EASE tool Methodology

https://egnos-user-support.essp-sas.eu

The following document describes the methodology that is behind the EASE (Egnos sAvingS in AgriculturE) tool available in the EGNOS User Support Website. The purpose is to facilitate the understanding of the criteria that is followed to derive the corresponding cost-benefit analyses (CBA) on the use of EGNOS in comparison with less accurate solutions: GPS alone or no machinery guidance at all.

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1 GENERAL CONSIDERATIONS

The methodology of the EASE (Egnos sAvingS in agriculturE) tool, available in the EGNOS User Support Website, has been developed according to the following general considerations:

- The cost-benefit analysis (CBA) is limited to those types of crops that do not require very high precision solutions, **i.e. extensive crops in dry areas**. Winter cereals (barley and wheat), legumes and sunflower are the typical crops for these farms, where water and high temperatures are the main crop yield limitation factors.
- The proposal for savings determination is based on the **objective improvement provided by EGNOS** with respect lower-accuracy solutions **in the pass-to-pass accuracy**.
- The methodology compares the potential results that could be obtained using EGNOS with respect to another GNSS solution of lower precision than EGNOS, which can be:
  - **Unaided driver**: The farmer does not use any assistance method to drive the tractor.
  - **GPS alone**: The farmer is using only GPS (or GPS + GLONASS), without any kind of correction solution, to drive the tractor.
- The methodology is based on the **reduction of the pass-to-pass error provided by EGNOS with respect to the case of an unaided driver or using only GPS**. *Table 1* shows the pass-to-pass accuracy values that are considered in the model for each technology involved.

Solution	Pass-to-pass error
Unaided driver	10% of working width [1], [2] **or** 0.6 m (the higher is taken)
GPS alone	1 m [3]
EGNOS manual	0.4 m [4]
EGNOS autosteer	0.25 m [4]

Table 1: Pass-to-pass error considered for the different solutions of the proposed CBA model.

The case of unaided drivers requires some special attention, as the literature reports a pass-to-pass error of 10% of the working width, but without stablishing any kind of minimum error (best case scenario). Therefore, a problem appears for short implements, as, for instance, it would mean a 40 cm error for a working width of 4 m. The experience we have with farming users reveals that it is not the situation in practice, so some lower bound must be set for the pass-to-pass error of unaided drivers. In this sense, as a reasonable approximation we just consider 60 cm as the minimum pass-to-pass error for unaided drivers.

- The pass-to-pass error can occur in two ways with different consequences:
  - Overlap: the same area is treated twice, so there is a waste of inputs (if applicable), fuel and time.
  - Underlap: some area remains without treatment, so there is a reduction in quantity and/or quality of yields.

Considering these two options, in order to derive objectively the benefits of EGNOS for farmers as a function of the pass-to-pass error, we consider that the best option is to **assume**

that the error is committed always as an overlap over the previous pass, without any underlap. The reason is that it is easier to quantify the waste of resources than the yield reduction, which depends highly on each specific case. Furthermore, in practice, overlap is more common than underlap, as farmers tend to be very cautious and avoid skips, even planning the passes with working widths that are longer than the implement itself, to assure that no area remains untreated [2]. For them, in general, no treatment is rather worse than overtreatment.

- There are two different ways of expressing the pass to pass error, as it can be observed in *Table 1*:
  - **Percentage (%)**: it corresponds to a relative part of the working width, so the absolute level of the error, e.g. in metres, varies. In this sense, the longer working width, the larger overlap in metres. The use of a percentage error applies only to unaided drivers, specifically when using implements longer than 6 m. In this case, there is no guidance assistance to ensure a constant value and for the farmer is more difficult to control visually the overlap when using long implements, because there is more distance between passes and the driver has the previous reference further.

    Under these circumstances, EGNOS benefits are more pronounced if long implements are employed, as the overlap provided by EGNOS remains constant while the unaided driver's one increases with the working width. This phenomenon can be observed in the right part of the blue and green lines of *Figure 1*.
  - **Absolute length (m)**: it refers to a constant value in metres that does not change with the working width applied. Therefore, the same overlap value losses importance while the implement's length increases, e.g. a 1 m overlap corresponds to a 25% of a 4-metres working width but only a 10% if the working width is extended to 10 metres.

    In this situation, when comparing EGNOS with other solutions that provide also constant overlaps, EGNOS benefits are exponentially reduced as the length of the implement increases. This effect can be observed in the purple and red lines, as well as the left part of the green and blue lines of *Figure 1*.
- Taking into account the considerations commented in the previous points and the data of *Table 1*, we can establish the improvement in overlap reduction that is achieved with EGNOS. *Figure 1* shows a **chart with the results of the different possible comparisons**, namely versus unaided driver and GPS (alone). In this sense, some specific examples are provided below for clarification on where the numbers come from.
  - EGNOS manual / autosteer vs. unaided driver:
    - If the working width is lower than 6 m, a constant 60 cm overlap is considered for the unaided driver, so EGNOS overlap reduction remain constant to 20 cm (60 cm minus 40 cm). This constant absolute error is more relevant for shorter working widths. On the other hand, if the working width is higher than 6 m, then the 10% criteria is considered for the unaided driver overlap, so EGNOS provide a variable overlap reduction that increases as a function of the working width.

Woking width	Unaided driver overlap	EGNOS overlap	Overlap reduction
3	60 cm --> 20%	40 cm --> 13.3%	4%
4	60 cm --> 15%	40 cm --> 10%	5%

Woking width	Unaided driver overlap	EGNOS overlap	Overlap reduction
5	60 cm --> 12%	40 cm --> 8%	6.7%
6	10%	40 cm --> 6.7%	3.3%
10	10%	40 cm --> 4%	6%
20	10%	40 cm --> 2%	8%

Table 2: Overlap reduction for the case of EGNOS manual vs. unaided driver.

Woking width	Unaided driver overlap	EGNOS overlap	Overlap reduction
3	60 cm --> 20%	25 cm --> 8.3%	11.7%
4	60 cm --> 15%	25 cm --> 6.3%	8.8%
5	60 cm --> 12%	25 cm --> 5%	7%
6	10%	25 cm --> 4.2%	5.8%
10	10%	25 cm --> 2.5%	7.5%
20	10%	25 cm --> 1.3%	8.7%

Table 3: Overlap reduction for the case of EGNOS autosteer vs. unaided driver.

- EGNOS manual / autosteer vs GPS:
  - In this case, as the overlap values of both solutions are constant, the overlap reduction is always more relevant for smaller working widths.

Woking width	GPS overlap	EGNOS overlap	Overlap reduction
3	1m --> 33.3%	40 cm --> 13.3%	20%
4	1m --> 25%	40 cm --> 10%	15%
5	1m --> 20%	40 cm --> 8%	12%
6	1m --> 16.7%	40 cm --> 6.7%	10%
10	1m --> 10%	40 cm --> 4%	6%
20	1m --> 5%	40 cm --> 2%	3%

Table 4: Overlap reduction for the case of EGNOS manual vs. GPS.

Woking width	GPS overlap	EGNOS overlap	Overlap reduction
3	1m --> 33.3%	25 cm --> 8.3%	25%
4	1m --> 25%	25 cm --> 6.3%	18.8%

Woking width	GPS overlap	EGNOS overlap	Overlap reduction
5	1m --> 20%	25 cm --> 5%	15%
6	1m --> 16.7%	25 cm --> 4.2%	12.5%
10	1m --> 10%	25 cm --> 2.5%	7.5%
20	1m --> 5%	25 cm --> 1.3%	3.8%

Table 5: Overlap reduction for the case of EGNOS autosteer vs. GPS.

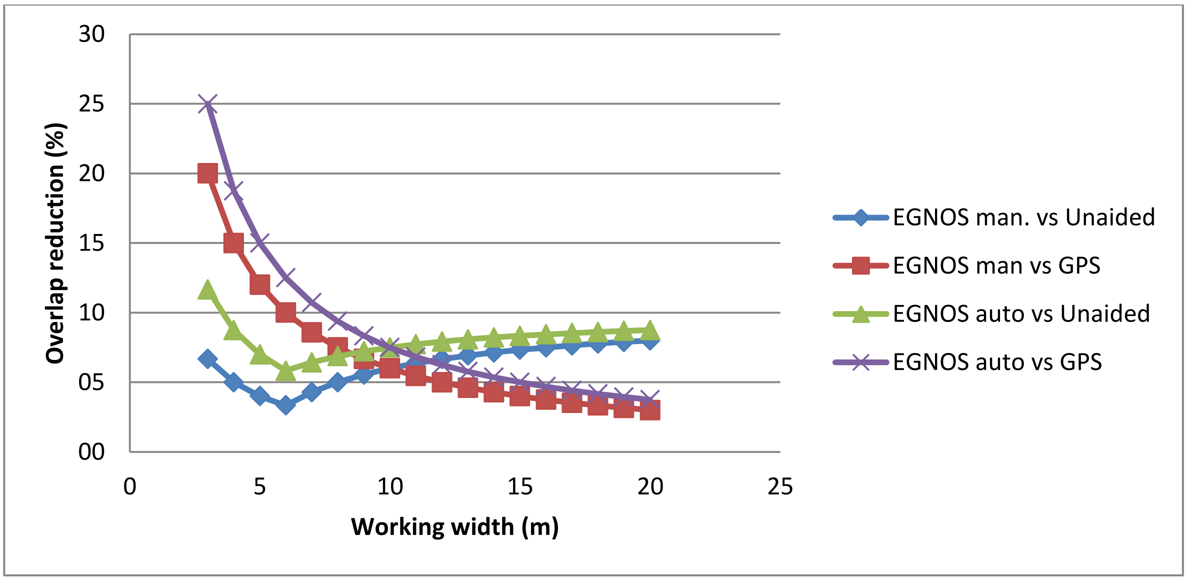

Figure 1: Overlap reduction achieved with EGNOS as a function of the working width.

- The summary of the different farming activities that are considered in the CBA model to derive EGNOS benefits is shown in *Table 6*. In the same table, it is stated **which kind of savings can be obtained** in each of the activities. The different classes of savings are described in detail and formally established along the following sections.

Activity	Savings		
	Fuel	Input (seeds, fertiliser, herbicide, …)	Time/Labour
Ploughing	✓	✗	✓
Sowing	✓	✓	✓
Spreading	✓	✓	✓
Spraying	✓	✓	✓
Harvesting	✓	✗	✓

Table 6: Activities and savings considered in the proposed CBA model.

- **The savings that are considered does not affect negatively the yields.** It means that following the EGNOS approach instead of any of the other two solutions, namely unaided driver or GPS, the yields achieved are at least the same as before, so an improvement of productivity is ensured. Even with EGNOS the yields could be even enhances thanks to the more precise performance of the different farming activities along the campaign.

2 FUEL SAVINGS

If we assume that the whole parcel needs to be covered for each farming activity, the reduction in the overlap provided by EGNOS gives rise to a decrease of the number of passes to be performed with the tractor to do so. If we accumulated all the overlapping area that is saved per pass thanks to the use of EGNOS, we obtain a global equivalent area that is saved to be treated twice:

Saved Area (ha) = Overlap reduction (%) x Parcel total area (ha)

There are savings that correspond to the fuel that would be wasted by the tractor along the whole saved area without using EGNOS, i.e. if the area is treated twice due to the higher overlap of the unaided driver or GPS solutions. In order to be able to quantify the fuel savings values, we need to know:

- Fuel price: As it varies with the specific country of application, we use the following website to get the up-to-date data for the different European countries: https://www.globalpetrolprices.com/diesel_prices/.

- Fuel consumption: Multiple references have been consulted to set some reasonable fuel consumption values. *Table 7* shows the final values that are set for each farming activity.

Activity	Fuel consumption (l/ha)	References
Ploughing	20	[5]-[8]
Sowing	8	[7]-[11]
Spreading	2	[8], [12]
Spraying	2	[8], [13]
Harvesting	12	[14], [15]

Table 7: Fuel consumption values per farming activity.

From this data, the fuel savings for a specific activity along a whole campaign can be derived as:

Fuel savings (€) = Number of times of activity x (Saved Area (ha) x Fuel consumption (l/ha) x Fuel price (€/l))

3 INPUT SAVINGS

Following the same reasoning as with the fuel savings, there are also savings related to the inputs (seeds, fertilizer, herbicide, etc.) that would be wasted in the overlapped area. In this case, it must be noted that, as already presented in *Table 6*, these savings only apply to those farming activities that imply the application of some kind of input to the field or crops. Thus, in order to quantify the savings that EGNOS provides thanks to the overlap reduction, the following data is required for each farming activity:

- Input rate: Amount of input that is applied per unit of area.
- Input cost: Price of the specific input used by the farmer.

The values that are considered for each farming activity are summarized in *Table 8*. They are set considering typical figures for cereal and other dry soil extensive crops, which are the target of this CBA model.

Activity	Input rate	Input cost
Sowing	200 kg/ha [16]	Data from farmer (€/kg)
Spreading	150 kg/ha	Data from farmer (€/kg)
Spraying	2 l/ha	Data from farmer (€/l)

Table 8: Values considered for the calculation of the input savings.

From this data, the input savings for a specific activity along a whole campaign can be derived as:

Input savings (€) = # times of activity x (Saved Area (ha) x Input rate (kg/ha or l/ha) x Input costs (€/ kg or €/l))

4 TIME/LABOUR SAVINGS

For the same reasons as commented in the previous sections, the farmer can save some time thanks to the reduction in the overlapped area due to the use of EGNOS. In order to quantify economically this benefit, we decide to translate the time savings into equivalent labour ones. For this purpose, it is needed to specify the following parameters:

- Mean speed (km/h): to derive the actual time that is saved, as the same saved area can be covered at different speeds. By default we consider a mean speed of 8 km/h.
- Labour cost (€/h): this value is rather different for each European country, so it must be taken from here: http://www.copa-cogeca.be/img/user/files/KAUNAS2013/EA(14)3559EN3.pdf

From this data, the time and equivalent labour savings for a specific activity along a whole campaign can be derived as:

Time savings (h) = Number of times of activity x ((Saved Area (ha) x 10000 (m2/ha)) / (Working width (m) x x 8 km/h x 1000 m/km))

Labour savings (€) = Time savings (h) x Labour cost (€/h)

5 NON-QUANTIFIABLE COSTS

It must be stated that there are also some EGNOS benefits that are difficult to quantify in economic terms and therefore cannot be included in the CBA model:

- vs. unaided driver:
  - Driver fatigue reduction
  - Possibility of working under low visibility conditions (nightfall/sunrise, night, fog, heavy rain, etc.)
- vs. both unaided driver and GPS:
  - Extension of the useful life of machinery
  - Improvement of soil yield

6 EGNOS COSTS

EGNOS is a free GPS augmentation service provided by the European Commission, so the only costs that involve it are those related to the acquisition of compatible equipment. In order to establish typical cost prices for EGNOS-enabled devices for agricultural machinery, one should take into account that there are multiple types and models of guidance equipment for farming machinery which are EGNOS enabled, covering a wide range of performances and costs. In this sense, one can find from basic EGNOS guiding devices, with no special features (e.g. no capability to apply higher precision solutions, such as commercial services or RTK is included) to more sophisticated ones that anyway include EGNOS as the basic service for guidance.

For the autosteering mode with EGNOS only the electrical solution, not the hydraulic one, is considered, as it is enough for EGNOS accuracy. In addition, it is assumed that the autosteering equipment must be able to be used not only in the tractor, but also in the harvester or combine.

After this analysis the following typical costs of EGNOS are set by default in the CBA. However, they are provided only as reference figures and the user can introduce any other value in the corresponding field of the CBA (see the “User Manual”).

- EGNOS manual mode: 1000 € to 2000 € --> default value: 1500 €
- EGNOS electric autosteer: EGNOS manual mode + (2000 € to 4000 €) = 3000 € to 6000 € --> --> default value: 4500 €

7 FARMER'S DATA

Considering the methodology described in the previous sections several data is required from the farmer to implement the proposed CBA model. However, in order to facilitate the completion of the CBA some specific values has been identified as typical ones and set by default in the different input fields of the tool. Anyway, it must be noted that the representativeness of the CBA results increases if the farmer do not rely on the values by default but provide their own actual data. The different parameters required from the farmer for the CBA as well as their corresponding default values are shown in *Table 9*.

Parameter	Default value
Country (optional)*	Blank
Crops area (ha)	20
Crop type (optional)*	Blank
Fuel price (€/l)	If no country selected: 1 If a country is chosen: it is taken from https://www.globalpetrolprices.com
Number of times of activity	1
Working width (m)	5
Ploughing fuel consumption (l/ha)	20
Sowing fuel consumption (l/ha)	8
Sowing input application (kg/ha)	200
Seeds price (€/kg)	1
Spreading fuel consumption (l/ha)	2
Spreading product price (€/kg)	
Spreading application (kg/ha)	150
Spraying product price (€/l)	1.5
Spraying fuel consumption (l/ha)	2
Spraying input application (l/ha)	2
Harvesting fuel consumption	12
Mean speed (km/h)	8
Labour cost (€/h)	If no country selected: 15 If a country is chosen: it is taken from http://www.copa-cogeca.be/img/user/files/KAUNAS2013/EA(14)3559EN3.pdf

Parameter	Default value
Cost of EGNOS manual (€)	1500
Cost of EGNOS autosteer (€)	4500

*Table 9 Famer's data and defaults values. *Each CBA only covers one type of crops, despite that they are located (or not) in different parcels. If the farmer has more than one type of crops, several implementations of the CBA must be performed.*

8 EXAMPLES

These examples do not aim at reproducing real cases, just at showing how the proposed CBA model works by means of a very simple case. The objective is to provide clarification to the aforementioned ideas and procedures, not obtaining representative results.

8.1 FARMER'S DATA

The farmer data that is considered in the examples is presented in *Table 10* and *Table 11*. For those parameters that are not specified here, the default values stated above in are used.

Parameter	Value
Country	Spain
Crops area (ha)	20
Crop type	Wheat
Fuel price (€/l)	1
Labour cost (€/h)	15

Table 10: General farmer's data for the CBA examples.

	Ploughing	Sowing	Spreading	Spraying	Harvesting
Number of times along campaign:	1	1	1	1	1
Working width (m):	10	5	5	10	10
		Seed price(€/kg)	Input price(€/kg)	Input price (€/l)	
		0.7	0.5	17	

Table 11: Activity farmer's data for the CBA examples.

8.2 RESULTS

From the aforementioned data and following the methodology explained in the previous sections, these CBA results are achieved.

8.2.1 EGNOS vs. unaided driver

8.2.1.1 *EGNOS manual vs. unaided driver*

Task	# times	Fuel (l)	Fuel (€)	CO2 emissions savings (kg)	Inputs (€)	Labour (h)	Labour (€)	Total EGNOS savings (€)
Ploughing	1	24.00	24.00	63.6	0.00	0.15	2.25	26.25
Sowing	1	6.40	6.40	16.96	112.00	0.2	3.00	121.40
Spreading	1	1.60	1.60	4.24	60.00	0.2	3.00	64.60
Spraying	1	2.40	2.40	6.36	40.80	0.15	2.25	45.45
Harvesting	1	14.40	14.40	38.16	0.00	0.15	2.25	16.65
TOTAL	---	48.80	48.80	129.32	212.80	0.85	12.75	**274.35**

Table 12: EGNOS manual vs. unaided driver: EGNOS savings per farming activity.

EGNOS savings (€)	**274.35**
EGNOS investment (€)	1500
Amortization (# of campaigns)	6

Table 13: EGNOS manual vs. unaided driver: amortization of EGNOS investment.

Campaign	Accumulated EGNOS profit (€)
0	-1500.00
1	-1225.65
2	-951.30
3	-676.95
4	-402.60
5	-128.25
6	146.10
7	420.45
8	694.80
9	969.15
10	1243.50

Table 14: EGNOS manual vs. unaided driver: EGNOS profit along campaigns.

8.2.1.2 *EGNOS autosteer vs. unaided driver*

Task	# times	Fuel (l)	Fuel (€)	CO2 emissions savings (kg)	Inputs (€)	Labour (h)	Labour (€)	Total EGNOS savings (€)
Ploughing	1	30.00	30.00	79.5	0.00	0.19	2.81	32.81
Sowing	1	11.20	11.20	29.68	196.00	0.35	5.25	212.45
Spreading	1	2.80	2.80	7.42	105.00	0.35	5.25	113.05
Spraying	1	3.00	3.00	7.95	51.00	0.19	2.81	56.81
Harvesting	1	18.00	18.00	47.7	0.00	0.19	2.81	20.81
TOTAL	---	65.00	65.00	172.25	352.00	1.26	18.94	**435.94**

Table 15: EGNOS autosteer vs. unaided driver: EGNOS savings per farming activity.

EGNOS savings (€)	**435.94**
EGNOS investment (€)	4500
Amortization (# of campaigns)	11

Table 16: EGNOS autosteer vs. unaided driver: amortization of EGNOS investment.

Campaign	Accumulated EGNOS profit (€)
0	-4500.00
1	-4064.06
2	-3628.13
3	-3192.19
4	-2756.25
5	-2320.31
6	-1884.38
7	-1448.44
8	-1012.50
9	-576.56
10	-140.63

Table 17: EGNOS autosteer vs. unaided driver: EGNOS profit along campaigns.

8.2.2 EGNOS vs. GPS alone

8.2.2.1 *EGNOS manual vs. GPS alone*

Task	# times	Fuel (l)	Fuel (€)	CO2 emissions savings (kg)	Inputs (€)	Labour (h)	Labour (€)	Total EGNOS savings (€)
Ploughing	1	24.00	24.00	63.6	0.00	0.15	2.25	26.25
Sowing	1	19.20	19.20	50.88	336.00	0.6	9.00	364.20
Spreading	1	4.80	4.80	12.72	180.00	0.6	9.00	193.80
Spraying	1	2.40	2.40	6.36	40.80	0.15	2.25	45.45
Harvesting	1	14.40	14.40	38.16	0.00	0.15	2.25	16.65
TOTAL	---	64.80	64.80	171.72	556.80	1.65	24.75	**646.35**

Table 18: EGNOS manual vs. GPS alone: EGNOS savings per farming activity.

EGNOS savings (€)	**646.35**
EGNOS investment (€)	1500
Amortization (# of campaigns)	3

Table 19: EGNOS manual vs. GPS alone: amortization of EGNOS investment.

Campaign	Accumulated EGNOS profit (€)
0	-1500.00
1	-853.65
2	-207.30
3	439.05
4	1085.40
5	1731.75
6	2378.10
7	3024.45
8	3670.80
9	4317.15
10	4963.50

Table 20: EGNOS manual vs. GPS alone: EGNOS profit along campaigns.

8.2.2.2 *EGNOS autosteer vs. GPS alone*

Task	# times	Fuel (l)	Fuel (€)	CO2 emissions savings (kg)	Inputs (€)	Labour (h)	Labour (€)	Total EGNOS savings (€)
Ploughing	1	30.00	30.00	79.5	0.00	0.19	2.81	32.81
Sowing	1	24.00	24.00	63.6	420.00	0.75	11.25	455.25
Spreading	1	6.00	6.00	15.9	225.00	0.75	11.25	242.25
Spraying	1	3.00	3.00	7.95	51.00	0.19	2.81	56.81
Harvesting	1	18.00	18.00	47.7	0.00	0.19	2.81	20.81
TOTAL per parcel		81.00	81.00	214.65	696.00	2.06	30.94	**807.94**

Table 21: EGNOS autosteer vs. GPS alone: EGNOS savings per farming activity.

EGNOS savings (€)	**807.94**
EGNOS investment (€)	4500
Amortization (# of campaigns)	6

Table 22: EGNOS autosteer vs. GPS alone: amortization of EGNOS investment.

Campaign	Accumulated EGNOS income (€)
0	-4500.00
1	-3692.06
2	-2884.13
3	-2076.19
4	-1268.25
5	-460.31
6	347.63
7	1155.56
8	1963.50
9	2771.44
10	3579.38

Table 23: EGNOS autosteer vs. GPS alone: EGNOS profit along campaigns.

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