Planning of the Agrifood supply chain: a case study for the FVG region

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Abstract - **The aim of this paper is to discuss the planning of regional Agri-food supply chain using an integrated database territorial information. The objective is to optimize the chain performance using alternative solutions. Evidences are obtained with a case study performed in FVG region applied to maize-crop. Firstly it is explored the chain network composed by farms, collection points and processing plants; then territorial, agronomic and climate information are integrated to simulate realistic production forecast model applied to maize crop. Finally a program from graph analysis is used to allocate the production through the chain. The economic performance is evaluated using the net revenues varying with the intensification of maize production and adoption of different organization solutions (independent and cooperative). Conclusions are that the chain performance is influenced by a combination of technology and organization decisions and the policy maker can use these results to orient their targets about regional planning.**

Keywords - **data integration, supply chain, decision support system, crop simulation, regional policy.**

I. INTRODUCTION

The arena of competition of the agri-food supply chain is moving from individual firms operating on spot markets towards vertically integrated organizations and networks (Onderstejin et al, 2006). Standing from an economic point of view, the integration of agriculture and food industry in the regional agri-food chain is an excellent instrument for promoting the development of local production systems, by increasing the value added of agricultural crops and enhancing the collaboration among different partners. This process has been interpreted with different paradigms: the industrial organization emphasizes the imperfect competion caused by the competitive gap among enterprises operating in specific agro-industrial sectors, causing structural changes that drive to not competitive conducts and inequality distribution of profits. The monopoly solutions could maximize the supply chain's value added; however retailers, being in dominant position, gain more profits while all other parties do not necessarily receive benefits from the increased supply-chain efficiency (Tirole, 1988). Other consequences of market power concentation are the price changes at one level not quickly transmitted to other levels because of the existence in time lags between the price adjustments at the respective stages and asymmetries in reaction to positive and negative price shocks (Bunte, 2006). Five strategic factors are the drivers of competition in this contest: (1) rivalry among existing firms, (2) barriers to new entrants, (3) threat of substitute products or services, (4) bargaining power of suppliers, and (5) bargaining power of buyers (Porter, 1985). The interplay of these five forces is thought to determine the boundaries of a firm's competitive strategy and its survival. Recent studies indicate that the food supply chain has evolved into a network (Lazzarini et al, 2001), favouring the diffusion of information to accelerate the spread among partners of production/processing technologies, information about market and financial opportunities (Omta, 2002; Pittaway et al, 2004). The neo-institutional theory provides theoretical ground for supporting organizational changes to remedy to the growth of transaction costs in imperfect market conditions (Ménard and Valceschini, 2005, Rama, 2009). The integration between agriculture and food industry can contribute to solve these market efficiency problems and contribute to the occupation and GDP at local level. In Italy Agriculture and Food industry represent the 18,26% of the national GDP (tab. 1) but food industry is becoming mpre and more important. In recent years, the growing concentration of food industry was followed by the integration of national groups in multinational companies (Barilla, Ferrero, Parmalat, Cremonini, Scotti and others) causing structural and economic change at local/regional level (Fanfani and Brasili 2008; Rosa and Galizzi, 1994).

Table 1 – Italy: components of the Agri-food system. Source INEA, 2008

Components	mio €	%
Value added Agriculture	28.442	11,35

Intermediate consumption	23.198	9,26
Trade and distribution	98.289	39,24
Value added Food industry	26.467	10,57
Value added Service of restauration	37.668	15,04
Indirect taxes agro-industry	13.891	5,55
Support to the production	2.931	1,17
Investment agro-industry	19.603	7,83
Total value agri-food system	250.489	100,00
Total VA agri-food system	250.489	18,26
Total VA industry	381.446	27,81
Total VA service	1.003.021	73,12
Total VA Italy	1.371.834	100,00

The Agri-food supply chain integrates complementary sectors playing a growing role in the formation of the chain value for cost saving, quality perception, marketing strategies. The concept of Agri-food is embedded into the "food supply chain" (FSC) to explain the organizational change caused by the agreements between farmers and their partners at different levels of the Agri-food chain. This has stimulated cooperative efforts among members to reach the optimal size for a competitive business: specifically, the coordination of production, processing, exchange and logistic functions at different levels of the chain, has contributed to accelerate the innovation in product/process development, design, quality control and food security. This organization model gains competitive advantage procured by the industrial organization (product development, brand protection, scale economies, vertical integration, price control) with lowering the average costs over market price (Fortuin and Omta, 2009; Milgrom and Robberts, 1990).

Networks collaboration plays an important role in the adoption of technical and organizational changes (Pittaway et al, 2004) and is becoming the place where farmers interact within one or several related industrial partners in a vertical networks belonging to the same supply chain. The collaborations among partners, increases the exchange efficiency with a broader intelligence of the system (Omta, 2004). The supply chain network includes many forms of organizations (suppliers, local processing companies, groups, trust cooperatives, customers agreements with third parties) forming largest group embracing institutions such as research organizations, governmental institutions, and financial partners motivated to work together to achieve common objectives and strategic advantage. Hence the network is an enhanced form of supply chain where the internal and external resources of a firm are tied up together and transformed into innovative and lower cost products (Gellynck et al, 2006). With the optimal use of both internal and external resources in these integrated group, the firms are able to gain advantages for the more efficient production strategies in domestic and international markets (Lengnick-Hall, 1992). The supply chain network becomes unavoidable in case the successful businesses, it requires greater industrial size to achieve scale economies and more rapidity to adapt to demand changes.

In this respect an issue of growing importance is the integration of the food chain operation in a local food district to spread among farmers the opportunities in food industry (Bahlmann and Spiller, 2008). Our approach takes into account also the energetic and ecological aspects of crop production and externalities of relevant interest for the regional institutions growingly concerned about multi-objective strategies to grant the simultaneous achievement of energetic, economic and environmental targets.

The integrated agri-food chain is able to supply quantity and quality of the commodity in order to satisfy the demand of the processing plant compatible with the saturation of its production capacity. The advantages of regional planning agro-food chain has been described in few studies by focalizing the production and logistic aspects using a GIS approach to assess land availability at regional level; by concentrating on the environmental requirements for crop species, with climate, soil and terrain features and developping a model to support agro-ecological decisions for crop production compatible with the maintenance of soil fertility and food industry needs (Fiorese and Guariso, 2010). An innovation strategy conceives the possibility to increase the farmers' income with implementation of traditional production system associated with DOP Parmigiano Reggiano cheese in Italy that is a successful example of local supply chain contributing to the employment and perpetuation of artisanal, environmentally benign, and labour-intensive production techniques (Sonnino and Marsden, 2006; De Roest and Menghi, 2000).

This paper is organized as follows: the first part is a general description of the agriculture with potential supply of different crops using the simulation with agro-climatic models; the second part illustrates the methodology with a 5 step analysis; the third part is dedicated to results; the fourth part reports the comments.

II. DESCRIPTION OF THE REGIONAL BASIN FOR THE AGRIFOOD SUPPLY CHAIN

The territorial planning of the agrifood supply chain needs information about the regional basin characterized by the presence of: i) production units represented by farms and parcels responsible of the supply of crop commodities; ii) collection points (CP) delegated to concentrate the crop supply and to organize for the next processing step; iii) processing plants (Pl) transforming crops into final product. The phisical pattern of the crops through the chain is ensured by the transport network. The success of the regional planning depends on the configuration and flexibility of the resource basin and is supported by agronomic and climatic conditions, technology innovation, and policies. Such policies support financially and with suitable regulations the needed organizational adjustments. In table 2 the structure of Agriculture in FVG region is reported; composed by 24 thousand farms managing 225 thousand ha with an average surface of 9,43 ha per farm; most of the agriculture is concentrated in larger farms: the 56,3% of the cultivated land is owned by 2.349 farms that represent only the 10% of the total.

Table 1 – Farms and surface classified by size in FVG region. Source ISTAT

variable	< 1	1-2	2-5	5-10	10-20	20-50	> 50	Total
farm (n)	2.817	4.151	7.829	4.002	2.671	1.732	617	23.819
%	11,83	17,43	32,87	16,80	11,21	7,27	2,59	100,00
land (ha)	1.696	5.845	25.111	28.125	37.365	50.973	75.406	224.521
%	0,76	2,60	11,18	12,53	16,64	22,70	33,59	100,00
land/farm	0,60	1,41	3,21	7,03	13,99	29,43	122,21	9,43

Frequently the regional planning uses geografic information techniques (GIS), soil representation[a] combined with more traditional statistical sources (ISTAT, INEA, ISMEA) giving an accurate representation of local conditions affecting the crop supply.

Modern farm technologies improve consistently the crop yield by combining agronomic and climatic condition at local level in order to simulate models able to predict the crop response of farmers' decisions. Figure 1 illustrate the approach that is followed in this research: the area of interest with parcels magnified and georeferenced is coloured.

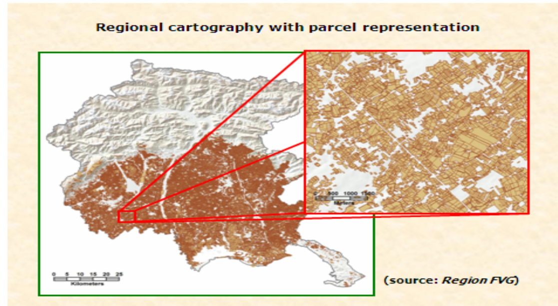


Fig 1 – Configuration of the production area with parcel magnitude. Source: Insiel regional cartography

III. METHODOLOGY

The agri-food supply chain optimization is developed with reference to the regional basin that is composed by 18 thousand farm with their parcels, 53 collection points and 2 processing plants. The first methodological problems afforded regards the integration of databases with different formats; hereinafter, an example of integration of layers of information used for the analysis is illustrated.

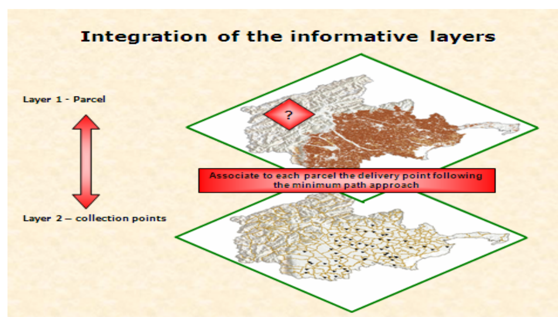


Fig 2 – Integration of different layer of information

The economic optimization of the agri-food supply chain within the spatial allocation of crop supply is formulated as a multiobjective regional planning strategy addressed to satisfy private and social needs; hence, considerations about externalities and LCA could also be included in this analysis. The profit maximization is assumed to be the difference between revenues realized at the final step and the costs afforded throughly the entire supply chain: production, collection, transport and processing influenced by crop type, soil productivity, technology, climate conditions, mechanical and labour operations. The allocative problem is based on a compromise between the potential increase of crop supply in the basin that causes a decline in costs of collection and processing, counterbalanced by rising costs of transport growing with the distance between production sites and processing plants.

[a] DTM refers to a representation of the Earth's surface (or subset of this), excluding features such as vegetation, buildings, bridges, etc. The DEM often comprises much of the raw dataset, which may have been acquired through techniques such as photogrammetry, LiDAR, IfSAR, land surveying, etc. A digital surface model (DSM), on the other hand, includes buildings, vegetation, and roads, as well as natural terrain features and may be useful for landscape modeling data terrain models that allow to survey and describe specific features

Once the crop has been delivered to the collection points, it is hauled to processing plant Pl[b]. The distances between CP and Pl require to solve an interactive location/allocation problem represented in figure 3 (Panichelli and Gnansounou, 2008).

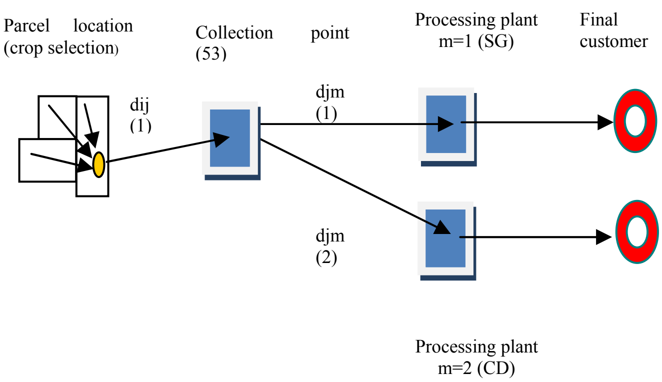


Fig 3 – Shortest path calculation model

A. *Information sources and scheme of the analysis*

The regional informative system is composed by:

- Regional database, provided by Insiel with the inventory of the farms relevant for this research (about 15.000) and their parcels (updated to 2006), are described with morphological and pedological soil features, administrative borders, and % of area dedicated to a specific crop. The georeferenced parcel is the elementary production unit with minimum size owned by a farm with uniform attributes, reported in the real estate cadastre register, and described by some mandatory elements such as geometry, owner, label for identification on printed maps;
- Moland, regional map of soils, based on the combination of hydrological and land-use, is used to evaluate spatial planning policies and measures for natural risks reduction modelling with two main objectives: i) to assess of the effectiveness of mitigation and adaptation measures in the context of wider regional development policies; ii) to define spatial planning options for adaptation to weather driven natural hazards;
- Road map network: database about regional road classified by type (high-way, state, regional, provincial, communal roads) used for hauling crop from farm to collection point and from collection point to processing plant;
- Meteo station network: composed by 13 units scattered in the region. Data are used to simulate 140 climatic areas affecting the crop yields in the region;
- Collection point network is used to concentrate the crop supply to be delivered to processing plant after conditioning. Most of these CP are managed by cooperative organizations (Consorzi agrari). Farmers usually deliver their crops to CP by signing seasonal contracts at the beginning of the season;
- Processing plant network: composed by two units located at different distances from farmers.

The analysis is developped in six steps:

The first step, is the identification of the crops over the area under investigation. This means that information about soil, climate and agronomic conditions for each of the potential crops are collected, along with information about the crop activities to identify the technology used affecting costs, energy consumption and emission. The farmgate production cost is the full cost including growing, collection, harvesting, hauling, storage.

The second step is the collection of the soil features: morphology, soil pedology, climate, ownership and other to evaluate the suitability of the area to the selected crop. All these information are usually available from digital cartography, allowing a continuous representation of data. The information database is to include only one surface cadastre layer (3D), with geospatial objects linked to the surface layer. The surface information is organized in layers and the multilayer information is organized at the object level. Defined for each surface parcel will be indicators that will point to the multilayer objects related (or connected) to the surface parcel.

The third step is to evaluate the land supply of each parcel with assigned crop (crop land supply). This step implies a number of information including political decisions about the land use options, and specifically the extent to which current agricultural practices may be intensified. A careful comparison of benefits from current agriculture with respect to the possible gains from the supply chain is also required. However, it must be noticed that a complete elaboration of the agricultural plan (food and non-food crops, agricultural technology, land suitability, transport, storage and processing, costs, energy balance, etc.) may become very complex (e.g., the model developed by De La Torre Ugarte et al., 2003) if a powerful simulation program is not available.

The fourth step is the assignement of the crop to each suitable parcel area and the estimation of the production with simulation. When more than one crop is possible on a

[b] The distance is not the only decisional variable to be taken into account because a plant can be more efficient even if situated at the longer distance or it can offer better contractual condition for crop delivery

parcel, an optimization problem will assign the crop in function of yield and rotation constraints.

The fifth step is the crop produced in parcel delivered to the concentration point for conditioning.

The sixth step consists in the crop delivery from CP to one of the two processing plants for final processing.

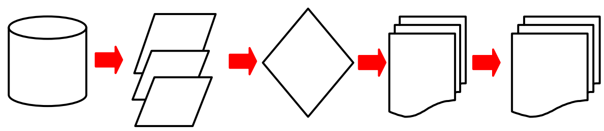


Fig 4 – Scheme of the steps of the analysis

Figure 4 describes the scheme of the agri-food supply chain path.

In the following table is reported the list of farm operations for Maize production with energy and cost per ha. A detailed list of operations with energy consumption including the energy to build machinery is also reported.

Table 3 – List of farm operation for mais production (technology 1)[c]

Maze Cultivation technique				
Day	Operation	Time of labour (h/ha)	Fuel consumption (Kg/ha)	Energy consumption (Mj/ha)
102	Plowing	1,9	43	1806
131	MinFert (N75)	0,1	5	210
132	Planting	1,1	4	168
135	Herbicide (glif2.5)	0,2	1	42
158	MinFert (N75)	0,1	5	210
176	Irrigation (35mm)	6,5	1	42
181	Irrigation (25mm)			
191	Irrigation (35mm)			
200	Irrigation (40mm)			
256	Irrigation (35mm)			
311	Harvest	0,3	16	672
Total				

[c] Gasoline energy consumption in Mj/ha for farming operations and hauling (diesel emission factors per MJ: 74 gCO_2, 0.04 gN_2O, 0.028 gCH_4, Sinanet, 2008; electricity

B. *Cost analysis*

The cost is determined by taking into account the all factors used to perform the functions at different stages of the agri-food supply chain: production, concentration, transport, processing and delivery to final customer.

The chain costs are the following:

- crop production costs in a given parcel (see table 2);
- crop concentration: costs for storage, loading /unloading at collection point;
- processing costs: cost of plant;
- transport cost: hauling crops from parcel to CP and from CP to processing plant.

The transport costs are determined in function of the prehexisting network formed by parcels, collection points, processing plant and road system with junctions and intersections connecting the different road nodes. Data are collected from a variety of sources and assembled to build the geographic and cost components of the supply chain network. Collecting costs are the same for the all crops on a total weight only the moisture content differentiate the dry crop transport cost; in our case they are limited to corn crop. The optimization process consists in finding the shortest distance between parcel and collection point *j* and from the collection point *j* to processing plant *m*; finally the two costs are summed together (see fig. 3). The farmgate price will be calculated with a market and a cooperative solution in order to compare the profit share and inform policy maker about their decision in regional planning. In the market approach, farmers and processors are two agents that operate independently and the farmer's price is given by market. In the cooperative approach, the farmer's compensation is obtained with the final revenue of the processed product minus production, processing and transport costs. The allocation of farmer crop to processing plant is solved with a simulation algorithm based on the minimization of marginal cost between the two processing plants that are equally accessible to producers.

C. The assignement problem

The assignment problem consists in determining the least cost of delivery mais crop in the region FVG produced in a parcel and delivered to one of the 53 CP and from CP to one of the two Pl assumed both with fixed capacity equal to 200 thousand tons, same technology but located at different distances from the CP. It is an iterative routine that exclude at each run the less efficient locations and allocate the product to the selected CP scattered in the region.

Definition:

- CC = {pre-defined network of 53 collection points in Friuli Venezia Giulia region};
- CD = {collection points deliverying to the processing plant 2 (CD-Cereal Docks)};
- SG = {collection points deliverying to the processing plant 1 (SG-San Giorgio)}.

Hypothesis: $CD \cup SG = CC$.

Assumption:
q_i = *quantity of feedstock available at the ith collection point*

$$d_{CDi} = \begin{cases} \text{distance of the } ith \text{ - collection point from the processing plant Cerea Docs} & \text{if } i \in CD \\ 0 & \text{otherwise} \end{cases}$$

$$d_{SGi} = \begin{cases} \text{distance of the } ith \text{ - collection point from the processing plant San Giorgio} & \text{if } i \in SG \\ 0 & \text{otherwise} \end{cases}$$

the total delivery distance of the 53 CP from processing points is:

$$d_{TOT} = \sum_{i=1}^{53} d_{CDi} + \sum_{i=1}^{53} d_{SGi} \quad \text{(total delivery distance)}$$

D. Description of the allocative algorithm

1- Assume $CD = CC$ (inizialize the procedure by asssuming that the all CP deliver to processing plant 2 (Cereal Docks) and compute d_{TOT};

2- For each CP deliverying to processing plant 2 it is associated the value $d_{TOTi} = d_{TOT} - d_{CDi} + d_{SGi}$ (actually it is assumed that the ith collection point delivers to the plant 1 and it is computed the inherent variation d_{TOT});

3- The collection point corresponding to the minimum d_{TOTi} is associated to the PP1 (*SG)*;

4- If the sum of the feedstock quantities delivered by each of the collection points that deliver to PP1 is greater than the processing capacity of the plant 1, the last CP will be associated to the PP2 , otherwise we return to step 2 and impose $d_{TOT} = d_{TOTi}$ minimum.

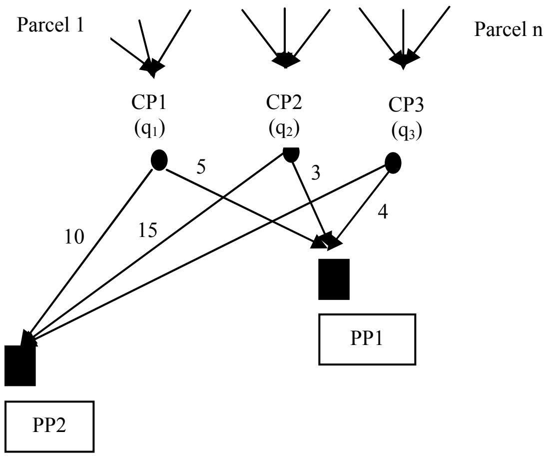
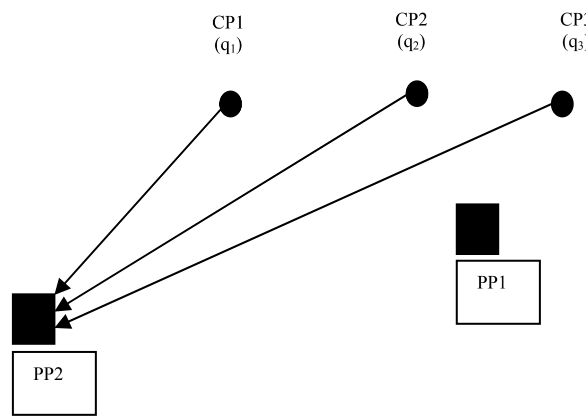


Fig .5- Description of the regional basin in FVG region

Description of the algorithm for the allocation of the feedstock to processing plant

Step 1 - *CD = {CP1, CP2, CP3} e SG = {*$\varnothing$*}*

d_{TOT} = 10 + 15 + 20 + 0 + 0 + 0 = 45 (max value)



Step 2 - search for minimum distance

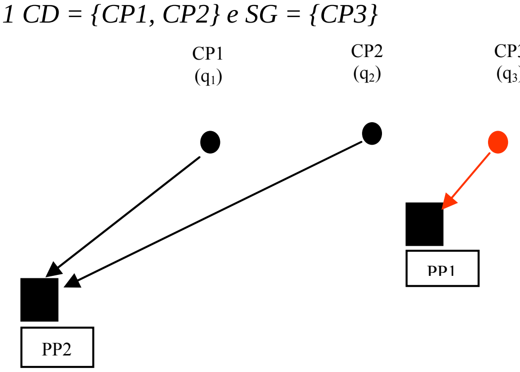
Substitute. CP1 $d_{TOT1} = d_{TOT} - d_{CD1} + d_{SG1}$ = 45 – 10 + 5 = 40

Substitute. CP2 $d_{TOT2} = d_{TOT} - d_{CD2} + d_{SG2}$ = 45 –15+ 3 = 33

Substitute. CP3 $d_{TOT3} = d_{TOT} - d_{CD3} + d_{SG3}$ = 45 –20+ 4 = 29

Step 3 – CP assignement

3.1 CD = {CP1, CP2} e SG = {CP3}



Step 4 – control delivery

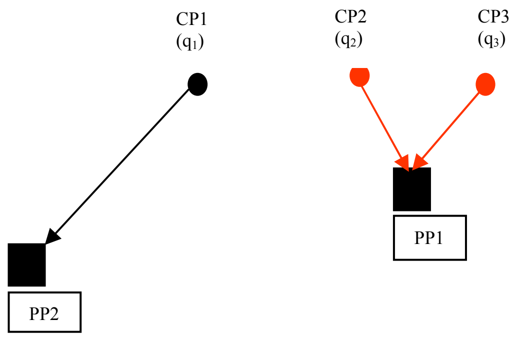
4.1- If $q_3 > Pl1_{capacity} \Rightarrow$ *CD = {CP1, CP2, CP3} e SG = {∅ }* Exit

Else $d_{TOT} = d_{TOT3} = 29$ *goto 2*

2.2- $d_{TOT1} = d_{TOT} - d_{CD1} + d_{SG1} = 29 - 10 + 5 = 24$

$d_{TOT2} = d_{TOT} - d_{CD2} + d_{SG2} = 29 - 15 + 3 = 17$

3.2- *CD = {CP1 } e SG = { CP3, CP2 }*

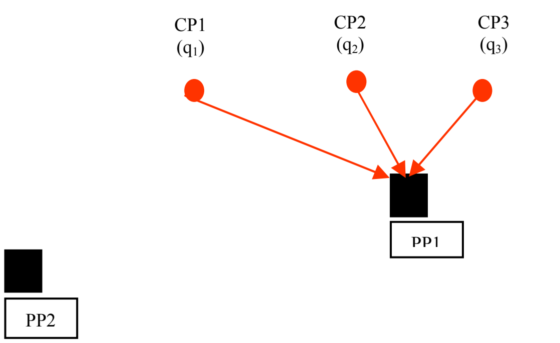


4.2- If $q_3 + q_2 > P1_{capacity} \Rightarrow$ *CD = {CP1, CP2} e SG = {CP3}* Exit

Else $d_{TOT} = d_{TOT2} = 17$

2.3- $d_{TOT1} = d_{TOT} - d_{CD1} + d_{SG1} = 17 - 10 + 5 = 12$

3.3- *CD = {∅ } e SG = { CP3, CP2, CP1 }*



4.3- If $q_3 + q_2 + q_1 > P1_{capacity} \Rightarrow$ *CD = {CP1 } e SG = {CP3, CP2 }* Exit

Else $d_{TOT} = d_{TOT1} = 12$ Exit

E. 8 - The optimization problem

The optimization is based on the profit equation that is the difference between the revenue at the final processed crop step minus the chain costs (production, transport, storage, conditioning and processing). Processing plants are evaluated on the basis of available information on commercial production technologies and the average cost functions of farm and processing plants are fitted using data from INEA-RICA and bibliographic source.

The profit equation is the following:

F.O Max m Σi Σj Σk Σm uk*ck*xijkm*pk –uk*xijkm* cgik – uk*xijkm* ctc*dij - uk*xijkm* ctm djm - uk*xijkm*cpj - uk*xijkm* cpm - ukck*xijkm*ce*dmn (1)

where

- x_{ijkm} is the variables representing the size of the parcel i.th measured in hectare (ha), owned by a farm, cultivated with crop k.th;
- u_k is the annual yield of the k.th crop, in dry ton/ha. The crop yield are simulated using agro-climatic models elaborated with data of 13 regional meteo stations that produced 140 climatic areas (Danuso, 2010);
- u_k*x_{ijkm} is the production of crop k.th obtained from parcel i.th, hauled from farm i.th (i = 1..18000), to collection point j.th (j = 1..53), and from collection point j.th to processing plants m.th (m = 1..2, see fig. 2);
- c_k is the conversion coefficient of agricultural crop into final processed product;
- p_k is the final price of processed crop k;
- c_{gik} is the annual unit cost, in €/ton, for growing crop k, in parcel i using a technology g;

The production costs will depend on type of crop, parcel (quality, position, form), climate, technology used;

- c_{tc} is the road transportation cost by tractor in €/dry ton/km for hauling one ton of crop from parcel i to CP j, including harvest, loading/unloading. return trip;
- c_{tm} is the transport cost by truck in €/dry ton/km for hauling one unit of crop from CPj to Plm;
- c_e is the unit cost for transport liquid ethanol to the pump;
- c_{pj} is the conditioning cost of the collection point j;
- c_{pm} is the cost of processing plant m; it is assumed the two plants are equal in size and technology so the scale economies are not considered in the optimization.
- c_{dm} is the transport cost from plant m to pump n;
- d_{ij} for j = 1..53 is the distance from parcel i to CP j;
- d_{jm} is the distance from collection plant j to processing plant m;

- d_{mn} is the distance from processing plant to the pump (for simplicity the pump is one so n = 1)

Production costs are calculated for each crop by using data from ERSA and other sources RICA-INEA and calibrated according with agronomic, climatic conditions and technology used. All costs are explicits assuming the farm operations are performed by an external company and paid in cash.

The constraints of the objective function are the following:

$$\Sigma j\ \Sigma k\ x_{ijkm} \leq Si \quad \forall I \tag{2}$$

$$x_{ijkm} \geq 0 \tag{3}$$

It imposes that the sum of all parcels'areas Xjik, must be less/equal to the total available land Si (in ha), values of parcels must be not negative. The processing plants accessible are two; the allocative problem consists in choosing the most convenient path to deliver the crop supply to a given plant. The problem can be split in two parts: the first one is optimization of land assignment to crops, with location/allocation problem; the second is the optimization with profit maximization.

Land availability and assignment to crop

The previous objective function (1) is rewritten by collecting the common term (u_k*x_{ijkm}):

$$\text{F.O Max m } \Sigma i\ \Sigma j\ \Sigma k\ \Sigma m\ (u_k{*}x_{ijkm}){*}\ c_k{*}p_k - c_{gik} - c_{tc}{*}d_{ij} - c_{tm}\ d_{jm} - c_{pj} - {*}\ c_{pm} - c_k{*}c_e{*}d_{mn}$$

The objective function is maximized by setting the highest possible value of net revenue per unit product:

p_k*$c_k - c_{gk}$

If this value is negative, the problem has not a feasible solution, if not the process continue with the search the value of x_{ijkm} that satisfy the constraint (2). For each parcel i, there is only one value of k if the land parcel is invested in a monoculture; otherwise the parcel is used for different crops; in the first case the surface invested is a % of the total determined on the basis of oppotunistic evaluation related to farm management because most of the farms use maize silage as the main crop for milk production and maize for other uses is a residual part.

When parcel is used for different crops, the decision to cultivate maize crop is dictated by economic (net revenue) and agronomic options (rotation, monoculture, set-aside). Every step of simulation will generate information about land use for maize crop, allocation to CP and Pl, and profit redistribution among partners. Two types of chain organization have been hypothesizised the one is the free market solution where the producers and other partners of the chain act indipendently, the other one is the cooperative solution that assumes the farmers manage the subsequent stages of the chain. By varying the market price of the final product it is estimated the supply reaction and the profit redistribution within the two types of organizations; the results will be usefull to evaluate the economic convenience of different chain organization.

IV. CASE STUDY: THE MAIZE SUPPLY CHAIN: LOCATION/ALLOCATION IN THE FRIULI V.G. REGION

This case study is developed for the Friuli V.G., a region located in the North East part of Italy where the integration of agriculture and food industry offers excellent examples of food supply chain in wine, meat and dairy sectors. The total arable land is 224.521 ha, the surface dedicated to cereals is 117.339 ha, the surface invested in Maize in 2008 was 85 thousand ha and declined to 68 thousand in 2009. To assess suitable land for crops cultivation, the following spatial data are gathered from digitized regional cartography: Moland with pedological (1:250.000), phytoclimatic (1:500.000) and land use (1:25.000) cartographies (ERSA).

Suitable area for crops is the land satisfying one or more of the following parameters:

- altitude above sea level: below than 100 m;
- maximum slope: less than 10%;
- soil containing rocks, gravels, pebbles less than 5 centimeters;
- thin upper layer: not deep enough for root development;
- soil: excluding those with pH lower than 5,0 or higher than 7,5;
- average annual rainfall at least 700 mm/year and average temperature between 10 °C and 15 °C;
- protected natural areas, permanent prairies and public property areas are excluded.

Land suitable for crops accounts for a smaller portion of the total land available which fits the requirements for crop production. In the following table the land use data are reported; they indicate that the area dedicated to cereals is the 52%, industrial crops are the 13,4%, horticulture represents the 0,5%, perennial crops are the 11,2%.

Tab 4 - The agricultural land in FVG region. Source: Rica-Inea (2008)

Product	Surface (ha)	%
Annual crops:	172.396,58	76,80
Cereals	117.339,30	52,30
Industrial crops	30.162,36	13,40
Horticulture and potatoes	1.182,19	0,50
Forage crop	14.214,07	6,30
Other crops	79,16	0,00
Set aside	9.419,51	4,20
Of which Public property	204,57	0,10
Perennial crops:	25.243,41	11,20
Viticulture	19.333,48	8,60
Olives	238,49	0,10
Orchards	2.904,08	1,30
Other	2.766,33	1,20
Of which Public property	28,78	0,00
Permanent prairies and pasture	26.881,00	12,00
Of which Public property	6.341,69	2,80
Total (Excluding Public property)	217.944,92	97,10
Public property	6.576,08	2,90
Total	224.521,00	100,00

For the purpose of this study the crop selected is Maize used to produce ethanol because of a political interest in this product related to a regional planning; however, this approach can be extended to any other crop for which information is available. The data base provided by Insiel indicate that the land dedicated to the agrifood chain, is less than the cultivated land in the region because a consistent quota doesn't accomplish with the parameters above and the use of maize in dairy farms. The available surface for maize is approximately 118 thousand ha.

The first part of the analysis is the allocation problem to find the shortest distance from parcel to the corresponding CP and from CP to Pl. The crop delivery from CP to one of the processing plants is a decision to be evaluated by considering the different competitive conditions of the two plants situated at different average distance from CP.

The transportation distances to processing plant 1 or 2 are consistently different; if the two plants would have the same size and use the same processing technology the solution based on transport cost minimization will privilege the plant situated at minimum distance from the CP; in this case the collection points have a cost advantage to haul their product to plant 1; instead the optimization is based on the difference of the distance of a CP from the two procesing plants that allow the cohexistence of these two processing plants with the crop supply.

However the computation will show that the transport cost are only a smal quota of the total costs and the difference between Pl1 and Pl2, very limited can be compensated by the processing plant with higher transport cost because the economic advantage of exploiting the plant capacity compensate the cost difference paid to farmers.

V. RESULTS

The allocation is solved first by dividing the region in two basins one having the processing plant CD and the other SG, then assigning the parcels to one of the 53 collection points and connectiong the CP to the Pl. The quantity delivered is almost equivalent for the two basins, the difference is due to the fact that the CP can deliver to only one of the two Pl. The average distances between parcel and CP of the two basins are not greatly different, but the transport costs from CP to Pl are different and this will affect the farmers' decisions.

The results about quality allocation to processing plant 1 or 2 are reported in table 5 and 6

Tab 5 - Maize crop simulation: assignement of crop Maize to collection point and processing plant 1 (Cereal Docks)

Basin 1 = Cereal Docks					
Collection points (nr)	**Nr Parcels per CP (nr)**	**Total SAU parcels [ha]**	**Average distance [Km]**	**Yield per ha ton ss/ha**	**Quantity delivered ton ss**
1	10.417	4.257	4,00	7,49	3.188,7
2	2.395	1.156	3,06	7,74	894,6
3	4.573	2.211	3,05	6,91	1.527,9
5	6.500	2.555	4,03	7,46	1.905
7	3.866	2.535	4,02	8,21	2.081,4
8	7.391	3.123	3,02	7,62	2.380,5
9	5.786	3.964	4,07	7,36	2.916,9
10	3.901	2875	3,05	8,10	2.328,6
11	11.300	4.923	8,00	6,41	3.157,2
12	1.274	833	2,02	5,79	482,1
13	2.477	1.573	4,01	6,77	1.064,7
14	4.571	2.155	3,08	7,14	1.538,7
15	1.621	1.292	3,08	6,94	896,1
16	7.273	4.029	5,06	8,15	3.284,1
19	8.124	3.524	5,02	8,23	2.901,6
20	4.121	3.760	4,07	8,07	3.036
22	151	52	3,08	7,67	39,9
23	9.039	6.016	8,07	7,20	4.329,6
31	6.612	3.387	4,01	7,79	2.637,6
35	5.228	2.900	4,09	8,46	2.453,4
36	11.450	6.164	6,00	6,33	3.902,4
37	7.345	2.974	4,03	7,76	2.307,3
38	5.206	2.642	6,00	6,79	1.795,2
39	4.889	3.123	5,02	6,87	2.145,9
50	9.254	4.646	9,06	6,71	3.115,5
51	5.314	4.491	6,08	6,15	2.760
52	6.189	1.956	5,08	7,30	1.427,1
53	6.225	2840	4,09	7,21	2.047,5

Total	85956	4,34	7.23	62.545,5

Tab 6 - Maize crop simulation: assignement of crop Maize to collection point and processing plant 1 (San Giorgio)

Basin 2 = San Giorgio					
Collection points (nr)	**Nr Parcels per CP (nr)**	**Total SAU parcels [ha]**	**Average distance [Km]**	**Yield per ha ton ss/ha**	**Quantity delivered ton ss**
4	4.095	1.548	3,07	7,88	1.219,8
6	1.910	1.195	3,01	8,19	978,6
17	2.680	2.135	4,01	7,66	1.635,3
18	6.840	2.621	3,07	7,94	2.081,4
21	4.655	2.187	3,04	7,72	1.687,8
24	5.494	2.553	4,02	8,23	2.102,1
25	4.061	6.396	5,02	7,37	4.713,6
26	3.470	3.353	5,01	7,99	2.680,2
27	3.734	2.571	5,01	7,47	1.919,4
28	19.751	8.110	10,00	7,84	6.356,1
29	7.213	3.088	3,05	8,25	2.547,3
30	10.971	5.600	6,01	7,38	4.132,5
32	6.527	2.570	3,05	8,54	2.194,8
33	6.066	5.614	4,03	6,98	3.919,5
34	3.217	4.338	6,05	7,17	3.109,5
40	7.912	3.619	4,02	8,02	2901
41	4.938	3.308	4,02	8,17	2.702,1
42	3.717	2.166	4,05	8,17	1.769,4
43	1.573	1.665	3,04	7,75	1.290,3
44	813	699	1,06	7,88	550,5
45	5.100	2.418	3,05	7,99	1.931,7
46	8.248	3.854	5,04	8,26	3.182,4
47	3.634	1.416	3,05	8,06	1.140,6
48	3.609	1.630	4,07	7,87	1.282,8
49	2.459	678	7,03	7,85	532,5
Total		75.332	4,15	7,86	58,561,2

The optimal allocation is complicated by the configuration of the road network requiring to solve decisional problems as: search the minimum distance compatible with traffic intensity, urban areas, intersections; bridges and other obstacles; hence distances are calibrated with the time requested to complete the pattern.

Sorting and grouping the CP reported in table 7 by distance, we have more detailed information about the size of the supply basin. For 31 CP the average distance between parcel and CP varied in the range between 3 and 6 kilometers; (more than the 50% of the parcels); for the remaining 22 CP the distance varied between 5 and 9 km.

The average size of the parcel is 0,5 ha value whatever is the distance parcel – CP, there are no significant differences in production technologies giving economic advantage depending on the parcel size, but farmers could select different technologies depending on local climate and agronomic conditions. There are no evidences of scale economies in production or transport hence the delivery costs vary linearly with the distance and there is no convenience for a parcel to switch from a CP to another because they are assigned on the basis of the minimum distance.

Tab 7 – CP sorted by distance

Collection distance	points (nr)	Parcels per DP (nr)	Total SAU parcel (ha)	Average distance (Km)	Quantity delivered (ton ss)	Yield (ton ss/ha)	Cost of production (€120/ton)	Cost of delivery at CP(€)	Total cost prod + del (€)	UC-CP + prod + del (€/ton*km)
2-2,99	3	12.859	6.009	2,80	15.396	7,74	153.960	38.489	192.449	17,00
3-3,99	17	88.974	48.659	3,56	125.528	7,79	1.255.280	314.246	1.569.526	18,91
4-4,99	14	67.346	35.754	4,29	90.967	7,65	909.670	227.820	1.137.490	20,73
5-5,99	8	39.082	23.598	5,35	58.854	7,59	588.540	148.512	737.052	23,50
6-6,99	4	22.545	12.516	6,25	29.524	7,03	295.240	74.327	369.567	25,73
7-7,99	5	49.856	25.491	7,48	62.531	7,22	625.310	160.945	786.255	29,25
8-8,99	2	14.517	9.261	8,60	20.889	6,79	208.890	52.929	261.819	31,79
	53	295.179	161.288	5,47	403.689	7,40	4.036.890	1.017.268	5.054.158	na

A. Sensitive analysis

The supply curve of corn crop over a range of prices is simulated by using the response of production to cost changes. The estimated relation net revenue-quantity allows to find the optimal intensification of land use corresponding to the maximum net revenue (NR).

In table 8 are reported the NR for farmers and processors that in this organization solution are considered independent agents. The effect of final price changes is calculated for a ton equivalent of crop at different level of crop intensification. Two final prices are considered the first one is close to the breack even point, the second one is close to the present market price of an equivalent fuel. The solutions obtained are non linear, cost function is concave according with the variable return to scale and is estimated using data from regional INEA-RICA observatory (for farm cost accounts) and from literature (for processing costs). With the independent market solution, farmers receive a fixed price that could be determined independently from the market price when is used an interprofessioal agreement between partners. The net revenues of farms and processing plants reported in figure 5 suggest the following considerations:

- net revenues tend to grow with the intensification of production for farmers and processors with different speeds reflecting the respective production costs.
- Farmers: the fixed price has been settled at 190 €/ton and corresponds to the present corn market showing a

recovery after a period of depression that followed the speculative bubble of 2006-2008.

- The net revenues are different fo the two basins: beside more distants the farmers deliverying to CD obtained a higher net revenues that increase with the intensification at 20% and then started to decline; the farmers deliveryng to SG.
- Farm net revenues are slowly growing for CD; the maximum is reached at 20% intensity and for SG the maximum is achieved at 42% intensity level.

Processing plants net revenues are estimated for the two Pl with two final proces and different levels of crop intensity.

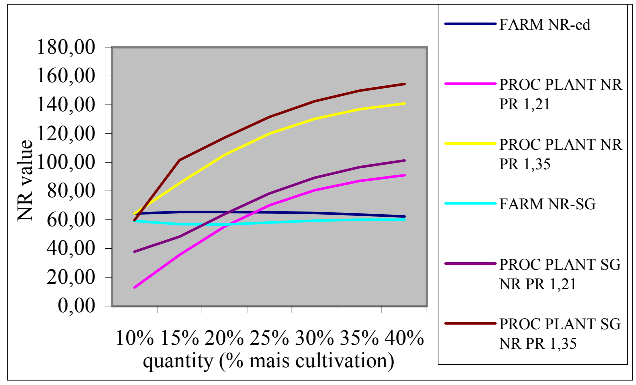
With final price equal to 1,21 the net revenues are less than the farm ones at early stage of crop intensification and they rapidly grow to reach the maximum over the 40% crop intensity.

Tab 8 - Net revenue per ton obtained with price simulation at the pump

Processing plant	Quantity %	Farmer** €/ton	Pump price 1,21 Process. plant €/380 liter*	Pump price 1,35 Process. plant €/380 liter*
CD	10%	64,32	12,93	64,32
SG		59,11	37,74	59,69
CD	15%	65,43	35,55	85,37
SG		57,07	48,33	101,53
CD	20%	65,45	55,17	104,98
SG		56,80	63,78	116,98
CD	25%	65,27	70,18	119,99
SG		58,07	78,22	131,42
CD	30%	64,68	80,45	130,26
SG		59,34	89,14	142,34
CD	35%	63,65	87,00	136,81
SG		60,02	96,57	149,77
CD	40%	62,30	90,94	140,75
SG		60,07	101,28	154,48

* quantity equivalent to 1 ton of mais crop
** profit doesn't change with market price

Fig 5 – Net revenues for different chain agreements and market prices



VI. CONCLUSIONS

The strategic planning of regional agri-food supply chain may offers significant advantages in enhancing the role of local production system in the economic developmnet: the first one is to increase profits by elimitating the inefficiencies due to transaction costs and imperfect transmissions and covering the risk by subscribing production contract.

The second is to favour the specialization of the food district in typical regional crops valorised with "ad hoc" marketing strategies. The third one is the solution of logistic problems by exploting the local network for hauling the production to the most convenient processing plant. The two main problems discussed in this work are the production and logistic problems of the agri-food chain using information coming from integrated data base.

The regional bureau supplies information as GIS, soil maps, cadastre maps, climate assembled to simulate with higher precision the events affecting the crop system, to predict the quantity and quality of the crop produced and plan the transport to CP or Pl. The crop simulation is performed at the parcel level by using different production technologies according with the local agronomic and climatic conditions. The logistic problems of transport are divided in two parts: delivery costs from parcel to one of the 53 predefined collection point (CP) and delivery cost from CP to one of the two predefined processing plants.

The first problem is solved by following the minimum distance approach refined with the definition of the road network to optimize the combination of different types of roads, traffic conditions and others. Results reported in table 5, 6 and 7 suggest the dimension of the CP by estimating the following parameters: average distance between parcel and CP, number of parcels, quantity of product delivered; the most important result was the predominant size of the CP mesured with the average distance varying in the range between 3 and 5 km.

The selection of the most convenient processing plant is based on the assumption that the crop supply is enough to feed both processing plants then the strategy consists in saturating the first plant capacity with the crop supply delivered by the most efficient CP evaluated in terms of cost distance and the residual crop is allocated to the second processing plant. With this solution it is possible to evalute the delivery costs and the efficiency in terms of saving delivery cost by comparing plant 1 and 2.

Three are the possible solution to absorb this cost:

1. the cost difference is beared by a public organization which interest is to create the best condition of functioning for the supply chain and the presence of local processing facililities will increase the demand for agricultural crops.
2. the cooperative opportunity: farmers involved in the processing operations, will receive an amount corresponding to the loss in delivery cost but the margin is variable because depends on the balance results.
3. the last solution is to increase the unexploited capacity of the more distant processing plant for decreasing the average cost to compensate the transport cost. In this case it is important for the plant 2 to be able to attract more crop to be competitive with the firt one.

This work has demonstrated the possibility to use a complex informative system to afford the problem of regional planning the agrofood supply chain by simultaneously considering production and processing operations. Some problems remain still open to further investigation: 1) the economy of the agri-food chain can be afforded with different organization models such as free market, coopearative or hybrid with public intervention, not discussed in this paper; 2) the LCA and particularly the energy consumption must be considered because it is another method to afford the efficiency of the regional production basin measured with the distance ; 3) the crop planning must be afforded by allowing different crops to be cultivated on the same parcel, constrained with the rotation or set aside.

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