INTEGRATING GEO-REFERENCED MULTISCALE AND MULTIDISCIPLINARY DATA FOR THE MANAGEMENT OF BIODIVERSITY IN LIVESTOCK GENETIC RESOURCES

AN INTEGRATED SUSTAINABILITY INDEX FOR THE GEO-MONITORING OF THE SWISS BROWN ORIGINAL LOCAL SOCIO-ECONOMIC, SOCIO-DEMOGRAPHIC AND ENVIRONMENTAL CONTEXT

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OUTLINE

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  - Why do we need to integrate data in livestock conservation ?
  - What is expected from data integration ?
  - Integrative function of geographic information
  - State of the art
- GLOBALDIV in Switzerland: a case study
  - Selection of variables
  - Multi-criteria analysis: method based on satisfaction thresholds
  - Thresholds determination
- Results
  - Thematic maps of selected criteria
  - Sustainability index
- Conclusions

GLOBALDIV WP 5: tasks

- Reviewing methods for the prioritization of breeds for conservation and on **integration of data from different sources** to accomplish this task. Particular attention will be given to the use of geographical information for complex spatial data representation, mining and analysis
- Reviewing the potential of methods based on geographic information (GI) in the integrated analysis, representation and communication of data of different types and from different disciplines (e.g. genetics, socio-economics, climatic, etc.) placing them in a spatial framework, to draw a complete picture of diversity in the context where it is to be conserved

WHY DO WE NEED TO INTEGRATE DATA IN LIVESTOCK CONSERVATION ?

- Management and conservation of livestock genetic resources imply breed prioritization, and therefore decision making
- Decision making rests on the simultaneous analysis of several criteria to be taken into account…
- … in order to identify and to favour sustainable breeding conditions

MULTIDISCIPLINARY DATA TO BE INTEGRATED

Main data categories (or criteria) are:

1. Population and evolutionary genetics
2. Animal husbandry practices
3. Socio-economic and socio-demographic data in the regions where animals are bred
4. Environmental information: climatic and geophysical characteristics of the places where animals are bred
5. Political and administrative boundaries: geographical units where policies have to be applied

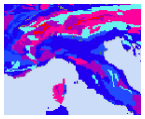
WHAT IS EXPECTED FROM DATA INTEGRATION ?

- These different categories of data must be compared in order to:
  a. identify hidden relationships
  b. describe specific situations (simultaneousnesses)
  c. identify data combinations conducting to specific effects
  d. calculate synthetic indicators (economic values, extinction probability, etc.)
- … to be able to depict complex scenarios and to support decision making for conservation and prioritization of breeds

HOW CAN WE COMPARE THESE DISTINCT THEMATIC COMPONENTS ?

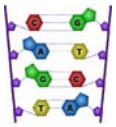
Administrative boundaries
Socio-Economic data
Socio-demographic data

Environmental data:
topography, climate,
soil, etc.



Geographic coordinates
X, Y

GEODATABASE



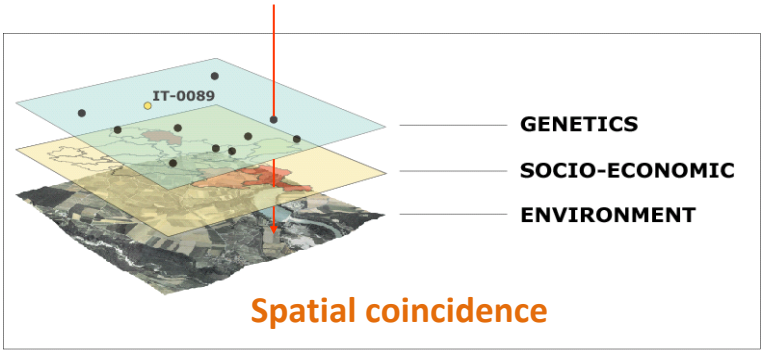
Sampling
Genetic data

GIS

Questionnaires
Husbandry pratices

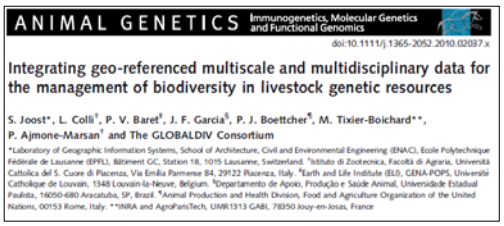
THE INTEGRATIVE FUNCTION OF GEOGRAPHIC INFORMATION

- Geographic data is key to permit the integration of the different categories of information within a GIS
- Geographic coordinates (X for longitude and Y for latitude) constitute additional variables in the data sets able to interconnect the different thematic databases



STATE OF THE ART

- A variety of studies implementing GIS approaches for the integration of different categories of data and specifically applied to livestock sector were reviewed in the context of the GLOBALDIV project (Joost et al. 2010)
- Applications to topics including
  - biodiversity conservation
  - livestock impact on the environment
  - landscape and pasture management
  - behavior and welfare
  - disease control
  - rural economy and development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Integrating geo-referenced multiscale and multidisciplinary data for the management of biodiversity in livestock genetic resources

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- The application of GIS to livestock sector accelerated during the last 10 years, but remains marginal

GLOBALDIV in Switzerland

- The task of GLOBALDIV WPs is to review studies, methods, strategies, etc.
  No research
- Exception with Switzerland because AGRI GEN RES does not belong to a framework programme, Swiss partners not funded by the EC
- The Swiss Federal Office for Agriculture (FOAG) funds Swiss partners
- Condition: implement GIS and the data integration concept in the context of a case study dedicated to the Original Brown Swiss (OBS)
- **Goal**: **assess the sustainability of OBS husbandry in Switzerland**

→ To be considered as a «prototype study» or « feasibility study » to test a given approach

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OBS unique genetic pool

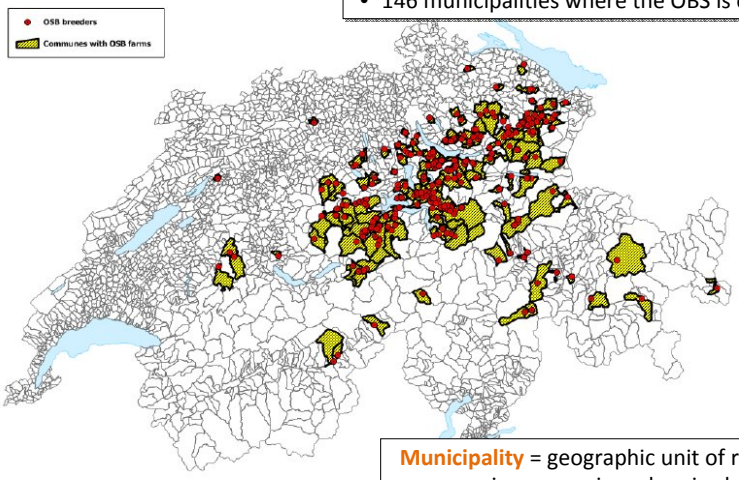
- OBS is under supervision in Switzerland. Important breed to watch over because it owns an internationally valuable genetic inheritance
- There is a high probability that several genotypes of OBS are unique and were never exported out of Switzerland
- It is then very important for Switzerland to conserve and to increase the value of this unique genetic pool

Method and main objective

- We need a multidisciplinary approach to integrate different types of information (social, economic, demographic and environmental) in a GIS to assess the sustainability of OBS husbandries in Switzerland
- **Additive multicriteria aggregation method** (Joerin 2009; Munda&Nardo 2003) to create a sustainability index characterizing municipalities where the OBS is bred
- **Objective**: highlight regions of Switzerland where the most sustainable conditions are met to favour breeding activities

Spatial distribution of OBS across Switzerland

- Analysis at the communal level (2727 communes)
- 146 municipalities where the OBS is currently bred



Red = location of OBS farms
Yellow = corresponding munipalities

Municipality = geographic unit of reference, many socio-economic and socio-demographic variables available (Federal Statistical Office (BFS))

Selection of relevant variables

- Once the reference geographic unit is chosen, relevant variables have to be selected
- Participatory approach: relevant variables have to be selected by experts (people from breeder associations, governmental agencies, scientists)
- No time to implement the participatory approach into this "prototype study". "Within-Lab" participatory approach to select relevant criteria…
- We selected 7 variables (criteria) to characterize municipalities:
    - Demographic balance (1980-2005)
    - Median available income (2005)
    - Unemployment rate (2005)
    - Proportion of farmers (2005)
    - Number of hectares with cattle breeding activities (2000)
    - Proportion of grazing surface (1997)
    - Evolution of the number of jobs in agriculture (2001-2005)

Testing independance of selected variables

- Correlation matrix among the 7 variables, computed for the 2727 Swiss communes
- Selected criteria show a satisfying level of independence
- Useful non-redundant information
- We observe positive correlations (max = 0.2) among socio-economic variables
- Idem among "rural-oriented" variables (max = 0.47)
- Negative correlations among these 2 sets of variables

	Demogr_bal	Med_avail_inc	Unempl_rate	Prop_farm	Hect_br_act	Prop_graz_surf	Evol_job_agric
Demogr_bal	1.00	0.20	0.14	-0.21	0.10	-0.06	0.07
Med_avail_inc		1.00	0.14	-0.22	-0.09	-0.24	-0.04
Unempl_rate			1.00	-0.37	-0.15	-0.30	-0.07
Prop_farm				1.00	0.06	0.25	0.02
Hect_br_act					1.00	0.47	0.34
Prop_graz_surf						1.00	0.16
Evol_job_agric							1.00

Table 1: Correlation matrix for the 7 variables chosen for the multi-criteria analysis.

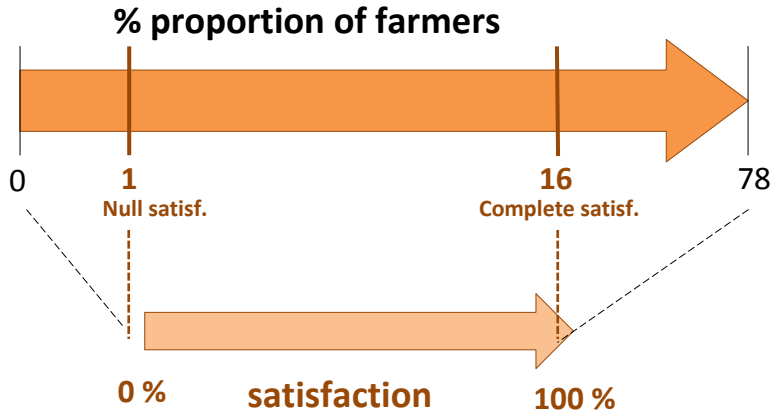
Satisfaction thresholds

- On the basis of the 7 selected variables (or criteria), we need to build a composite multi-criteria index
- We need to define 2 thresholds for each criterion: for which value of the criterion experts deem that we reach…
  - i) complete satisfaction ? (= 1 → 100% satisfaction)
  - ii) no satisfaction at all ? (= 0 → 0% satisfaction)
- Scale the range of values of selected criteria between 0 and 1
- Bound to 0 or 1 scores exceeding the thresholds to obtain a % of satisfaction (satisfaction score) on criteria *j*
- → attenuation of extreme values since we cut the tails of the distributions
- Calculation of a weighted sum (with weights w_j) of the J satisfaction scores s_j
- We obtain a global satisfaction index S (a percentage of satisfaction)

$$S = \sum_{j=1}^{J} s_j \cdot w_j$$

Example with the proportion of farmers per municipality

- Values of the variable range from 0 to 78%
- Complete satisfaction was set to 16% by experts
- No satisfaction at all set to 1% by experts
- Satisfaction ranges from 0 to 100%, between 1 and 16% of farmers per commune



Thresholds determination

- They should be defined and fine-tuned together with experts (participatory approach)
- The data range between null (0%) and complete satisfaction represents the same satisfaction variation for all criteria used (% of satisfaction is comparable between the different criteria)
- For instance, a population increase of 700 people equals an increase of 10'000 CHF of available income

	Demogr. bal. (sum total)	Median avail. income (in 1000 CHF)	Unempl. rate (in %)	Prop. of farmers (in %)	Nr. of hect. with cattle breeding act. (sum total)	Prop. of grazing surface (in %)	Evol. nr. of jobs in agric. (full-time equiva-lents)	
Min	0	20	2.1	1	3	6	0	S=0%
Max	+700	30	0.7	16	16	30	+10	S=100%

Thresholds corresponding to null and complete satisfaction levels for the 7 variables used

Calculation of the multicriteria index: **ranking**

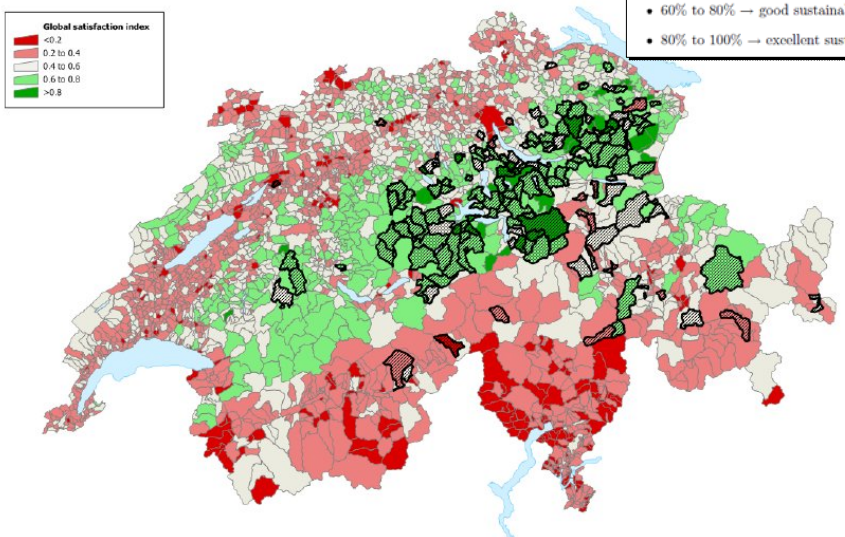
- Calculation of the sum of the scaled scores (satisfaction levels) over the 7 criteria…
- … to get a sustainability index (global satisfaction level) for each commune, ranging from 0% to 100% (satisfaction percentage)
- **Ranking** on these scores
- Optional **weighting** of criteria: here the weight is the same for each variable [1/7] but it can be adapted by experts if necessary

Scores in the 7 socio-economic/demographic variables and sustainability index for the 146 Swiss communes breeding OBS cattle (sorted by sustainability index values).

Commune	Sustainability index	Demogr. bal. (sum total)	Median avail. income (in 1000 CHF)	Unempl. rate (in %)	Prop. of farmers (in %)	Nr. of hect. with cattle breeding act. (sum total)	Prop. of grazing surface (in %)	Evol. nr. of jobs in agric. (full-time equivalents)
Mosnang	0.952	664	28.97	0.415	13.25	128	38.59	29.05
Schönenberg (ZH)	0.874	515	32.58	0.889	8.78	31	36.17	28.81
Steinerberg	0.869	427	25.72	0.781	15.42	32	53.57	27.92
Beinwil (Freiamt)	0.843	264	28.14	0.531	16.07	22	23.00	14.53
Ennetbürgen	0.835	1366	33.59	1.219	4.26	40	36.45	21.26
Schenkon	0.826	1156	33.09	0.903	4.84	17	27.54	7.73
Ennetmoos	0.823	573	25.99	0.960	11.26	40	26.36	15.61
Menzingen	0.822	982	28.42	1.313	6.31	84	36.70	26.60
Oberdorf (NW)	0.822	660	27.60	1.114	8.73	53	36.89	8.31
Schwellbrunn	0.821	335	24.04	0.886	18.13	61	48.98	12.11
Ernetschwil	0.820	629	20.40	0.310	14.30	41	38.80	9.15
St.Peterzell	0.809	401	25.74	1.194	14.06	34	48.92	28.89
Muotathal	0.808	701	25.08	0.599	7.12	82	23.81	24.16
Hütten	0.804	284	24.49	0.814	14.37	24	31.59	9.65
Bürglen (UR)	0.802	519	24.86	0.903	8.98	89	43.03	35.56
Dallenwil	0.798	565	26.70	0.849	6.21	37	46.16	8.69
Kerns	0.797	1091	22.37	0.784	7.08	134	35.91	26.60
Küssnacht (SZ)	0.791	3300	33.93	1.467	2.31	71	36.10	38.10
Grabs	0.789	1594	27.82	1.032	3.35	75	35.40	8.25
Menznau	0.786	614	22.44	0.772	7.52	71	33.25	53.79

Sustainability index obtained

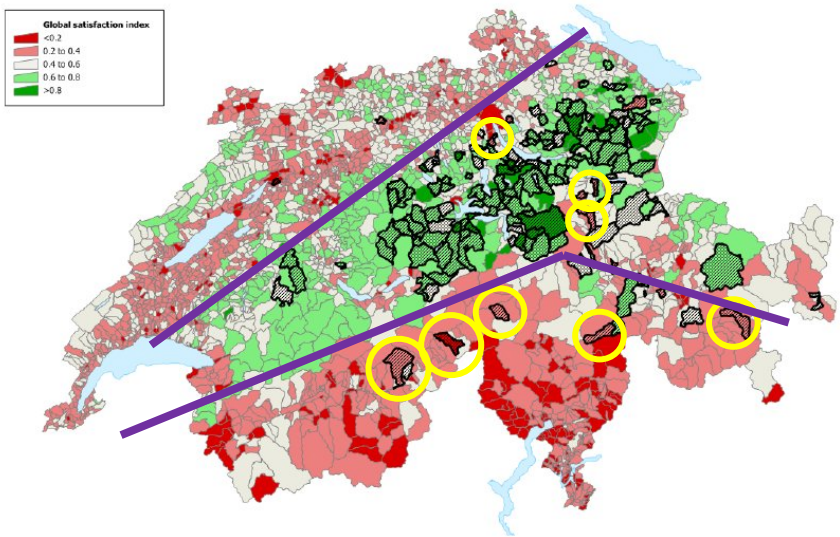
- 0% to 20% → very low sustainability
- 20% to 40% → low sustainability
- 40% to 60% → mean sustainability
- 60% to 80% → good sustainability
- 80% to 100% → excellent sustainability.



Observations

- Low sustainability values (< 40%) in Southern Alps and Plateau (Lausanne-Berne-Olten-Zurich) industrial regions
- High sustainability values (> 60%) in Northern Alps, mid-altitude areas located in a band stretching from Fribourg Prealps to Bodensee
- Very high sustainability values (> 80%) in Central /North-Eastern Switzerland (Cantons of Schwyz, St. Gallen, Appenzell, Luzern, Glaris, etc.)
- Communes currently with OBS show in general good sustainability values (region of origin of the breed)
- But the map permits to highlight a series of municipalities where conditions are not that good, and where detailed controls should be carried out (number of animals, genetic diversity, etc.) → **coupling** with **Early Warning System**

Spatial patterns and locations to check



Digital Elevation Models (25m resolution)

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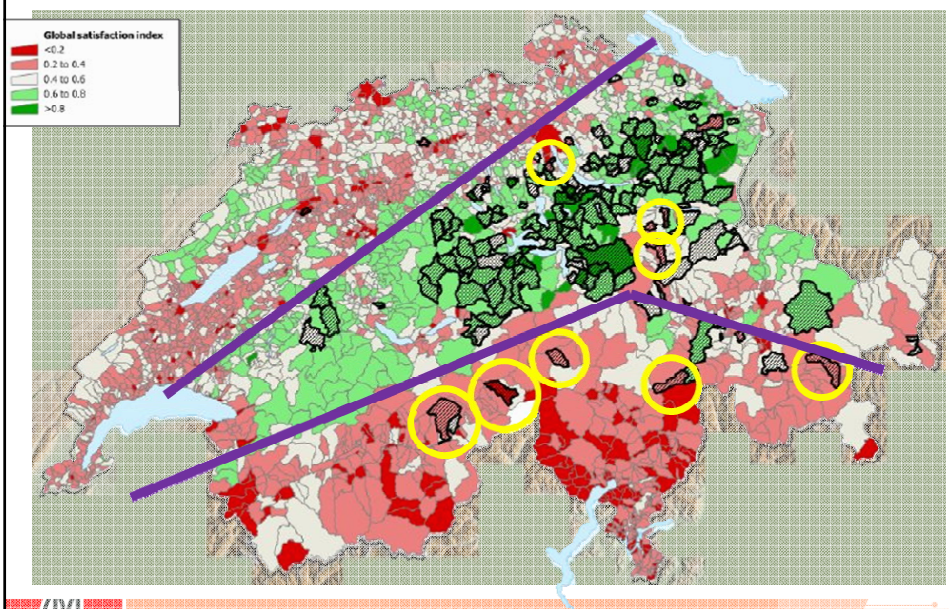

CONCLUSION

- Data integration is a key element to simultaneously analyse different criteria that may contribute to longterm sustainable breeding conditions
- Geographic coordinates constitute universal information shared by any object located on the Earth, easy to record, and permitting data integration
- Data integration is not trivial. There are factors to be taken into account to assure a correct comparability of data (projection system, scale) and to carry out correct statistical analysis (see Joost et al. 2010)
- But data integration is **powerful**. From multidisciplinary data integration and their judicious analysis will emerge new efficient prioritization methods

CONCLUSION (2)

- The **joining** of **GIS** and **multi-criteria analysis** is very interesting to assess the sustainability of local breeding conditions
- The approach requires the **participation** of **experts**:
  - Time consuming, but
  - Permits decisions to be better accepted and implemented
- Helpful diagnostic tool to assess local socio-economic, socio-demographic and environmental conditions where animals are bred
- Partial: **requires coupling with an Early Warning System** (see in particular the UK EWS including geographic criteria, Alderson 2009) in order to compare the sustainability index with demographic and genetic data
- This complementarity will provide robust support for decision-making related to breed prioritization

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