Spatial Decision Support Systems as a Means Towards Sustainable Agriculture ⋆

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Abstract: Sustainable agriculture follows the principles of nature to develop systems for raising crops and livestock that are, like nature, self-sustaining. Sustainable agriculture integrates three main goals: environmental health, economic profitability, and social and economic equity. Achieving those goals requires real-time location based information and services that enhance decision-making. The amount and the complexity of spatial information becoming available are dramatically increasing and so is the demand for tools easing the handling of such information. Therefore, farmers and regional experts in the field mostly rely on new spatial-data-oriented decision making tools. In this paper, we present two examples of such spatial decision support systems that we have implemented. The first and also the most important SDSS is a mashup of maps and tabular information providing an intuitive platform for efficient biomass-planning on the scale of a single production plant. The second SDSS is a collaborative route-planning system for utility vehicles using the geographical information provided by OpenStreetMap to provide adapted routing for heavy and large vehicles (e.g., lorries, tractors…). Finally, we explain how our biomass planner, currently suited for single production plants, can be combined with the collaborative route-planning system for utility vehicles to enable efficient biomass-planning on a larger scale.

Keywords: planning, decision support systems, site-specific production planning, biomass-planning, route-planning, logistic-planning, knowledge management

1. INTRODUCTION

"Sustainable agriculture follows the principles of nature to develop systems for raising crops and livestock that are, like nature, self-sustaining" [Earles (2002)]. "Sustainable agriculture integrates three main goals: environmental health, economic profitability, and social and economic equity" [Feenstra et al. (2005)]. Achieving those goals requires real-time location based information and services that will allow better decision-making. The amount and the complexity of spatial information becoming available are dramatically increasing and so is the demand for tools capable of handling such information. Therefore, farmers and regional experts in the field mostly rely on new spatial-data-oriented decision making tools. The development of such Spatial Decision Support Systems (SDSS) mostly relies on public Geographical Information Systems (GIS) and Global Positioning System together with mobile Internet and sensory driven agricultural engineering. In this paper, we present two examples of such SDSS we have implemented. In section 2, we present the first and also the most important of our SDSS, a mashup of maps and tabular information providing an intuitive platform for efficient biomass-planning on the scale of a single production plant. In section 3, we introduce our second SDSS: A collaborative route-planning system for utility vehicles (CRUV) (Fichter (2009)) using the geographical information provided by OpenStreetMap (OSM) to provide more adapted routing for heavy and large vehicles (e.g., lorries, tractors…). Section 4 presents the results of evaluations for both SDSSs. Finally, in section 5, we explain how our biomass planner, currently suited for single production plants, can be combined with the CRUV efficient biomass-planning on a larger scale. Indeed, experimental research in the field of resource planning, like for example for a biogas plant, shows that most of the costs are related to transport and can only be optimized by relying on efficient route-planning.

2. BIOMASS PLANNER

Our biomass planner is a prototype for a Web-based Spatial Decision Support System (WSDSS) demonstrating the benefits of location based decision making using digitalized geographic information about ground allocation and soil quality. The biomass planner uses an extended version of the Biomas Yield Model (bym) that has been developed at the University of Applied Sciences in Eberswalde [Pior et al. (1999); Brozio et al. (2006)]. The bym has been implemented in the form of a scientific workflow

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⋆ This work has been realized in the IVIP project founded by the State Ministry for Economy, Transportation, Agriculture and Viniculture (MWVLW) and is part of the EU program: "Ziel 2 Programm RLP"

to ensure a flexible and robust software architecture for efficient and timely processing of the spatial information. A scientific workflow is a means of combining data and processes into a configurable, structured set of steps that implement semi-automated, computational solutions of a scientific problem [Ludascher et al. (2006); Taylor et al. (2007)]. We use our own, modified version of the workflow management system Kepler to design the bym as described in Tuot et al. (2008). The biomass planner can compute the yield for sixteen different crops depending on the soil quality and the rainfall levels. Different kinds of scenarios are taken into consideration that are conventional versus ecological farming and three different levels of rainfalls for dry, normal and wet.

2.1 Goals

The aim of the biomass planner is to help a user to decide which crops should be cultivated on which fields in order to maximize the overall biomass production. First, a crop rotation scenario that is a list of fields with associated crop rotations (one crop rotation per field), must be defined using the crop rotation manager and be loaded into the biomass planner. Weather condition scenarios can be defined through three levels of rainfall (dry, normal and wet). The yield can then be computed for this specific crop rotation and weather scenario. The results can be used to further fine-tune the crop rotation plan. Finally, the production plan, containing a detailed prognosis of the yields, can be exported for further process, e.g., in form of a spreadsheet for editing or as map for visualization.

2.2 Prerequisites

FLOrlp is a geographical information system developed by the State Ministry of Economy, Transportation, Agriculture, and Viniculture (MWVLW) in cooperation with the Fraunhofer Institute for Experimental Software Engineering (IESE). FLOrlp grants farmers and administrations online access to the state's geographic and alphanumeric data relevant for the funding process [Steffens and Geißner (2007)]. In terms of biomass-planning, the most relevant part of the information delivered by FLOrlp is the exact geographical coordinates of the field boundaries and the associated percentage of usable area available for cultivation. This information is made available by FLOrlp through the export feature. The resulting file in GML format can be used as input for the biomass planner. Since not all target users have access to the FLOflp system, the biomass planner also supports as input any file in GML format containing the exact geographical coordinates of the field boundaries. Then a default global value for the percentage of usable area for cultivation is used, therefore allowing the system to provide a first approximation for the biomass potential.

2.3 Step 1: Defining and loading a crop rotation scenario

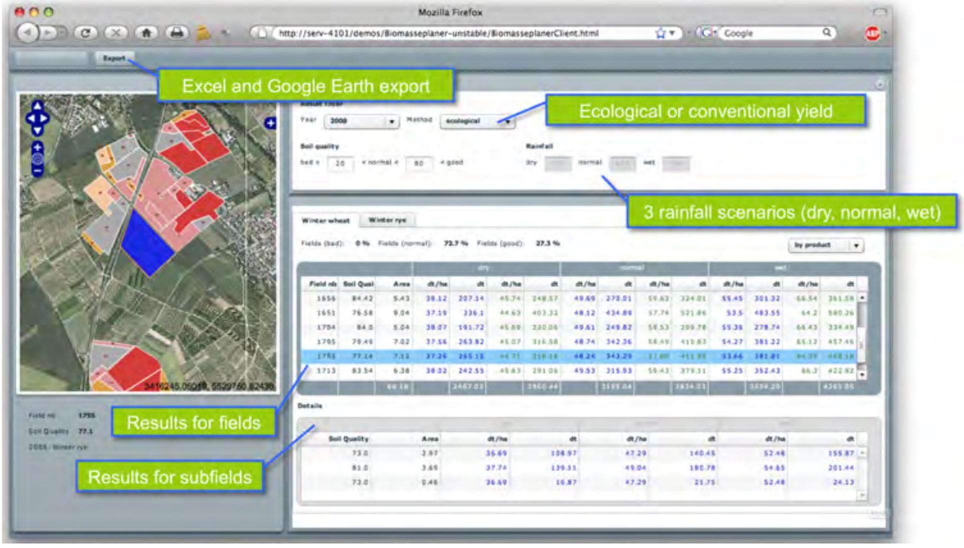
Since most of the fields already have a cultivation history, a crop rotation scenario is rarely established from scratch. Of course, there might be new fields where nothing has been cultivated yet but those are usually quite limited. Moreover, this history might be documented or not, but at least the is-situation is generally known by the user. Therefore, defining a crop rotation scenario is mostly a problem of identifying a specific field to get the is-situation in order to determine the next step in the crop rotation. One big issue is the fact that fields do not have a unique identifier as in terms of a primary key in a relational database. However, their geographical position appears to be more or less unique. Most of the time, fields have identifiers that are not unique and an optional human-readable description that helps the user identifying them such as "Next to village *XYZ* on road *ABC* with the big tree next to the river“. Therefore, this non-uniqe identifier and the description can hardly be used for automatic processing. Nevertheless, the field identifier and the description can still be helpful in certain circumstances, for example, while working on a spreadsheet. A different appoach is to rely on the unique geographical position of a field and use a map view to identify them. Experience shows once more that when users are actually looking for a specific field, they usually have a pretty good idea where to find it on a map. Still, back to the problem of defining a crop rotation scenario, depending on the number of fields to be taken into consideration for biomass-planning, this task can become quite tricky and time consuming. Therefore we have developed the crop rotation manager (Fig. 2), a mash-up of maps in conjunction with a tabular information, providing an intuitive platform to define crop rotation scenarios. The main idea of the crop rotation manager is to allow the user to rapidly interact between the map and the tabular information. Once a crop rotation model has been defined, assigning this crop rotation to a specific field can be done by simple clicking on that field in the map or in the table. Currently, the user still has to define the crop rotations from scratch. However we are currently working on a new import mechanism. The last known is-situation can be imported from FLOrlp and the next crop rotation could be guessed using a rule-based system.

2.4 Step 2: Defining weather conditions scenario and computing the biomass potential

Once the user is finished with the crop rotation scenario definition, he can commit his work and switch to the biomass-planning view to define the weather conditions scenario (Fig. 1: rainfall scenarios). This can be done by defining three levels of rainfall in millimeters for dry, normal and wet. Default values for the three levels of rainfall are automatically defined when the electronic documentation of the fields is loaded. Indeed, the geographical bounds of the fields are extracted and used to query the German Weather Report Services (DWD) to get the average level of rainfall for the given bounds based on a ten years statistic. The average rainfall +/- 100 mm are set as default values and are only given to the user as hints and can therefore be overwritten. When the rainfall values are set, the user can start the computation. Depending on the size of the production site, that is the number of fields, the computation takes less than a minute in most of the cases.

2.5 Step 3: Interpreting results and fine-tuning

After the computing is finished, the results are displayed both in a tabular form (Fig. 3) and in the map (Fig. 4). In



Year: 2008 Method: ecological

Soil quality: bad < 20 < normal < 80 < good

Rainfall: dry normal wet

Field nb: 1755
Soil Quality: 77.1
2008 / Winter rye

Winter wheat | Winter rye

Fields (bad): 0 % Fields (normal): 72.7 % Fields (good): 27.3 % by product

			dry				normal				wet			
Field nb	Soil Qual	Area	dt/ha	dt	dt/ha	dt	dt/ha	dt	dt/ha	dt	dt/ha	dt	dt/ha	dt
1656	84.42	5.43	38.12	207.14	45.74	248.57	49.69	270.01	59.63	324.01	55.45	301.22	66.54	361.58
1651	76.58	9.04	37.19	336.1	44.63	403.32	48.12	434.89	57.74	521.86	53.5	483.55	64.2	580.26
1704	84.0	5.04	38.07	191.72	45.69	230.06	49.61	249.82	59.53	299.78	55.36	278.74	66.43	334.49
1705	79.46	7.02	37.56	263.82	45.07	316.58	48.74	342.36	58.49	410.83	54.27	381.22	65.12	457.46
1755	77.14	7.11	37.26	265.15	[illegible]	[illegible]	48.24	343.29	[illegible]	[illegible]	53.66	381.81	[illegible]	[illegible]
1713	83.54	6.38	38.02	242.55	45.63	291.06	49.53	315.93	59.43	379.11	55.25	352.43	66.3	422.92
		66.18		2467.02		2960.44		3195.04		3834.03		3554.20		4265.05

Details

Soil Quality	Area	dt/ha	dt	dt/ha	dt	dt/ha	dt
73.0	2.97	36.69	108.97	47.29	140.45	52.48	155.87
81.0	3.69	37.74	139.11	49.04	180.78	54.65	201.44
73.0	0.46	36.69	16.87	47.29	21.75	52.48	24.13

Fig. 1. A mash-up of maps and table information providing an intuitive platform for biomass-planning.

the tabular form, the user has access to the field identifier, the soil quality (a number from 0 for bad to 100 for very good) and the size of the field in hectar. For each of the three rainfall scenarios, the following information is available: the average yield in decitons per hectar, the yield in tons and finally one dynamic column where different kinds of yields (e.g., by-products with/without crop residues). The biomass planner implements a full interaction between the map and the tabulars, enabling the user to either click on the map and get the corresponding lines in the tabular selected or vice-versa. A very important feature of the biomass planner is that all results are given both on the level of fields and subfields, sometimes revealing soil differences within a field. This can be helpful when taking into consideration the methods of precision farming [Bongiovanni and Lowenberg-Deboer (2004)]. The map offers different overlays and one of them is the subfields. The upper tabular contains all the fields and selecting a field will display all the information about its subfield in the lower tabular.

2.6 Step 4: Exporting the results

Finally, once the user has reviewed the results, he can export them for further process. The biomass planner currently supports following export formats: kml and kmz for GoogleMaps and GoogleEarth as well as comma seperated value list(csv). With kml and kmz, the results can even be viewed on a portable device using the GoogleMapsMobile application. The csv file can, for example, be imported in the OpenOffice application OpenCalc or in Microsoft Excel. We already provide an examplary Microsoft Excel

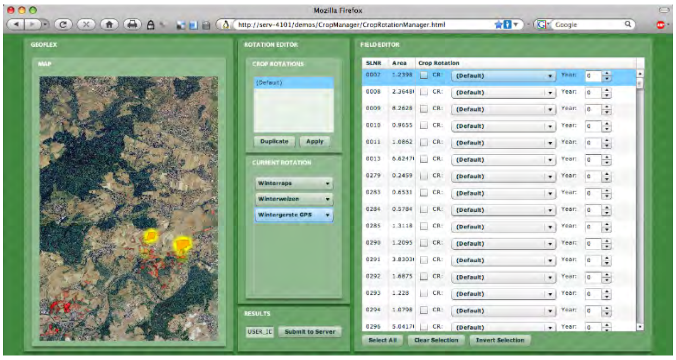
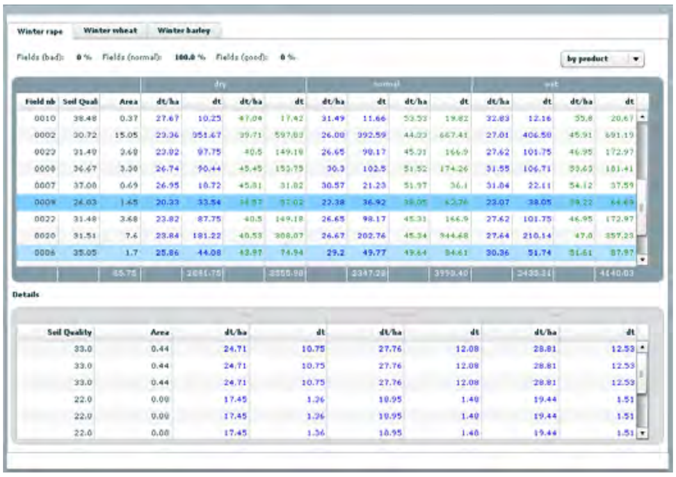


Fig. 2. A mash-up of maps and tabular information providing an intuitive platform to define crop rotation scenarios.



Winter rape | Winter wheat | Winter barley

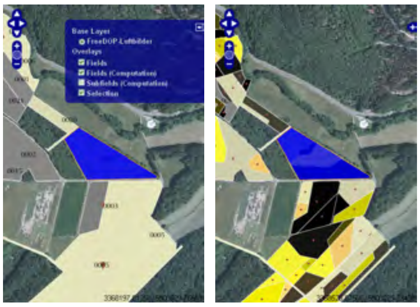
Fields (bad): 0 % Fields (normal): 100.0 % Fields (good): 0 % by product

			dry				normal				wet			
Field nb	Soil Qual	Area	dt/ha	dt	dt/ha	dt	dt/ha	dt	dt/ha	dt	dt/ha	dt	dt/ha	dt
0010	38.48	0.37	27.67	10.25	47.04	17.42	31.49	11.66	53.53	19.82	32.83	12.16	55.8	20.67
0002	30.72	15.05	23.36	351.67	39.71	597.83	26.08	392.59	44.33	667.41	27.01	406.50	45.91	691.19
0023	31.40	3.68	23.82	87.75	40.5	149.18	26.65	98.17	45.31	166.9	27.62	101.75	46.95	172.97
0008	36.67	3.38	26.74	90.44	45.45	153.75	30.3	102.5	51.52	174.26	31.55	106.71	53.63	181.41
0007	37.08	0.69	26.95	18.72	45.81	31.82	30.57	21.23	51.97	36.1	31.04	22.11	54.12	37.59
0009	26.03	1.65	20.33	33.54	34.57	57.02	22.38	36.92	38.05	62.76	23.07	38.05	39.22	64.69
0022	31.48	3.68	23.82	87.75	40.5	149.18	26.65	98.17	45.31	166.9	27.62	101.75	46.95	172.97
0020	31.51	7.6	23.84	181.22	40.53	308.07	26.67	202.76	45.34	344.68	27.64	210.14	47.0	357.23
0006	35.05	1.7	25.86	44.08	43.97	74.94	29.2	49.77	49.64	84.61	30.36	51.74	51.61	87.97
		65.75		2051.75		3555.98		2347.28		3999.40		2435.21		4140.03

Details

Soil Quality	Area	dt/ha	dt	dt/ha	dt	dt/ha	dt
33.0	0.44	24.71	10.75	27.76	12.08	28.81	12.53
33.0	0.44	24.71	10.75	27.76	12.08	28.81	12.53
33.0	0.44	24.71	10.75	27.76	12.08	28.81	12.53
22.0	0.08	17.45	1.36	18.95	1.48	19.44	1.51
22.0	0.08	17.45	1.36	18.95	1.48	19.44	1.51
22.0	0.08	17.45	1.36	18.95	1.48	19.44	1.51

Fig. 3. The results from biomass planner in tabular form.



(a) Fields. (b) Subfields.

Fig. 4. The map view from the biomass planer with different overlays for fields and subfields.

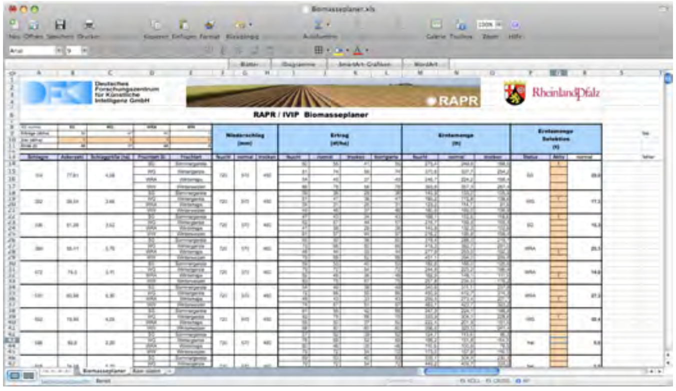


Fig. 5. A Microsoft Excel spreadsheet with macros to process the production plan exported as cvs from the biomass planner.

spreadsheet with *macros* to further process the production plan (Fig. 5)

3. COLLABORATIVE OPEN-SOURCE ROUTING SYSTEM FOR UTILITY VEHICLES (CRUV)

Wikipedia and similar Web 2.0 projects are good examples showing that collaborative approaches can provide qualitatively and quantitatively valuable information. Our main idea is to follow the same approach for a collaborative navigation system that could lead to better datasets and lower costs. Goodchild (2007a) introduces the term Volunteered Geographic Information (VGI) describing the widespread engagement of large numbers of private citizens in the creation of geographic information. Goodchild (2007b) further describes one of the biggest and most powerful sensor networks that could be used for the acquisition of geographic information: the six billion humans constantly moving about the planet collectively possess an incredible rich repertoire of knowledge about the surface of the Earth and its properties.

OSM is a project aiming at providing free geographical data that is acquired in a collaborative way and stored in a central database. The data is acquired by humans using GPS receivers and can then be annotated with additional relevant meta-information before being uploaded and integrated into OSM. OSM was founded in 2004 by Steve Coast whose motivation was to find an alternative to the expensive maps, required work with laptops and GPS technology. OSM has right now more than 50,000 participants from around the world, its community is still growing. In terms of quality, the geographical information of OSM is comparable to its competitors, like Google, Navteq or Tele-Atlas. In some cases, the OSM data might even be more accurate [heise.de (2008)]. However OSM still lacks detailed geographical information for some sparsely populated areas, but this will surely be fixed with time and taking into consideration the growing OSM community. OSM also has a very flexible framework to store additional meta-information that is relevant for routing ,e.g., speed limits, maximum weight.

This explains why we decided to use OSM for our CRUV system to store and retrieve all the necessary geographical information for routing. Like in OSM, users can login to add, modify or delete geographical information and the meta-information. Additionally, we introduced the possibility for users to rate the quality of the data and also to define different levels of trust regarding the input of other users or groups. Routing itself is realized using the pgRouting module for the PostgreSQL database, with PostGIS to support spatial operations. pgRouting supports different routing strategies for the shortest path like A* [Hart et al. (1968)] or [Dijkstra (1959)]. Out of the box, our system can handle meta-information like the maximum weight, maximum length, maximum height, maximum width, maximum and minimum speed limits, bridges, tunnels and road types. Thanks to a straightforward rule-based language, any additional attribute can also be taken into account for routing.

4. EVALUATION

4.1 Workshop with agricultural technicians

Five agricultural technicians in their final school year were chosen to evaluate the biomass planner and the route planner. All five candidates are already working on their own production site and have extensive knowledge about their respective work environment. Unfortunately, at that time none of the candidates had access to the electronical documentation of their fields. Therefore, based on the geographical position of their respective production sites, we created five different, imaginery production sites from scratch with random geometries for the fields and soil quality values taken from Sauer et al. (2003). The five candidates attended a one day workshop where they first got a detailed presentation of the project background and all three tools including live demonstrations. The candidates were then given a laptop and used the biomass planner to establish a production plan for another sixth imaginary production site. For technical reasons, the route planner could only be demonstrated on a designated laptop. Once all the candidates had solved the problem, they were given their respective imaginary production site and had to establish an appropriate production plan using the biomass planner. Finally, candidates were asked to fill in two satisfaction surveys, one for the biomass planner (Fig. 6) and one for the route planner (Fig. 7). The results of the survey for the biomass planner and for the route planner are summarized respectively in Fig. 8a and Fig. 8b. For both the biomass planner and the route planner, almost all features are for the users important and already well implemented. For the biomass planner, the feature D.8, that is resizing the map, is currently not implemented and represents a great improvement potential for the system. For the route planner, B.4.2, B.5.2 and B.6.2 correspond to features that are not yet implemented. However, they are not really considered as important and have a relatively low priority for improvement.

4.2 Simple comparison between CRUV and other driving directions services

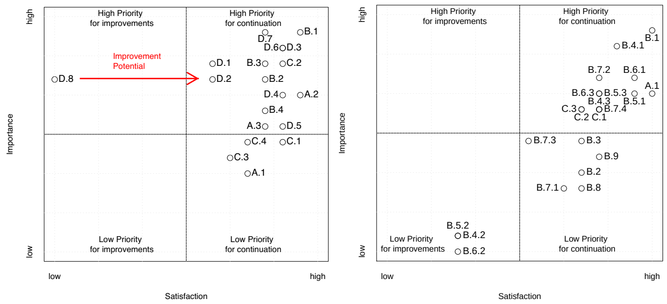
We did not yet perform an evaluation of our CRUV system in terms of routing quality but as a first result we realized some simple comparisons with other driving directions services. Fig. 9a depicts a comparison between CRUV and Map24 for traditional route-planning showing no quality difference. Fig. 9b presents a comparison between CRUV

	Satisfaction: very low	Satisfaction: low	Satisfaction: good	Satisfaction: very good	Importance: very low	Importance: low	Importance: important	Importance: very important
A. Pertinence of a biomass-planner:								
1. General demand for a biomass-planner			4	1		5		
2. Planning on field level			1	4		1	3	1
3. Planning on sub-field level			3	2	1	1	2	1
B. Demand for scenario support:								
1. Support for different precipitation levels (humid, average, dry)			1	4			1	4
2. Support for different soil quality (good, average, bad)			3	2		1	2	2
3. Possibility to set manually the precipitation levels			3	2		1	1	3
4. Support for automatic precipitation levels setting (DWD statistics)			3	2		2	2	1
C. Model complexity:								
1. Support for conventional vs. ecological yields			2	3		4		1
2. Support for yields with by-products			2	3			3	2
3. Support for crop root residues			5		1	3		1
4. Support for rye silage yields			4	1		3	2	
D. System usability:								
1. Interaction between map and tables		3		2			3	2
2. Support for multi-layer maps (soil quality, different yields)		2	2	1			4	1
3. Support for excel export			2	3			2	3
4. Support for Google Earth export			2	3		2	1	2
5. Support for Google Maps Mobile export			2	3		2	3	
6. Zoom			2	3			2	3
7. Move pane		1	1	3			1	4
8. Resize map	5					2		3

Fig. 6. Satisfaction survey for the biomass planner. The numbers in the table represent the number of user votes.

	Satisfaction: very low	Satisfaction: low	Satisfaction: good	Satisfaction: very good	Importance: very low	Importance: low	Importance: important	Importance: very important
A. Pertinence of a navigation system for utility vehicles:								
1. General demand for a navigation system for utility vehicles				5		1	3	1
B. Model complexity:								
1. Support for different strategies of driving directions (shortest vs. fastest)				5			1	4
2. Support for average speeds			4	1	1	3	1	
3. Support for intermediate stages			4	1	1	2	1	1
4. Support for different road types (motorway, highway, country road, country lane, private, private road):								
4.1 General demand			2	3		1		4
4.2 without priorities	3		2		4	1		
4.3 with priorities (none, few, normal, prefered, strong)			3	2		2	2	1
5. Support for bridges								
5.1 General			1	4	1		2	2
5.2 without priorities	3		2		4	1		
5.3 with priorities (none, few, normal, prefered, strong)			3	2	1		2	2
6. Support for tunnels								
6.1 General			1	4	1		1	3
6.2 without priorities	3		2		5			
6.3 with priorities (none, few, normal, prefered, strong)			3	2	1		2	2
7. Support for different vehicles types								
7.1 Support for turn-off restrictions			5		2	2	1	
7.2 Support for weight, height and width			3	2		1	2	2
7.3 Support for different fuel types	2		1	2	1	2	1	1
7.4 Support for maximal speed			3	2		2	2	1
8. Possibility to ignore lane direction			4	1	2	2	1	
9. Possibility to use OpenStreetMap meta-informations			3	2	1	3		1
C. System usability:								
1. Zoom			3	2		1	4	
2. Move pane		1	2	2		1	4	
3. Resize map		1	2	2		1	4	

Fig. 7. Satisfaction survey for the route planner. The numbers in the table represent the number of user votes.



(a) biomass planner.

(b) route planner.

Fig. 8. Graph satisfaction.

(a) Map24 Vs. CRUV.

(b) GoogleMaps Vs. CRUV.

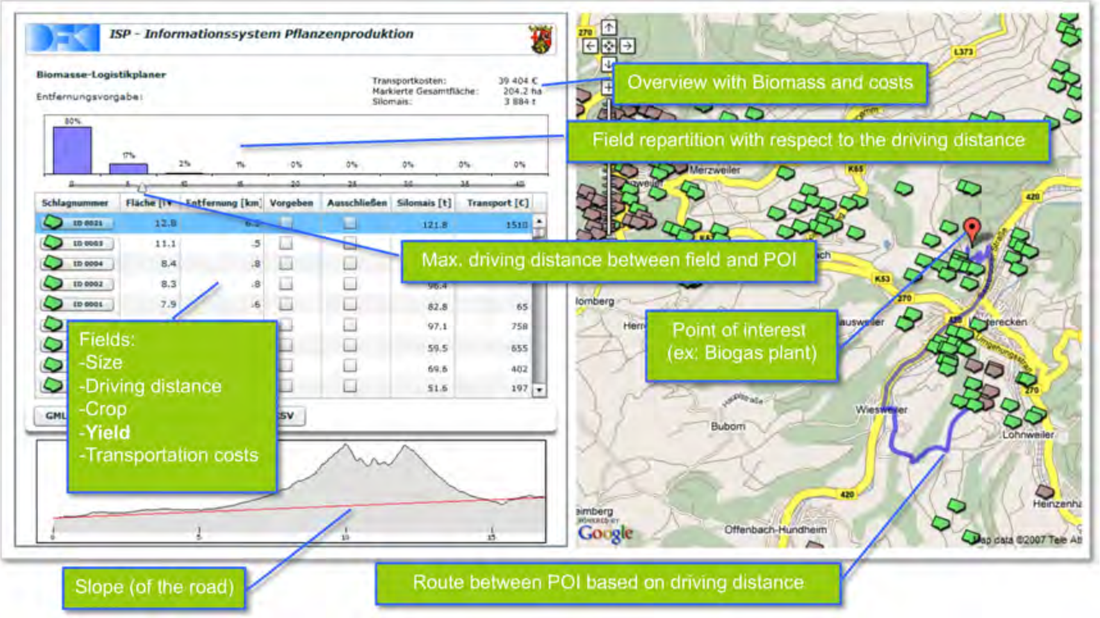
Fig. 9. Comparison between CRUV and other driving directions services.

and GoogleMaps where bridges below a specific maximum weight should be forbidden. GoogleMaps simply does not support such query and this explains the differences in the results. CRUV proposed a 2.8 km route, instead of 1.5 km for GoogleMaps, but privileging a bridge respecting the given maximum weight.

5. FUTURE WORK: COMBINING BIOMASS-PLANNING WITH ROUTE-PLANNING

The biomass planner is currently suited for single production plants but could be combined with the collaborative route-planning system for utility vehicles to enable efficient biomass-planning and logistic-planning on a larger scale. Indeed, experimental research in the field of resource planning, like for example for a biogas plant, show that most of the costs are related to transport and can only be optimized by relying on efficient route-planning [Gunnarsson et al. (2008)]. Fig. 10 is a snapshot of a mock-up for a mash-up of maps and table information providing an intuitive platform for biomass-planning and logistic-planning. The system takes as input a production plan established with the biomass planner that is a list of fields with their crop definition and the yield prognosis. The aim of the tool is to help deciding which fields should be taken into consideration depending on the yield and driving distance with respect to a Point Of Interest (POI), like a biogas plant. The user can specify the transport strategy by defining the number of available trucks and or trailers. A very important feature of the system is to be able to specify the characteristics of the vehicle(s) (e.g. length, width, height, and fuel consumption) that are used for route-planning. The *real* driving distance can therefore be taken into account instead of the typical flight distance.

The maximal distance between the POI and the field can be defined using a simple slider. To help optimizing the maximal driving distance, the user has access to all relevant information. All field relative information like the size, the driving distance between the POI and the field, the kind of crop, the yield and the transportation cost are summarized in the table on the left (Fig. 10). All the fields are visualized using the map on the right (currently based on GoogleMaps). The fields in green are within the maximum driving distance, the fields in gray are not. A graphical representation of the field repartition with respect to the driving distance is also available above the table. By selecting a field, using the table or the map, the user can explicitly choose to include or to exclude this field disregarding the maximum driving distance. The specific route between the POI and this field is drawn in blue on the map. The information about the slope of the route is



ISP - Informationssystem Pflanzenproduktion

Biomasse-Logistikplaner

Entfernungsvorgabe:

Transportkosten: 39 404 €
Markierte Gesamtfläche: 204.2 ha
Silomais: 3 884 t

Schlagnummer	Fläche [ha]	Entfernung [km]	Vorgeben	Ausschließen	Silomais [t]	Transport [€]
ID 0021	12.8	6.2	☐	☐	121.8	1510
ID 0003	11.1	.5	☐	☐	[illegible]	[illegible]
ID 0004	8.4	.8	☐	☐	[illegible]	[illegible]
ID 0002	8.3	.8	☐	☐	96.4	[illegible]
ID 0001	7.9	.6	☐	☐	82.8	65
[illegible]	[illegible]	[illegible]	☐	☐	97.1	758
[illegible]	[illegible]	[illegible]	☐	☐	59.5	655
[illegible]	[illegible]	[illegible]	☐	☐	69.6	402
[illegible]	[illegible]	[illegible]	☐	☐	51.6	197

Overview with Biomass and costs

Field repartition with respect to the driving distance

Max. driving distance between field and POI

Fields:
-Size
-Driving distance
-Crop
-**Yield**
-Transportation costs

Point of interest
(ex: Biogas plant)

Slope (of the road)

Route between POI based on driving distance

Fig. 10. A mash-up of maps and tabular information providing an intuitive platform for biomass-planning and logistic-planning (mock-up).

also visualized in the graphic below the table. Finally, an overview of the biomass potential and transportation costs is available at the top of the application.

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