the time we spent together and for being the wonderful person you are! It has been so nice to live with you during this five months!

Thanks to Eva, for being a so special person, and for giving me the possibility to be part of unforgettable experiences, as the reindeers separation, the ice fishing competition…

Thanks to Tom for our very pleasant conversations during the lunch time, and for making me be part of Jokkmokk’s choir!

Thanks to all the special persons I met in Jokkmokk, this five months spent in this so beautiful town over the Polar Artic Circle have been a very special time for me, a great gift, that I will never forget!