Project:

„Promotion of Locally Adapted Mechanization Concepts in Sub-Saharan Africa“

Information and Planning System (IPS) for Location-Adapted Mechanization Concepts

- Operators Manual –

Version for Kenya

Gesellschaft für Projekt- und Prozessmanagement in der Agrarwirtschaft

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1 Objectives

In the farming systems of the rain-fed and irrigated agriculture in Ethiopia and Kenya, in addition to insufficient production technology knowledge and a lack of capital, the availability of site-adapted agricultural mechanization is a central restriction. Due to the insufficient capital resources, a clear trend towards inter-farm mechanization can be seen in the target countries.

When it comes to purchasing agricultural machinery, not only farmers, but also agricultural institutions are faced with several challenges. Knowledge about modern agricultural machinery that allows production according to agro-ecological principles is hardly available. The basic knowledge for developing future-oriented solutions to mechanization issues is missing. As a result, local production conditions are not sufficiently taken into account when using agricultural machinery. For example, oversized machines lead to increased soil compaction and increased fuel consumption. Insufficient machine utilization causes higher fixed costs, leading to unprofitable investments. Implements that are not adapted to the location (for example for seedbed preparation) lead to unnecessary operations and thus to a loss of soil fertility, also promoting soil erosion.

Agricultural institutions lack access to site-adapted mechanization solutions in order to be able to offer these to smallholder farms. The development of site-adapted mechanization concepts requires a holistic understanding of the restrictions and development potential of farms and smallholders, including processes and decision-making structures. These processes can be supported with the help of a practice-oriented guideline and a computer-based information and planning system.

Thus, the objective of the project can be formulated as follows:

Agricultural institutions in Kenya and Ethiopia have improved their services to site-adapted mechanization based on a computerized information and planning system (IPS).

2 Important aspects related to prevailing farming systems

2.1 Farming systems in the target regions

In discussions with the project's cooperation partners in Ethiopia and Kenya, it was decided to take the following farming systems into consideration in context with the development of the IPS:

- Cash crop farms specialising in cereal production
- Fodder production with cattle (dairy cows)

The target regions concerning cash crop farms are Oromia in Ethiopia and Nakuru in Kenya. In Nakuru, typical farms for fodder production and livestock are also to be taken into consideration. In Ethiopia, the IPS will include cattle farmers with fodder production located within an area surrounding Addis Ababa by 75 km.

2.2 Typical farms and production structure

The production structure of typical farms in the target regions was discussed and described by the working group in Kenya and compared to agricultural statistics, which confirmed the assumptions.

Figure 1 shows typical cash crop farms in Nakuru with respect to the farm size and the share of farm enterprises on the available arable land. Distinctions are made between three farm size classes (small, medium, large). Each farm size class represents 33% of the total farming sector in the target region. While small-scale cash crop farms cultivate an average only 0.75 ha, large scale farms cultivate 50 ha. The medium group has 5 ha available for agriculture purposes.

Wheat, barley maize, potatoes and carrots are grown in the large farm size classes. This is the same in the middle class, however no Barley is cultivated. Small farms only producing maize and potatoes, mainly for home consumption.

Figure 1: Production structure of typical cash crop farms in Nakuru region (Kenya)

	Small-cale farm		Medium-scale farm		Large-scale farm	
Share of land	in %	in ha	in %	in ha	in %	in ha
Wheat			15%	0.75 ha	10%	5.0 ha
Barley					5%	2.5 ha
Maize	75%	0.56 ha	40%	2.00 ha	55%	27.5 ha
Potatoes	25%	0.19 ha	40%	2.00 ha	25%	12.5 ha
Carrots			5%	0.25 ha	5%	2.5 ha
Total		0.75 ha		5.0 ha		50 ha

Figure 2 describes a typical dairy cow farm in the Nakuru area. The classification according to farm size refers to the number of dairy cows (small: 3 cows, middle: 15 cows, large: 100 cows). Depending on the number of cows, the table also provides information on the available arable land and its use (hay, maize-silage, wheat).

Figure 2: Production structure of typical cattle farms in Nakuru region (Kenya)

		Small-cale farm (3 cows)		Medium-scale farm (15 cows)		Large-scale farm (100 cows)	
Share of land		in %	in ha	in %	in ha	in %	in ha
Wheat				20%	1.0 ha	20%	7 ha
Maize silage		25%	0,25 ha	40%	2.0 ha	40%	14 ha
Hay	Alfalfa	75%	0.75 ha	10%	0.5 ha	20%	7 ha
	Grass			30%	1.5 ha	20%	7 ha
Total			1.0 ha		5.0 ha		35 ha

2.3 Farming systems and mechanization

The following aspects are of particular importance concerning the mechanization of farming systems:

- The necessary work processes related to the farm enterprises taken into consideration
- The traction power of the available tractors (horse power)
- The technology level of the available agricultural machinery

a) Work processes

In order to grow the various crops, the farmers have to carry out work processes (ploughing, sowing, etc.). Type and scope of the work processes are determined by the relevant farm enterprise (e.g. wheat production). All work processes relevant to cash crop farms and cattle farms with fodder production are listed in the following table.

Figure 3: Work processes of the targeted farm enterprises

	Wheat	Barley	Maize	Potatoes	Carrots	Maize silage	Alfalfa silage	Alfalfa hay
Ploughing	X	X	X	X	X	X	X	X
Seedbed preparation	X	X	X	X	X	X	X	X
Sowing / Planting*)	X	X	X	X	X	X	X	X
Fertilizer application	X	X	X	X	X		X	X
Spraying	X	X	X	X	X	X		
Ridging maize			X					
Inter-row cultivation			X	X		X		
Combine harvesting	X	X	X					
Potato/Carrot harvesting				X	X			
Silage chopping						X	X	
Mowing grass/alfalfa							X	X
Turning grass/hay							X	X
Raking grass/hay							X	X
Baling hay								X
Loading hay bales								X
Silage compacting in silo						X	X	
Transport	X	X	X	X	X	X	X	X

*) incl fertilization of maize and beans

b) Tractor performance

In the target regions, tractors in the power category between 80 and 150 hp are used by most of farmers. In the context of the IPS development, in this range three performance classes were defined (compare Figure 4), plus an additional category with a 35-hp-tractor for smallholder farmers.

- Extra low performance class: 35 hp
- Low performance class: 80 hp
- Medium performance class: 110 hp
- High performance class: 150 hp

The type and working width of the implements (plough, drill, etc.) corresponds to the tractor performance.

c) Technology level

In addition to tractor performance, the tractors are differentiated according to technology level.
A distinction is made between three tractor groups:

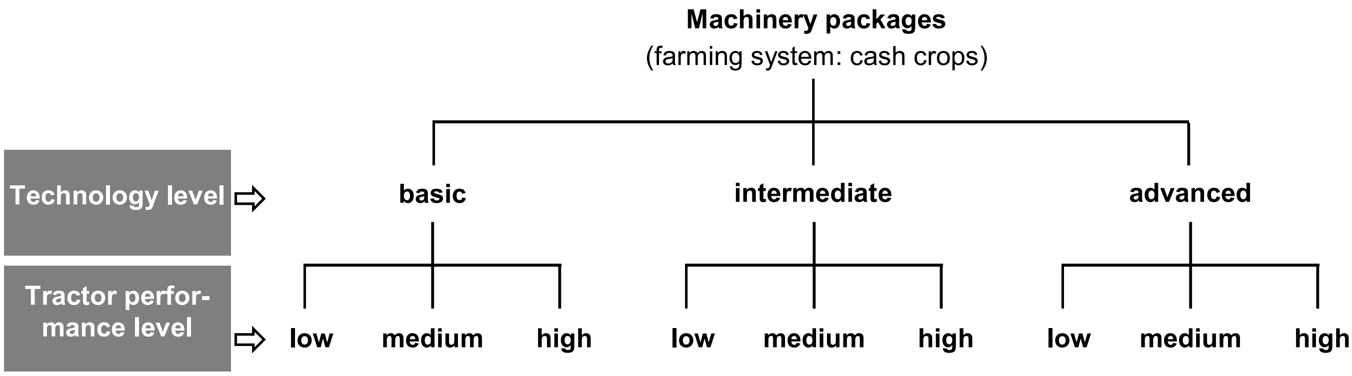
- Basic: Tractors with simple technical equipment and a relatively short life span. An example are tractors from China.
- Intermediate: Tractors with technically improved assemblies (engine, gearbox, hydraulics, etc.). Examples are tractors from India and Eastern Europe.
- Advanced: Tractors with modern technical equipment. Tractors of manufacturers from Western Europe and North America are examples of this.

In the IPS, it is assumed that the technology level of the implements corresponds to the technology level of the tractors. This means that a "basic" tractor, for example, would only be combined with "basic" implements.

2.4 Machinery packages

Combining the three tractor performance levels with the three technology levels, up to nine possible machinery packages can be defined, as displayed in the following figure.

Figure 4: Approach to identify machinery packages



Although nine different machinery packages are theoretically possible, not all combinations of the three tractor performance levels with the three technology levels can be found in the target countries.

While in the 80-hp-class all three technology levels are existing in the farming sector of the target regions, for the 110-hp-class only the 'intermediate' and 'advanced' technology levels can be found and in the 150-hp-class even only machines of the advanced technology level are existing.

In addition, for the fodder production enterprises of cattle farms even the 80-hp-class is found.

Figure 5: Machinery packages included in the IPS

		Cash crop farms				Cattle farms			
		Tractor performance (hp)				Tractor performance (hp)			
		30	80	110	150	30	80	110	150
Techn. level	Basic	X	X				X		
	Intermediate		X	X			X		
	Advanced		X	X	X		X		

In order to compare the costs of the different machinery packages not only between each other, the IPS also contains a separate scenario, showing the costs of hired services providers for each of the work processes included in the IPS.

2.5 Excursus: Gender aspects

In the development of the IPS, gender aspects also need to be considered. In particular, the formulation of site-adapted mechanization concepts should take into account issues in which work is performed to a large extent by women. The following findings were obtained from a questionnaire-based survey during an internal project training course with women.

Women are heavily involved in various crop cultivation work processes, especially on small-scale farms. Very often, women perform their tasks purely manually. Typical work processes carried out by women (manually) are:

- Land levelling
- Creation of seed ridges (maize)
- Planting and harvesting of potatoes and vegetables
- Application of organic and mineral fertilizers
- Weeding with hand hoe
- Threshing and winnowing of grain crops
- Land clearing (removal of crop residues after harvest)

In the IPS, mechanization packages for all of these work processes are included.

3 Conceptual basis of the IPS

The computerized information and planning System (IPS) aims to identify location-adapted mechanization concepts (i. E. number of specific machines required) for predefined farming systems based on a least-cost selection from different options.

3.1 Required number of machines

The demand of machines is determined by the size of the area to be cultivated on a particular farm or in a certain region and by the tasks (= work processes) to be performed on the area. The usage capacity of available machines is determined by many factors e.g. size and technical condition of the machines, suitable weather conditions for specific field work, availability of personnel, and others more. Since these factors change over the year, the capacity of each individual machine needs to be defined individually for different periods during the year. For this purpose, the calendar year is subdivided into 24 individual periods (half months) in the IPS.

The figure below shows the capacity and demand of a specific tractor ("Tractor 1") based on an exemplary size of area to be cultivated and usage capacity over the year, whereas only some periods are displayed for reasons of transparency. The tractor is used for various work processes for wheat and for maize in different periods of the year.

Figure 6: Capacity and demand of machinery utilization on the example of 'Tractor 1'

Area to be cultivated
(on farm or in region)

				Usage demand of 'Tractor 1' in various periods (in hours)									
				Apr			Aug		Sep		Oct		
Farm enterprise	Size	Unit.	Costs	04a	04b	...	08a	08b	09a	09b	10a	10b
Wheat	300	ha	112.080			...	90,0		60,0	165,0		
Maize	200	ha	99.718	56,0	60,0	...					40,0	
...			...									
Total:	500	ha	...	56,0	60,0	...	90,0		60,0	165,0	40,0	

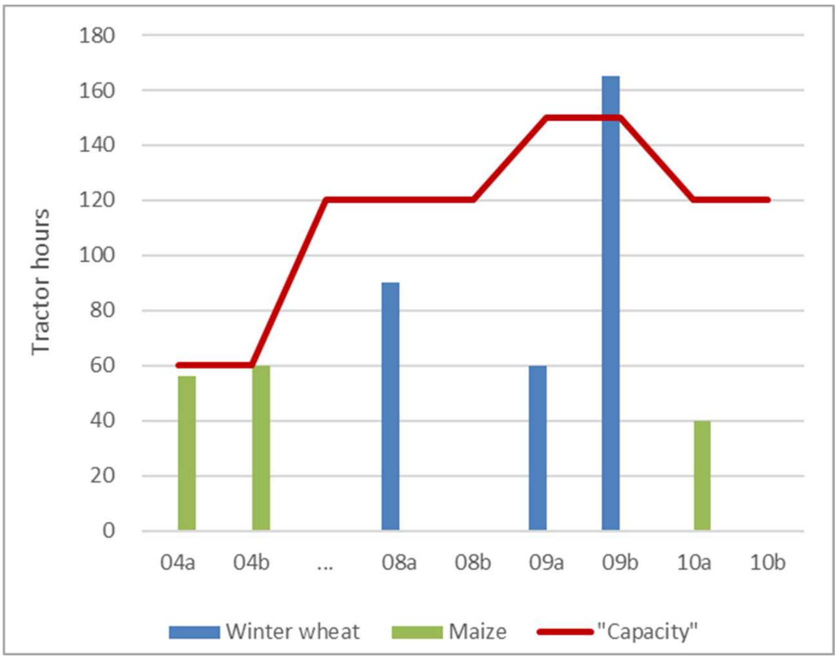
Machines

				Capacity of the machines in various periods for ONE maschine								
				Apr		...	Aug		Sep		Oct	
Name	Unit		Costs	04a	04b		08a	08b	09a	09b	10a	10b
Tractor 1	1	h	66,30	60	60	...	120	120	150	150	120	120
Cultivator	1	ha	10,10			...	192	192	192	120	120	120
Disc harrow	1	ha	8,90			...	240	240	240	150	150	150
...												

Coefficients in green coloured cells = data input
Coefficients in white coloured cells = calculated results

For determining the number of machines needed for a given area to be cultivated, those periods (half months) are relevant, where the scarcity of capacity is most severe. Although the total annual capacity of a machine might be sufficient for a larger area, a second machine can be necessary if the capacity in a certain period is deficient. This issue becomes more transparent when displaying the coefficients from Figure 6 in a diagram as shown in Figure 7.

Figure 7: Diagram with capacity and demand of machinery utilization (example of 'Tractor 1')



The red line in the diagram represents the capacity of the tractor hours over the year, while the columns illustrate the demand in the various periods. As long as the columns are below the red line, the capacity is sufficient. In the second half of September (period '09b') however, the column exceeds the capacity line. If some of the tractor hours scheduled for the "09b" period could be shifted to the period before or after, the situation could still be OK. If not, however, a second tractor will be needed, although the tractor's total annual capacity may not even be fully utilized.

In the same way as farm enterprises determine the demand of machinery, individual work processes for specific fieldwork tasks may lead to further need. This becomes relevant when farmers use their machines (in addition to their own field work) to offer mechanisation services to other farmers, or when machines are solely used for offering mechanisation services by commercial service providers or co-ops. Thus, not only "farming" enterprises are relevant to planning, but also "custom-service" mechanisation activities.

To balance the demand and capacity of machines, a number of intermediate planning steps are necessary between the user-defined area to be cultivated (determining the demand) and the capacity of the individual machines available.

Figure 8 illustrates the full data flow necessary to balance demand and capacity of machines. This data flow not only covers the physical units of machinery use (e.g. tractor hours) but also the mechanisation costs in order to be able to compare the costs of different technically suitable mechanisation concepts for a given area to be cultivated.

The intermediate data processing is not necessarily visible to the user, but can be opened if a user wants to change or add data, which is standardized by default. In most cases, only the top level ("Area to be cultivated") is what the user will need for interacting with the system since the area to be cultivated is the only information that the user needs to provide. This level represents the front-end of the system and requires a graphic user-interface, consisting of dialog-masks for data entry and a combination of tabular and graphical output.

The levels below the top level represent the back-end of the system and need to be pre-defined and constantly kept up-to-date by experts. Starting from the bottom level ("Machines"), experts have to provide all relevant information about each single machine in a data base list, then combine various machines to work processes and finally define, which work processes are needed for certain farm enterprises.

Figure 8: Data flow for balancing demand and capacity of machinery

Area to be cultivated
(on a farm or in a region)

Farm enterprise	Size	unit	Costs	Demand Apr 04a	Demand Apr 04b	
Winter wheat	300	ha	112,080			...
Maize	200	ha	99,718	56.0	60.0	...
,,,			,,,			
Total:	500	ha	211,798	56.0	60.0	...

The top level represents the front-end of the system, offering a user-interface for determining the demand of machinery use, based on the area to be cultivated with various crops.
For reasons of space availability, only April is displayed.

Farm enterprise: 1 ha Wheat

Mech,process	Size	unit	Costs	TrHrs	Period
Discing	1	ha	29.42	0.3	08a
Cultiv,. medium	0.5	ha	19.15	0.2	09a
Cultiv,. deep	1	ha	50.03	0.55	09b
,,, (rest)		ha	275.00		
Total			373.6	1.05	-

Farm enterprise: 1 ha Maize

Mech,process	Size	unit	Costs	TrHrs	Period
Cultiv,. deep	0.5	ha	19.15	0.2	10a
Cultiv,. medium	0.5	ha	25.02	0.28	04a
Discing	1	ha	29.42	0.3	04b
,,, (rest)		ha	425.00		
Total			498.59	0.78	-

For each farm enterprise the required work processes need to be defined and assigned to a certain period,
Similar processes with different demand of traction power (e,g, deep and shallow soil cultivation) need to be defined as separate processes,
The "size" of a process can be less than "1" if only a part of the area is concerned.

Work processes

Machine	Use	unit	Costs
1 ha Discing			
Tractor 1	0.3	h	20.52
Disc harrow	1	ha	8.90
1 ha Cultivating. medium			
Tractor 1	0.4	h	28.20
Cultivator	1	ha	10.10
1 ha Cultivating. deep			
Tractor 1	0.55	h	39.93
Cultivator	1	ha	10.10

Each work process consists of multiple machines, usually tractor + one or more attached implements.
Each work process refers to a certain unit. mostly 1 ha, However. units can also be 1 hour, 1 tonne, 1 m³, etc,
The combination of machines in on work process determines also the costs of the process,

Machines

Name	Unit		Costs	Capacity Apr 04a	Capacity Apr 04b	,,,
Tractor 1	1	h	66.30	60	60	...
Cultivator	1	ha	10.10			
Disc harrow	1	ha	8.90			...

The basis of the data flow is the list of machines with all information about costs and performance capacity for each individual machine.

3.2 Machinery cost calculation

After determining the required number of machines as described above, the annual costs of the complete machinery package (= tractors with all implements of a certain category) can be calculated.

The coefficients, which are, for the costs calculation, required to be entered for each machine individually, are:

- Acquisition costs (effective purchase price including all extra costs for acquiring a machine like transport fees, administrational fees for initial setting into operation, etc.)
- Annual payments for insurance, technical supervision, and other use-independent (fixed) costs (e.g. taxes, fees, etc.)
- Repair costs (can be estimated based on acquisition costs)
- Consumption of diesel (or electricity) per working unit *)
- Costs for other use-dependent (variable) inputs (e.g. binder twine, plastic coat for silo bales)
- Standard lifespan in time (years) and in working units *)
- In case of rented machines: rent paid per working unit *)
- Use capacity during 24 half-month-periods in hours

*) working units: e.g. hours, hectares, m³, etc.

Parameters, which are entered as standard values to be used for all machines are:

- Consumption of oil and, if applicable, AdBlue as a percentage of diesel consumption
- Prices for diesel, oil, AdBlue per litre and for electricity per kWh
- Interest rate for calculating financing costs (weighted average of costs rates for borrowed and owned capital)
- Residual value (estimated as percentage of acquisition costs)
- Costs for housing the machines (can be estimated based on space requirements of machines)

Further optional data which *can* be entered for each machine individually (but which are not used for calculations) include Traction power of tractors and traction power requirements of implements, working width, maximum speed, weigh, load on coupling joint, cumulated energy demand.

The mechanisation costs as calculated in the IPS include the direct machinery costs, labour costs and, for the special purpose of determining the minimum cost-covering price for offering mechanisation services, also allowances for overheads and risk.

Figure 9: Costs of machines and work processes as calculated in the IPS

<table>
<tr><td>Variable costs
of all machines and implements used for the work process</td><td rowspan="2">Total machinery costs of work process</td><td rowspan="3">Total direct costs of work process</td><td rowspan="4">Total costs of work process</td><td rowspan="5">Price basis for offering mechanization service</td></tr>
<tr><td>Fixed costs
of all machines and implements used for the work process</td></tr>
<tr><td colspan="2">Labour costs
for all personnel carrying out the work process</td></tr>
<tr><td colspan="3">Overheads (estimated as a percentage of total direct costs)</td></tr>
<tr><td colspan="4">Risk allowance (estimated as a percentage of total direct costs)</td></tr>
</table>

The machinery costs include fixed and variable costs. Fixed costs are those, which are independent from the annual use of a machine, they even occur when not using a machine at all but keep it ready to be used. Variable costs increase with growing annual use and vice versa, in many cases even proportionally. For this reason, fixed costs are in the first step calculated per year (because they are constant per year) and then converted to costs per working unit (e.g. per tractor-hour), while variable costs are in the first step calculated per working unit (e.g. per tractor-hour, because they are constant per unit) and then converted to costs per year.

In the IPS the calculation of the average annual costs of a single machine may look as shown in the following example for a tractor, assuming the following basic data:

Acquisition costs (A)	$ 100,000
Residual value (R)	$ 20,000
Standard lifespan: Number of years (N)	10 years
Standard lifespan: Number of hours of use (n)	10,000 hours
Interest rate for financing (i)	5%
Annual use	800 hours

	$ per year	$ per hour
Fixed costs (independent of annual use)	/ 800 hrs/y →	
Depreciation (A – R) / N	8,000	10.00
Interest (A + R) / 2 × i	3,000	3.75
Other (may incl. insurance, techn. supervision, etc)	0	0.00
Total fixed costs	**11,000**	**13,75**
Variable costs (depending on the annual use)	← × 800 hrs/y	
Repairs (estimated on basis of A)	10,400	13.00
Fuel and lubricants (based on fuel consumption)	17,280	21.60
Total variable costs	27,680	34.60
Total costs (fixed + variable)	**38,680**	**48.35**

While it is easy for most cost items to assign them to one of the two categories, fixed and variable, such a categorization can become difficult for the *depreciation*. The depreciation describes the loss of the value of a machine over time, i.e. the difference of its value at the beginning of its lifespan (= acquisition costs) and at the end of its lifespan (= residual value). The average annual loss of the value of a machine per year of its lifespan (= average annual depreciation) is calculated with the following formula:

$$Average\ annual\ depreciation = \frac{Aquisition\ costs - Residual\ value}{Number\ of\ years\ of\ livespan} = \frac{A - R}{N}$$

As long as the residual value and lifespan of a machine is considered to be independent from the annual use of the machine, the calculated depreciation is a *fixed* cost. However, increasing annual use of machine *can* reduce the residual value and the lifespan of a machine, turning the depreciation into a *variable* cost. The following paragraphs explain how the lifespan and the residual value of a machine can be determined for cost calculations.

Determining the lifespan of a machine

The lifespan of a machine is limited by two different parameters: the maximum time of use (in years) and the maximum lifetime working capacity (in working units, such as hours, hectares, m^3, etc.).

The time-based lifespan limit of a machine is justified with the ongoing technical progress that makes it necessary to replace a machine after a certain number of years (usually after 8 to 15 years) in order to take advantage of improved technological developments.

While the time-based lifespan limit of a machine might be extended (foregoing the advantage of benefiting from technical progress), the lifetime working capacity is an absolute limit that should not be exceeded, since otherwise the risk of high, uneconomic repair costs is increasing dramatically.

For machinery calculations, both lifespan limits need to be observed: the limit, which is reached earlier determines the expected lifespan! The following example for a high-quality tractor may illustrate and explain the interrelations:

Time-based lifespan limit:	maximum 10 years (exemplary assumption)
Capacity-based lifespan limit:	maximum 10,000 hours (exemplary assumption)

Therefore, the average annual use of the tractor at 100% utilization of it's capacity is:

10,000 hours / 10 years = 1,000 hours/year

If the *actual* average annual use of the tractor will be

a) below 1,000 hours/year,	the time-based limit of 10 years will be reached earlier than the capacity-based limit of 10,000 hours, or, in other words, the tractor will have worked less than 10,000 hours after 10 years of use.
b) above 1,000 hours/year,	the capacity-based limit of 10,000 hours will be reached earlier than the time-based limit of 10 years, or, in other words, the age of the tractor will still be below 10 years when it has worked 10,000 hours.

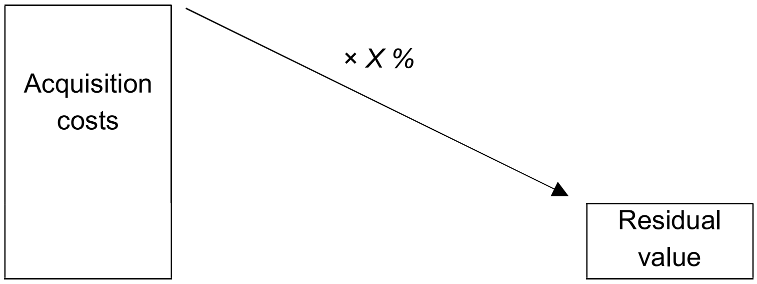
Example for case a: Actual average annual use of the tractor = 800 hours/year (exemplary assumption)
⇨ Total lifetime working load: 800 hours/year × 10 years = 8,000 hours
⇨ Total lifetime working load < capacity limit of 10,000 hours
⇨ Lifespan of 10 years will be reached
⇨ Lifespan of 10 years will be used to calculate depreciation

Example for case b: Actual average annual use of the tractor = 1.200 hours/year (exemplary assumption)
⇨ Total lifetime working load = capacity limit of 10,000 hours
⇨ Lifespan of 10 years will not be reached
⇨ Working capacity limit will be reached already after:
10,000 hours / 1,200 hours/year = 8.33 years
⇨ Lifespan of 8.33 years will be used to calculate depreciation

Since the above calculated 1,000 hours/year average annual use of the tractor at 100% utilization of it's capacity marks the turning point when the fixed lifespan limit of 10 years becomes variable and falls below 10 years, it is also the turning point, at which depreciation changes from fixed to variable. Therefore, the value that results from dividing the capacity-based lifespan limit by the time-based lifespan limit (e.g. 10,000 hours / 10 years) is generally referred to as "Depreciation Threshold".

Determining the residual value of a machine

In order to avoid lengthy calculations and continuous manual adjustments of the absolute residual values of each and every machine individually, the IPS allows to determine the residual values of the machines as a percentage of their acquisition costs as illustrated in the following figure:



Example: 100,000 × 20% = 20,000

In the IPS, the required percentage rate to be multiplied by the acquisition costs can be determined using one of the following two options:

Option 1: percentage rate is determined as a user-defined *fixed* value (independent from the annual machine use), using one fixed percentage rate for *all* machines.

Option 2: percentage rate is a *variable*, which is calculated by the IPS individually for each machine depending on its annual use (within user-defined limits).

In case of the second option, the percentage rate is calculated by the IPS based on the lifetime workload of the machine, assuming that the loss of value over time increases with increasing use of the machine. The calculation method applied in the IPS follows the following basic concept:

If	100% of the lifetime capacity limit will be used	⇨ residual value =	0% of acquisition costs
	90% of the lifetime capacity limit will be used	⇨ residual value =	10% of acquisition costs
	80% of the lifetime capacity limit will be used	⇨ residual value =	20% of acquisition costs
...		...	
	20% of the lifetime capacity limit will be used	⇨ residual value =	80% of acquisition costs
	10% of the lifetime capacity limit will be used	⇨ residual value =	90% of acquisition costs

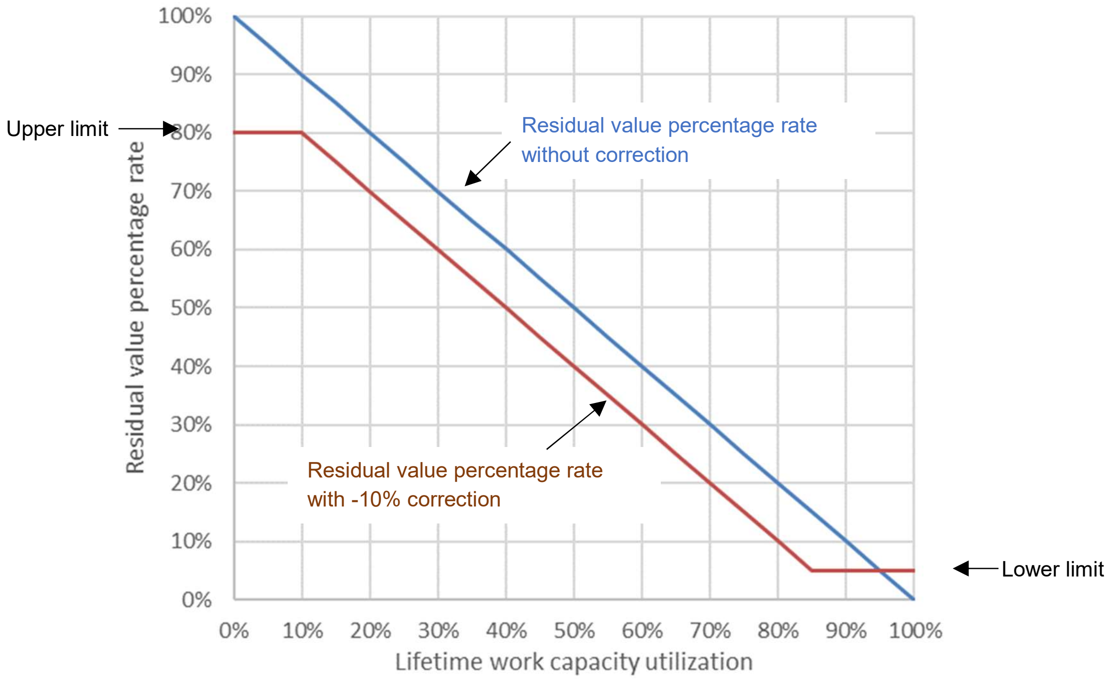
In real life, such a simplified calculation would not reflect the actual residual values of machines, but it is a first step in estimating. To be more realistic, the IPS user can adjust the calculated residual values by setting a lower and upper limit of the residual value percentage rate. In addition, the user can set a correction rate to increase or decrease the calculated residual values.

Example: If the user sets 5% for the lower limit and 80% for the upper limit, and -10% value correction, the calculated residual value of a tractor with acquisition costs of 100,000 will:

- not fall below 5,000 (because of 5% lower limit)
- not exceed 80,000 (because of 80% upper limit)
- be 10,000 less than the calculated value, for all cases in-between the allowed range (because of the -10% correction)

In general, the residual value percentage rate is calculated by the IPS as shown in the following graph, assuming either no corrections (blue line) or the above mentioned corrections (red line).

Figure 10: Different options determining the residual value of a machine in the IPS



In the IPS, the selection of the different options and, if applicable, the limits and corrections values, are set by the user by calling the Data Entry Assistant and clicking the button for the 'basic settings' on the dashboard dialog.

Calculating the average annual depreciation

When calculating the average annual depreciation, the IPS combines both fields described above: calculating the effective lifespan and the residual value of a machine.

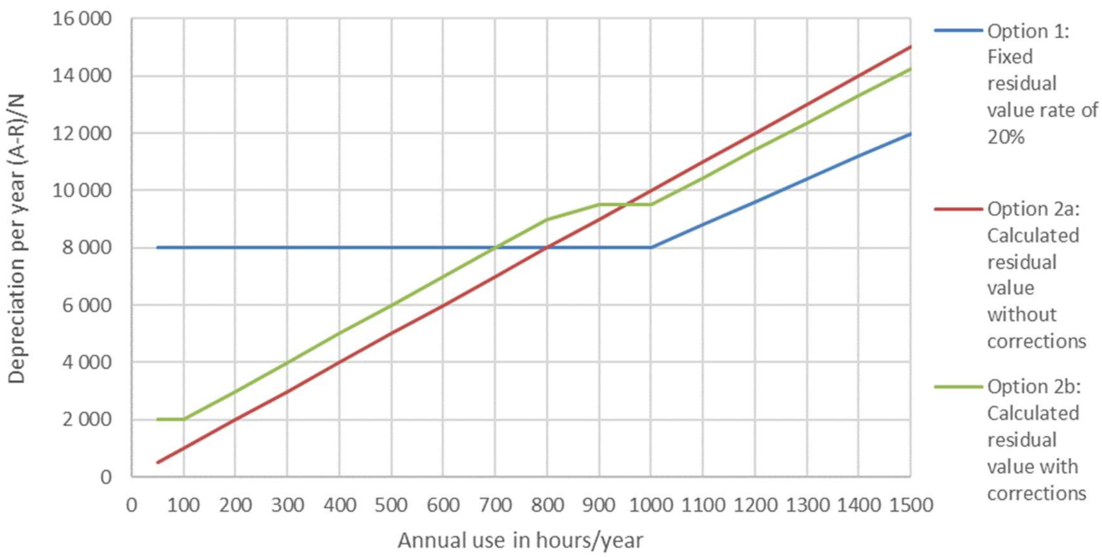
For the above mentioned high-quality tractor (exemplary assumption) with acquisition costs of 100,000, a time-based lifespan limit of maximum 10 years and a capacity-based lifespan limit of maximum 10,000 hours, the calculation of the annual depreciation would look as follows for different levels of annual use of the tractor, considering the different options that the IPS provides:

Basic data				Option 1: Fixed residual value rate of 20% (exemplary assumption)		Option 2: Calculated residual value.			
Annual use in hours/year	Lifespan in years (N)	Lifetime workload in hours	Utilization of lifetime capacity in %			without corrections		with corrections	
				Residual value (R)	Deprec. (A-R)/N	Residual value (R)	Deprec. (A-R)/N	Residual value (R)	Deprec. (A-R)/N
50	10.00	500	5%	20,000	8,000	95,000	500	80,000	2,000
100	10.00	1,000	10%	20,000	8,000	90,000	1,000	80,000	2,000
200	10.00	2,000	20%	20,000	8,000	80,000	2,000	70,000	3,000
300	10.00	3,000	30%	20,000	8,000	70,000	3,000	60,000	4,000
400	10.00	4,000	40%	20,000	8,000	60,000	4,000	50,000	5,000
500	10.00	5,000	50%	20,000	8,000	50,000	5,000	40,000	6,000
600	10.00	6,000	60%	20,000	8,000	40,000	6,000	30,000	7,000
700	10.00	7,000	70%	20,000	8,000	30,000	7,000	20,000	8,000
800	10.00	8,000	80%	20,000	8,000	20,000	8,000	10,000	9,000
900	10.00	9,000	90%	20,000	8,000	10,000	9,000	5,000	9.500
1000	10.00	10,000	100%	20,000	8,000	0	10,000	5,000	9.500
1100	9.09	10,000	100%	20,000	8,800	0	11,000	5,000	10.450
1200	8.33	10,000	100%	20,000	9,600	0	12,000	5,000	11.400
1300	7.69	10,000	100%	20,000	10,400	0	13,000	5,000	12.350
1400	7.14	10,000	100%	20,000	11,200	0	14,000	5,000	13.300
1500	6.67	10,000	100%	20,000	12,000	0	15,000	5,000	14.250

*) The corrections used in the example for the residual value percentage rate are (again): 5% lower limit, 80% upper limit, -10% value correction

The following graph illustrates the calculated average annual depreciation for different levels of annual use of the tractor, considering the different options that the IPS provides:

Figure 11: Annual depreciation according to different options for determining the residual value of a machine in the IPS



Since both values, the effective lifespan (in years) and the residual value of a machine, are calculated by the IPS before applying the formula for the depreciation (A - R) / N, all parameters for the formula are given (= fixed) for the user-defined data entry of the area (in hectares) to be mechanized. In the IPS, depreciation is therefore always listed as a fixed cost, although it will be recalculated as soon as the user changes the area to be mechanized.

Calculating the average annual interest costs

Investing in goods ties up capital. Interest must be paid on external finance, and no interest can be earned on equity. The interest cost incorporates both the interest expenses to be paid on external finance (borrowed capital) and the opportunity costs for using own capital.
Interest costs are generally part of the fixed costs as the annual use of a machine will never have an influence on the annual cost amount.

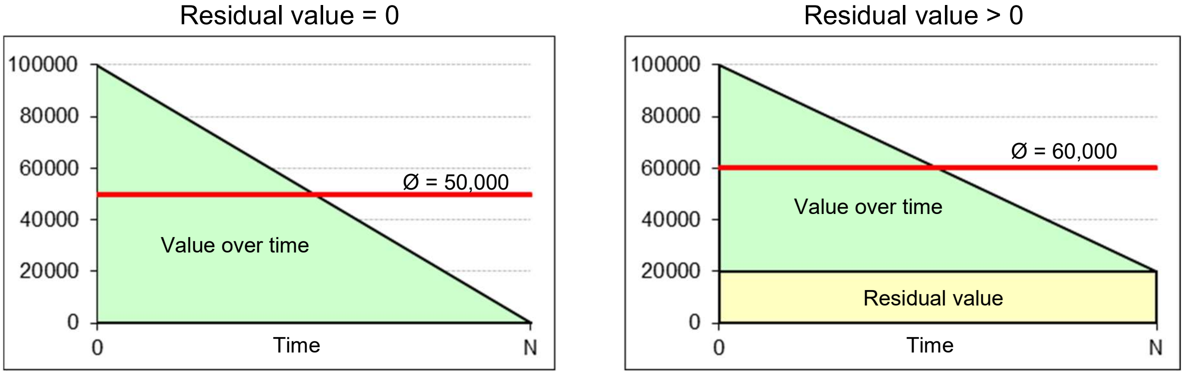
The amount of the average annual interest cost depends on

- the average fixed asset value for which interest costs occur, and
- the interest rate (i) per annum.

$$Interest\ costs = Average\ asset\ value\ over\ the\ entire\ duration\ of\ use \times Interest\ rate\ (i)$$

Interest rate =	weighted cost rate (% p.a.) from proportion of external finance and proportion of equity
Average asset value =	Average of the value at the beginning (= Acquisition costs) and of the value at the end of the useful life (= Residual value)

Figure 12: Determining the average asset value of machines



Calculation:

$$Average\ asset\ value = \frac{Aquisition\ costs + Residual\ value}{2} = \frac{A + R}{2}$$

If the residual value equals 0, the average fixed asset value over time is: $\frac{A}{2}$

The complete formula for determining the average annual interest costs is therefore:

$$Average\ annual\ interest\ costs = \frac{A + R}{2} \times Interest\ rate\ (i)$$

Determining the repair costs

Repair costs are generally part of the variable costs as they raise with increasing annual use of a machine. In the IPS, the repair costs are estimated on the basis of machine-specific coefficients, which relate the repair costs to the acquisition costs of the machines. For the tractor-example shown above, the repair costs were determined as follows:

Acquisition costs	$ 100,000
× Machine-specific coefficient	1.3
= Total repair costs of the tractor in complete life-time	$ 130,000
/ Capacity-based lifespan (number of hours of use in life-time (n))	10,000 hours
= Repair costs of the tractor per working unit ($ per hour)	$ 13.00 per hour

The machine-specific coefficients as used in the IPS are as follows:

Self-propelled machines	Coefficient
Tractors	1.3
Trucks	0.59
Loaders	0.57
Self-propelled field choppers	0.5

Implements	Coefficient
Ploughs	1.5
Disc harrows	1.6
Seed drills	0.5
Single-seed planter	0.3
Potato planter	0.7
Fertilizer spreaders	0.1
Boom sprayers	0.1
Tyne ridgers	0.9
Inter-row cultivators	0.6
Combine harvesters	0.3
Potato harvesters	0.3
Mounted field choppers	1
Grass mowers	1.4
Hay turners	1.5
Swath rakes	2.1
Balers	0.17
Trailers	0.4

Determining the costs for fuel and lubricants

Costs for fuel and lubricants are generally part of the variable costs as they raise with increasing annual use of a machine. The calculation is based on 'quantity multiplied by price'. For the tractor-example shown above, the costs were determined as follows:

Diesel:	15 litres per hour	×	$ 1.40 per litre	=	$ 21.00 per hour
Oil:	0.15 litres per hour	×	$ 4.00 per litre	=	$ 0.60 per hour
Total:					$ 21.60 per hour

The average quantity of oil is generally estimated at 1% of the diesel consumption.

4 Structure and application of the IPS

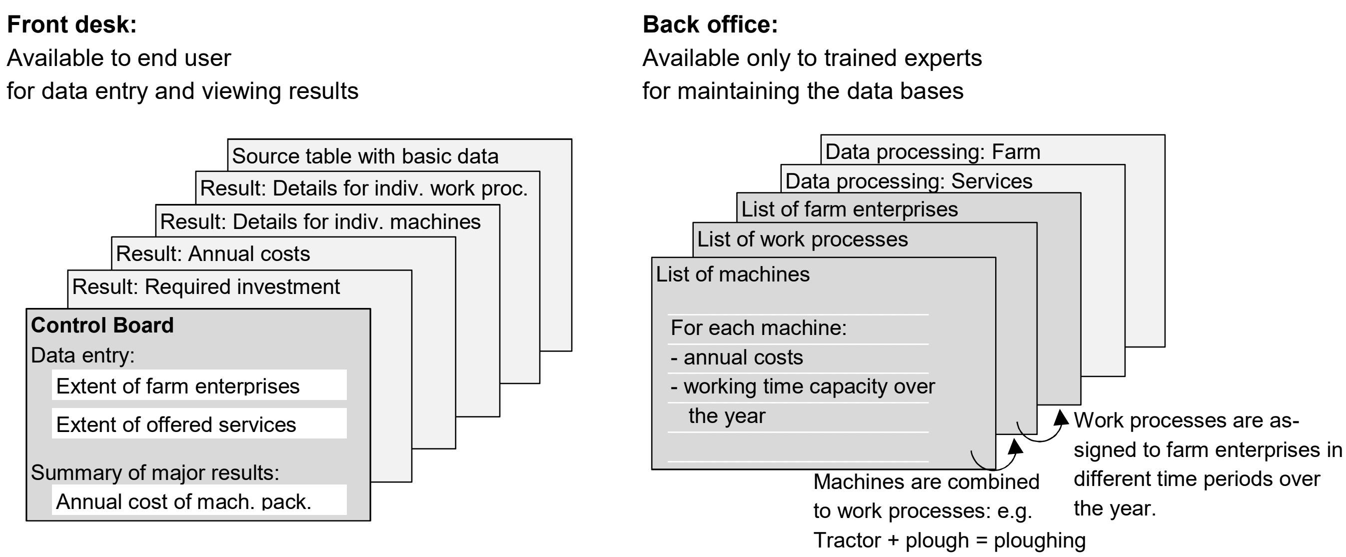
4.1 Structure of the IPS

The Information and Planning System (IPS) for Location-Adapted Mechanization Concepts consists of two sections:

a) Front desk: the part which is available to the end user for data entry (extent of farm enterprises and of offered mechanization services) and with all the result output tables,

b) Back office: the part which is available only to trained experts maintaining the databases with machines, work processes and farm enterprises.

Figure 13: Structure of the Information and Planning System



The IPS is based on Microsoft Excel. Each of the tables / masks shown in the figure above is located on a separate Excel sheet. However, the common Excel user-interface (e.g. menu ribbon, row and column headers) is not available to the front desk user. All necessary commands to carry out any user interaction are available only through command buttons at the top of each sheet. All programming of additional specific functions is done with Visual Basic for Application (VBA), which is an Excel built-in programming language.

Users of the back office have full access to all Excel menus and functions and have, in addition, also VBA programmed command buttons available with assisting functions for the specific tasks necessary to maintain the databases with machines, work processes and farm enterprises.

4.2 Front desk

4.2.1 General aspects

All data entry required from the end user defining the mechanization requirements together with the most important coefficients of the results are located on one sheet, which is called the *Control board*.

This user-given data defining the mechanization requirements comprises the extent of farm enterprises (hectares of cultivated crops) with all their work processes and/or the extent of single work processes for which the necessary cost-minimized mechanization equipment is to be determined. The extent of farm enterprises and the extent of single work processes ca be combined without any restriction.

The *Control board* also shows the major results in graphical and tabular form for all pre-defined alternative mechanization packages. Since the annual costs of all mechanization packages are simultaneously recalculated whenever the user is entering a value, the mechanization package with lowest annual cost can be identified at any time.

All other sheets of the *Front desk* offer detailed views of the results. In particular, there are result tables for:

Required investment: a table with a list of all the machines of all the different machinery packages, displaying the number of machines required together with the resulting investment costs (purchase price), the utilization of the machines in the peak periods, the expected annual use and the expected lifespan of the machines.

Annual costs: a table that presents all the individual fixed and variable cost items for all pre-defined alternative mechanization packages, as well as the expected consumption of fuel and lubricants.

Details for individual machines: a table where the user can select any of the machines from the database to display the full machinery cost calculation, the use of the machine over the year (= working time requirement according to half months) and major technical coefficients of the machine.

Details for individual work processes: a table where the user can select any of the pre-defined work processes from the database to display the full cost calculation, the use of the work process over the year (= working time requirement according to half months) and the annual costs of all machines belonging to the selected work process.

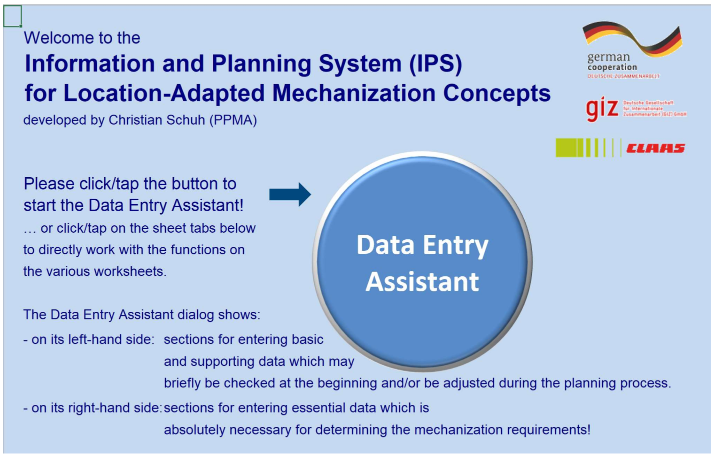
All sheets are further described and explained in the following sub-chapters.

All required data from the end user is entered using the *'Data Entry Assistant'*, which can be accesses from any sheet in the *'Front desk'* section. The '*Data Entry Assistant'* is leading the user through the different parts of required data allowing a step-by-step data entry process.

4.2.2 Data Entry Assistant

When the IPS is started, the welcome screen is displayed. Here, the user is prompted to start the *Data Entry Assistant*. The *Data Entry Assistant* is leading the user through the different parts of required data, allowing a step-by-step data entry process. The assistant can also be called from any sheet in the *Front Desk* section.

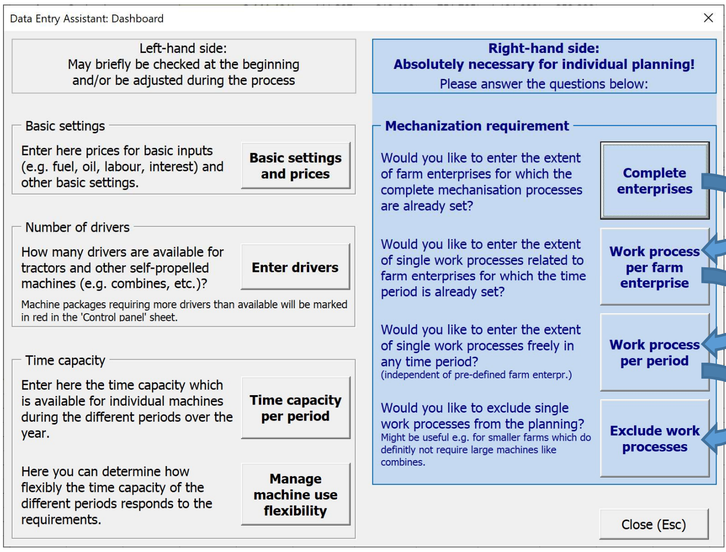
Figure 14: Screenshot of the welcome screen with the 'Data Entry Assistant'



The central element of the data input assistant is a kind of dashboard. It allows a guided step-by-step data entry process as well as quick jumping to any data entry section from any point during the analysis process. Pressing the command buttons will open data input dialogs, where the user can enter and change data, which are required for the analysis process. The input sections for individual user-specific data that are absolutely required for the analysis process is located on the right-hand side of the dashboard, while the left-hand side of the dashboard contains buttons to call dialogs for entering basic settings and sections for data manipulation during the analysis process.

Figure 15: Screenshot of the Data Entry Assistant's dashboard

The left-hand side of the dashboard contains input sections with basic settings and sections for data manipulation during the analysis process. Thus, the inputs may briefly be checked at the beginning and/or be adjusted during the analysis process.



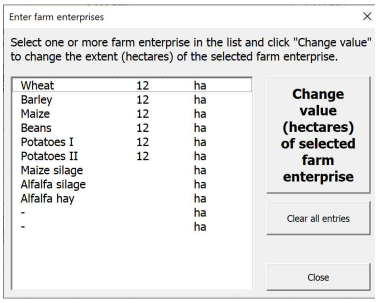
The right-hand side contains input sections for individual user-specific data that are absolutely needed for the analysis process!
There are command buttons available for calling up the data input dialogs for determining the mechanization requirements based in the entered extent of farm enterprises and/or single work processes to be mechanized.
The data entry can be done in a consecutive order or by jumping directly to the required section.

The single data input dialogs, which are accessible from the *Data Entry Assistant's* dashboard are shown and explained in the following.

Right-hand side of the Data Entry Assistant's dash board:

For entering the individual user-specific data determining the area to be mechanized (in hectares) on the right-hand side of the dashboard there are three possibilities (linked to three command buttons):

Farm enterprises with full mechanization (in hectares)

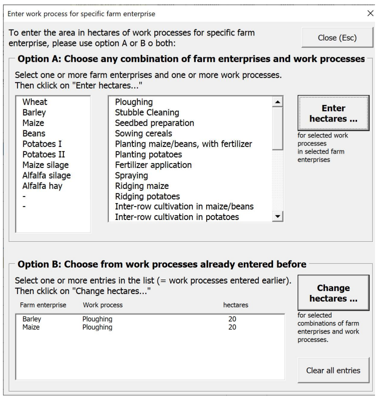


↓

For the farm enterprises as shown in Figure 1 and Figure 2 (like wheat, barley, etc.), the complete mechanization of all work processes is already pre-defined in the IPS. This includes the involved machines and the time requirements during specific periods.

Example: entering X ha of wheat adds in one step 8 work processes to the analysis, each of them already assigned to the correct time period (half-month) when the activity is performed. Figure 3 shows which work processes are assigned to which farm enterprises.

Single work processes for specific farm enterprises (in hectares)

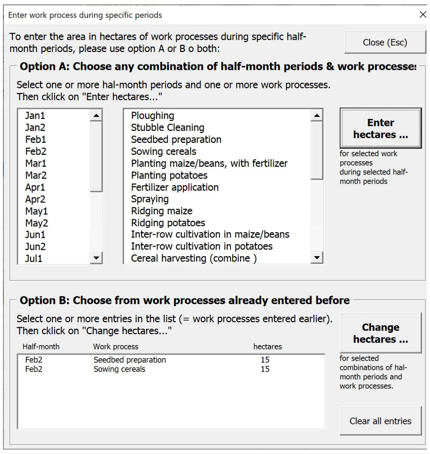


↓

For single work processes for specific farm enterprises as shown in Figure 3 the involved machines and the time requirements during specific periods are already pre-set.

Example: entering X ha of ploughing in wheat adds only this specific work processes to the analysis, already assigned to the correct time period (half-month) when ploughing is performed in wheat production.

Single work processes during specific time periods (in hectares)



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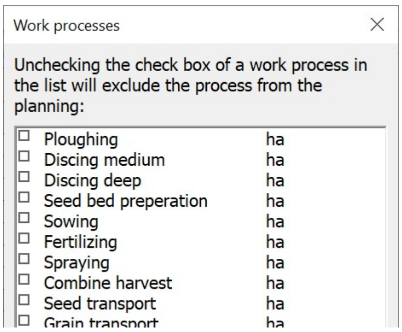
Any single work processes can be entered freely during any time period over the year. For these work processes the involved machines and the time requirements per hectare are already pre-set, but there is no pre-assignment to a specific half-month, as this can be entered freely by the user. This input section is most flexible as it allows to add work processes for farm enterprises that are not included in the IPS.

Example: entering X ha of ploughing in sweet potatoes (this farm enterprise is not included in the IPS) in first half of May adds only this specific work processes to the analysis and assigns it to the first half of May (independent of any farm enterprise).

Excluding certain work processes:

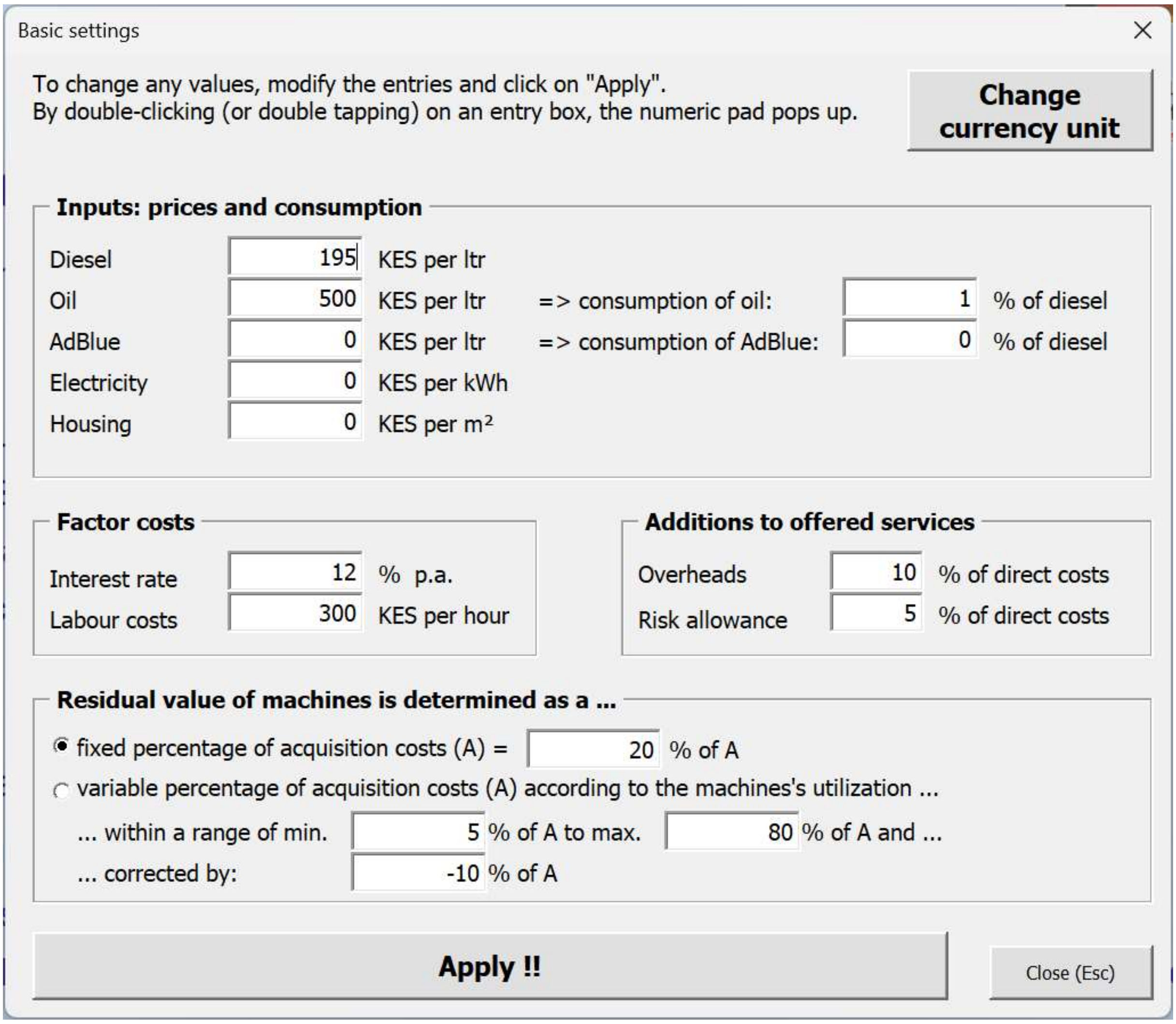
For each farm enterprise, a complete set of all necessary work processes is pre-defined. However, a farmer or service provider might wish to exclude certain work processes, e.g. harvesting with combine harvester, because he does not want to invest in this certain machine.



Left-hand side of the Data Entry Assistant's dash board:

On the left-hand side of the Data Entry Assistant's dash board there are command buttons to call dialogs for entering basic settings and option settings for data manipulation during the analysis process. Thus, the inputs may briefly be checked at the beginning and/or be adjusted during the analysis process.

a) Basic settings

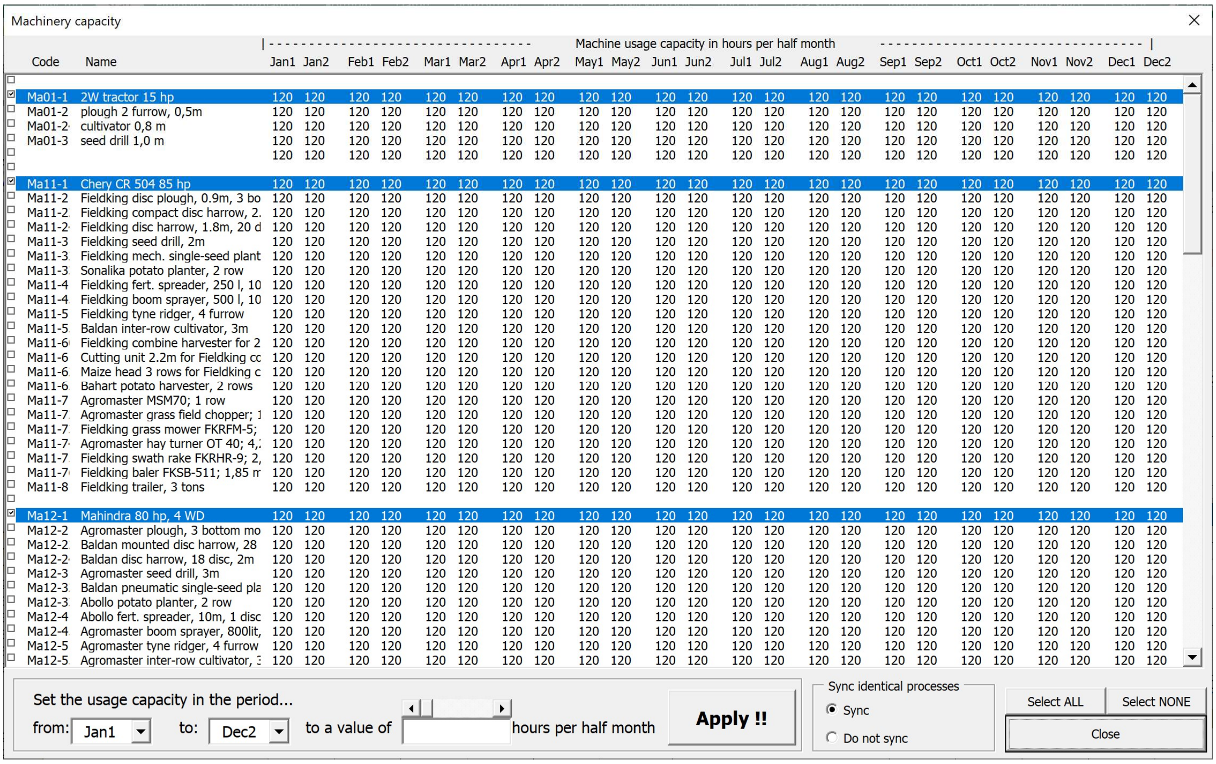


b) Number of drivers

Optionally, the number of drivers available for tractors and other self-propelled machines (e.g. combines, etc.) can be entered. Machine packages requiring more drivers than available will be marked in red in the 'Control panel' sheet.

c) Time capacity per period (changing machine capacity in specific time periods)

Each machine has a use capacity in hours per half month. This hour-capacity can be changed for each machine individually and for each half-month individually. Setting up this table is especially necessary, when setting up the IPS for a new region.



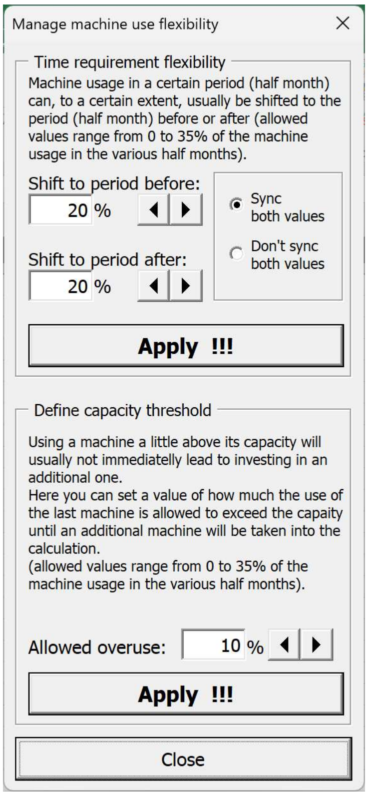
d) Manage machine use flexibility:

Working time requirement flexibility:

Machine usage in a particular peak period (half month) can, to a certain extent, usually be shifted to the period (half month) before or after (allowed values range from 0 to 35% of the machine usage in the various half months). This leads to a more balanced machine use over the year and might lead to less investment requirement. →

Define capacity threshold:

In addition, using a machine a little above its capacity in a certain period (half-month) will usually not immediately lead to investing in an additional machine. The user can set a value of how much the use of the last machine is allowed to exceed the capacity until an additional machine will be taken into the calculation (allowed values range from 0 to 35% of the machine usage in the various half months). →



4.2.3 Control board sheet

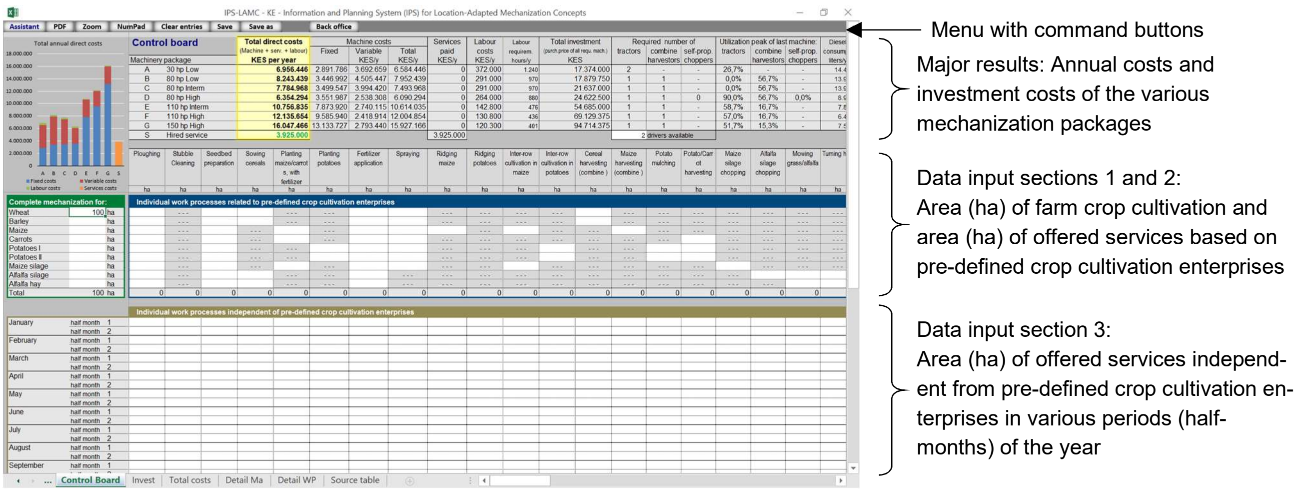
The Control board sheet provides a systematic summary of the entered individual user-specific data for determining the mechanization requirements (based on entered extent of farm enterprises and/or single work processes to be mechanized) and shows the major results in graphical (chart) and tabular form.

There are three data input sections for determining the mechanization requirements, which can be combined without any restriction:

- Area (ha) of farm crop cultivation enterprises, which need to be fully mechanized comprising all work processes as listed in Figure 3.
- Area (ha) of single work processes for specific crops (= pre-defined time period)
- Area (ha) of single work processes independent from pre-defined crop cultivation enterprises in any period (half-month) of the year.

In the upper part of the mask, the Control board shows the major results in graphical (chart) and tabular form: the total annual direct cost (= fixed and variable machinery costs plus labour costs) and the total investment cost (= total purchase price) for all pre-defined alternative mechanization packages. Since the annual costs of all mechanization packages are simultaneously recalculated whenever the user is entering a value, the mechanization package with lowest annual cost can be identified at any time.

Figure 16: Screenshot of the 'Control board'



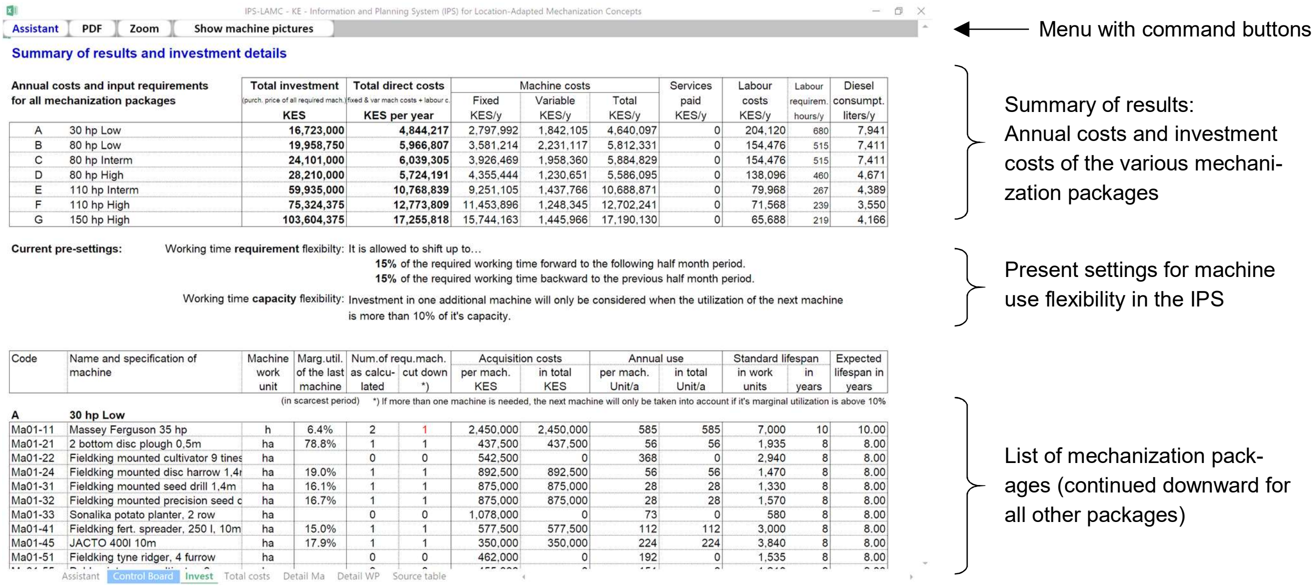
Through the command buttons in the menu row, the user can control the following:

- Assistant: call the Data Entry Assistant's dashboard (see chapter 4.2.2).
- PDF export of the present mask
- Zoom-settings of the mask
- NumPad: opens a numeric pad for user-friendly entry of numbers on tablets
- Clear entries: clear selected user-specific data with mechanization requirements (hectares to be mechanized)
- Save / Save as: saves the file

4.2.4 Required investment (on sheet "Invest")

The sheet "Invest" of the front desk contains a table with a list of all the machines of all the different machinery packages, displaying the number of machines required together with the resulting investment costs (purchase price), the expected annual use and the expected lifespan of the machines.

Figure 17: Screenshot of the mask for details about the required investment



Summary of results and investment details

Annual costs and input requirements for all mechanization packages		Total investment (purch. price of all required mach.) KES	Total direct costs (fixed & var mach costs + labour c.) KES per year	Machine costs Fixed KES/y	Machine costs Variable KES/y	Machine costs Total KES/y	Services paid KES/y	Labour costs KES/y	Labour requirem. hours/y	Diesel consumpt. liters/y
A	30 hp Low	**16,723,000**	**4,844,217**	2,797,992	1,842,105	4,640,097	0	204,120	680	7,941
B	80 hp Low	**19,958,750**	**5,966,807**	3,581,214	2,231,117	5,812,331	0	154,476	515	7,411
C	80 hp Interm	**24,101,000**	**6,039,305**	3,926,469	1,958,360	5,884,829	0	154,476	515	7,411
D	80 hp High	**28,210,000**	**5,724,191**	4,355,444	1,230,651	5,586,095	0	138,096	460	4,671
E	110 hp Interm	**59,935,000**	**10,768,839**	9,251,105	1,437,766	10,688,871	0	79,968	267	4,389
F	110 hp High	**75,324,375**	**12,773,809**	11,453,896	1,248,345	12,702,241	0	71,568	239	3,550
G	150 hp High	**103,604,375**	**17,255,818**	15,744,163	1,445,966	17,190,130	0	65,688	219	4,166

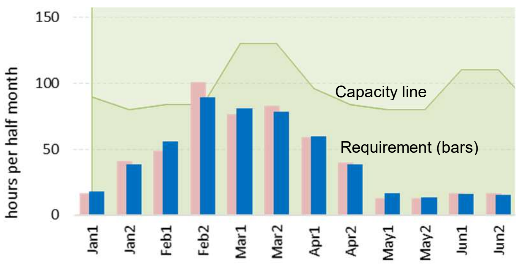
Current pre-settings: Working time **requirement** flexibilty: It is allowed to shift up to…
15% of the required working time forward to the following half month period.
15% of the required working time backward to the previous half month period.

Working time **capacity** flexibility: Investment in one additional machine will only be considered when the utilization of the next machine is more than 10% of it's capacity.

Code	Name and specification of machine	Machine work unit	Marg.util. of the last machine (in scarcest period)	Num.of requ.mach. as calcu-lated	Num.of requ.mach. cut down *)	Acquisition costs per mach. KES	Acquisition costs in total KES	Annual use per mach. Unit/a	Annual use in total Unit/a	Standard lifespan in work units	Standard lifespan in years	Expected lifespan in years
A	**30 hp Low**											
Ma01-11	Massey Ferguson 35 hp	h	6.4%	2	1	2,450,000	2,450,000	585	585	7,000	10	10.00
Ma01-21	2 bottom disc plough 0,5m	ha	78.8%	1	1	437,500	437,500	56	56	1,935	8	8.00
Ma01-22	Fieldking mounted cultivator 9 tines	ha		0	0	542,500	0	368	0	2,940	8	8.00
Ma01-24	Fieldking mounted disc harrow 1,4r	ha	19.0%	1	1	892,500	892,500	56	56	1,470	8	8.00
Ma01-31	Fieldking mounted seed drill 1,4m	ha	16.1%	1	1	875,000	875,000	28	28	1,330	8	8.00
Ma01-32	Fieldking mounted precision seed c	ha	16.7%	1	1	875,000	875,000	28	28	1,570	8	8.00
Ma01-33	Sonalika potato planter, 2 row	ha		0	0	1,078,000	0	73	0	580	8	8.00
Ma01-41	Fieldking fert. spreader, 250 l, 10m	ha	15.0%	1	1	577,500	577,500	112	112	3,000	8	8.00
Ma01-45	JACTO 400l 10m	ha	17.9%	1	1	350,000	350,000	224	224	3,840	8	8.00
Ma01-51	Fieldking tyne ridger, 4 furrow	ha		0	0	462,000	0	192	0	1,535	8	8.00

*) If more than one machine is needed, the next machine will only be taken into account if it's marginal utilization is above 10%

When the working time requirement of a machine exceeds its capacity during a certain period (half-month), while the capacity is sufficient during the rest of the year, the investor would usually not immediately buy another machine. Rather, some of the work in such a time scarce period will be shifted to the period before of the period after. This can be simulated in the IPS by using the "Working time requirement flexibility" settings.



The diagram to the right displays the working time capacity (line) and requirements (bars) for the Massey Ferguson 35 hp shown in the list above. The red coloured bars represent the original time requirement without flexibility in each half-month period. With flexibility settings allowing to shift 15% of the time requirements to the period before and 15% of the time requirements shifted to the period after, the distribution flattens, which is displayed by the blue coloured bars. However, in the second half of February (Feb2), the time requirement still exceeds the capacity of the machine by 6.4%. This percentage is called "Marginal utilization of the machine", which always refers to the scarcest period and always to the last machine (if more than one machine is required). This "Marginal utilization", is displayed for each machine in the list on the *Invest* sheet.

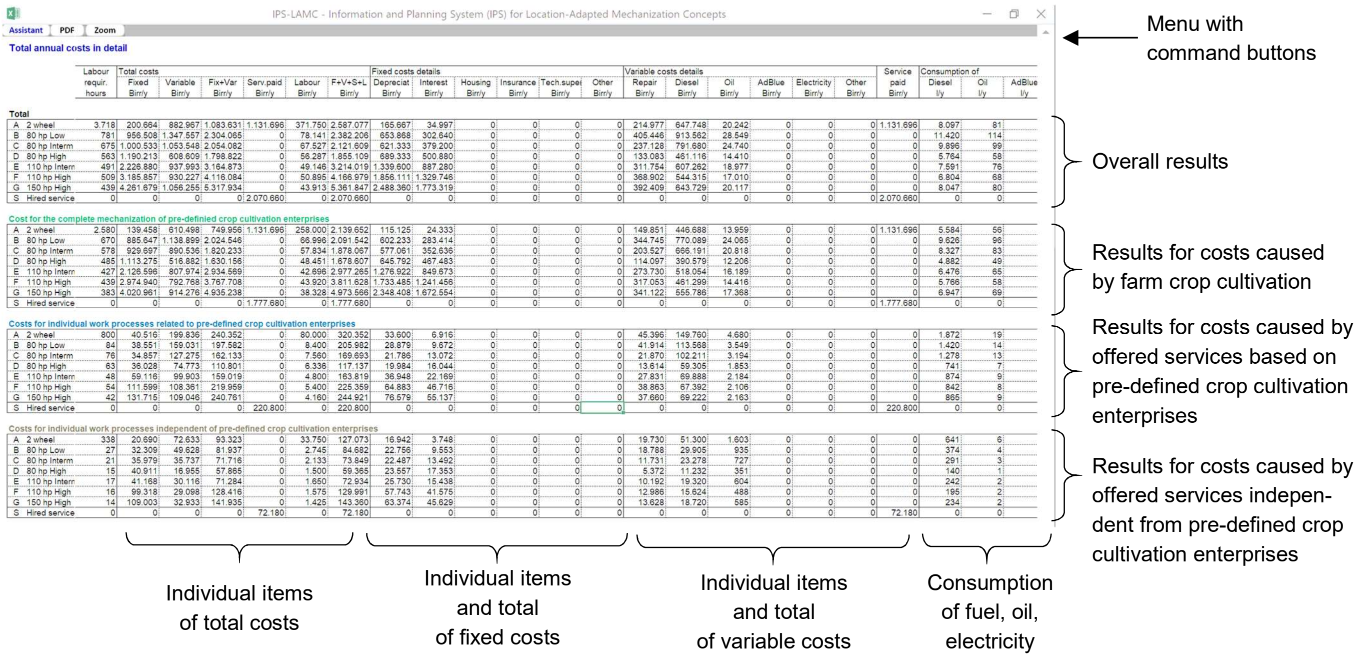
To avoid that the IPS will now consider one more tractor just because of the little additional requirement in the Feb2 period, the user can cut down the number of machines by setting a "Capacity threshold value", which allows the IPS to exceed the capacity of the machine by this value. In the example shown above, the threshold value is set to 10%, so that the IPS considers only one tractor instead of two. Both values are displayed in the list on the *Invest* sheet:

Number of required machines as calculated (without threshold): 2
Number of required machines cut down (with threshold): 1

4.2.5 Total annual costs in detail (on sheet "Total costs")

The “Total costs” sheet of the front desk contains a table that presents all the individual fixed and variable cost items for all pre-defined alternative mechanization packages, as well as the expected consumption of fuel and lubricants. These values are further broken down according to the cause of the machine activity: farm crop cultivation, offered services based on pre-defined crop cultivation enterprises (= pre-defined time period), offered services independent from pre-defined crop cultivation enterprises in any period (half-month) of the year.

Figure 18: Screenshot of the mask for details about annual costs


IPS-LAMC - Information and Planning System (IPS) for Location-Adapted Mechanization Concepts

Assistant | PDF | Zoom

Total annual costs in detail

	Labour requir. hours	Total costs Fixed Birr/y	Variable Birr/y	Fix+Var Birr/y	Serv.paid Birr/y	Labour Birr/y	F+V+S+L Birr/y	Fixed costs details Depreciat Birr/y	Interest Birr/y	Housing Birr/y	Insurance Birr/y	Tech.super Birr/y	Other Birr/y	Variable costs details Repair Birr/y	Diesel Birr/y	Oil Birr/y	AdBlue Birr/y	Electricity Birr/y	Other Birr/y	Service paid Birr/y	Consumption of Diesel l/y	Oil l/y	AdBlue l/y
Total																							
A 2 wheel	3.718	200.664	882.967	1.083.631	1.131.696	371.750	2.587.077	165.667	34.997	0	0	0	0	214.977	647.748	20.242	0	0	0	1.131.696	8.097	81	
B 80 hp Low	781	956.508	1.347.557	2.304.065	0	78.141	2.382.206	653.868	302.640	0	0	0	0	405.446	913.562	28.549	0	0	0	0	11.420	114	
C 80 hp Interm	675	1.000.533	1.053.548	2.054.082	0	67.527	2.121.609	621.333	379.200	0	0	0	0	237.128	791.680	24.740	0	0	0	0	9.896	99	
D 80 hp High	563	1.190.213	608.609	1.798.822	0	56.287	1.855.109	689.333	500.880	0	0	0	0	133.083	461.116	14.410	0	0	0	0	5.764	58	
E 110 hp Intern	491	2.226.880	937.993	3.164.873	0	49.146	3.214.019	1.339.600	887.280	0	0	0	0	311.754	607.262	18.977	0	0	0	0	7.591	76	
F 110 hp High	509	3.185.857	930.227	4.116.084	0	50.895	4.166.979	1.856.111	1.329.746	0	0	0	0	368.902	544.315	17.010	0	0	0	0	6.804	68	
G 150 hp High	439	4.261.679	1.056.255	5.317.934	0	43.913	5.361.847	2.488.360	1.773.319	0	0	0	0	392.409	643.729	20.117	0	0	0	0	8.047	80	
S Hired service	0	0	0	0	2.070.660	0	2.070.660	0	0	0	0	0	0	0	0	0	0	0	0	2.070.660	0	0	
Cost for the complete mechanization of pre-definied crop cultivation enterprises																							
A 2 wheel	2.580	139.458	610.498	749.956	1.131.696	258.000	2.139.652	115.125	24.333	0	0	0	0	149.851	446.688	13.959	0	0	0	1.131.696	5.584	56	
B 80 hp Low	670	885.647	1.138.899	2.024.546	0	66.996	2.091.542	602.233	283.414	0	0	0	0	344.745	770.089	24.065	0	0	0	0	9.626	96	
C 80 hp Interm	578	929.697	890.536	1.820.233	0	57.834	1.878.067	577.061	352.636	0	0	0	0	203.527	666.191	20.818	0	0	0	0	8.327	83	
D 80 hp High	485	1.113.275	516.882	1.630.156	0	48.451	1.678.607	645.792	467.483	0	0	0	0	114.097	390.579	12.206	0	0	0	0	4.882	49	
E 110 hp Intern	427	2.126.596	807.974	2.934.569	0	42.696	2.977.265	1.276.922	849.673	0	0	0	0	273.730	518.054	16.189	0	0	0	0	6.476	65	
F 110 hp High	439	2.974.940	792.768	3.767.708	0	43.920	3.811.628	1.733.485	1.241.456	0	0	0	0	317.053	461.299	14.416	0	0	0	0	5.766	58	
G 150 hp High	383	4.020.961	914.276	4.935.238	0	38.328	4.973.566	2.348.408	1.672.554	0	0	0	0	341.122	555.786	17.368	0	0	0	0	6.947	69	
S Hired service	0	0	0	0	1.777.680	0	1.777.680	0	0	0	0	0	0	0	0	0	0	0	0	1.777.680	0	0	
Costs for individual work processes related to pre-defined crop cultivation enterprises																							
A 2 wheel	800	40.516	199.836	240.352	0	80.000	320.352	33.600	6.916	0	0	0	0	45.396	149.760	4.680	0	0	0	0	1.872	19	
B 80 hp Low	84	38.551	159.031	197.582	0	8.400	205.982	28.879	9.672	0	0	0	0	41.914	113.568	3.549	0	0	0	0	1.420	14	
C 80 hp Interm	76	34.857	127.275	162.133	0	7.560	169.693	21.786	13.072	0	0	0	0	21.870	102.211	3.194	0	0	0	0	1.278	13	
D 80 hp High	63	36.028	74.773	110.801	0	6.336	117.137	19.984	16.044	0	0	0	0	13.614	59.305	1.853	0	0	0	0	741	7	
E 110 hp Intern	48	59.116	99.903	159.019	0	4.800	163.819	36.948	22.169	0	0	0	0	27.831	69.888	2.184	0	0	0	0	874	9	
F 110 hp High	54	111.599	108.361	219.959	0	5.400	225.359	64.883	46.716	0	0	0	0	38.863	67.392	2.106	0	0	0	0	842	8	
G 150 hp High	42	131.715	109.046	240.761	0	4.160	244.921	76.579	55.137	0	0	0	0	37.660	69.222	2.163	0	0	0	0	865	9	
S Hired service	0	0	0	0	220.800	0	220.800	0	0	0	0	0	0	0	0	0	0	0	0	220.800	0	0	
Costs for individual work processes independent of pre-defined crop cultivation enterprises																							
A 2 wheel	338	20.690	72.633	93.323	0	33.750	127.073	16.942	3.748	0	0	0	0	19.730	51.300	1.603	0	0	0	0	641	6	
B 80 hp Low	27	32.309	49.628	81.937	0	2.745	84.682	22.756	9.553	0	0	0	0	18.788	29.905	935	0	0	0	0	374	4	
C 80 hp Interm	21	35.979	35.737	71.716	0	2.133	73.849	22.487	13.492	0	0	0	0	11.731	23.278	727	0	0	0	0	291	3	
D 80 hp High	15	40.911	16.955	57.865	0	1.500	59.365	23.557	17.353	0	0	0	0	5.372	11.232	351	0	0	0	0	140	1	
E 110 hp Intern	17	41.168	30.116	71.284	0	1.650	72.934	25.730	15.438	0	0	0	0	10.192	19.320	604	0	0	0	0	242	2	
F 110 hp High	16	99.318	29.098	128.416	0	1.575	129.991	57.743	41.575	0	0	0	0	12.986	15.624	488	0	0	0	0	195	2	
G 150 hp High	14	109.003	32.933	141.935	0	1.425	143.360	63.374	45.629	0	0	0	0	13.628	18.720	585	0	0	0	0	234	2	
S Hired service	0	0	0	0	72.180	0	72.180	0	0	0	0	0	0	0	0	0	0	0	0	72.180	0	0	

The ***total*** costs include:
Fixed costs of machines, variable costs of machines and labour costs

The ***fixed*** costs include:
Depreciation, interest, housing, insurance, technical supervision, other

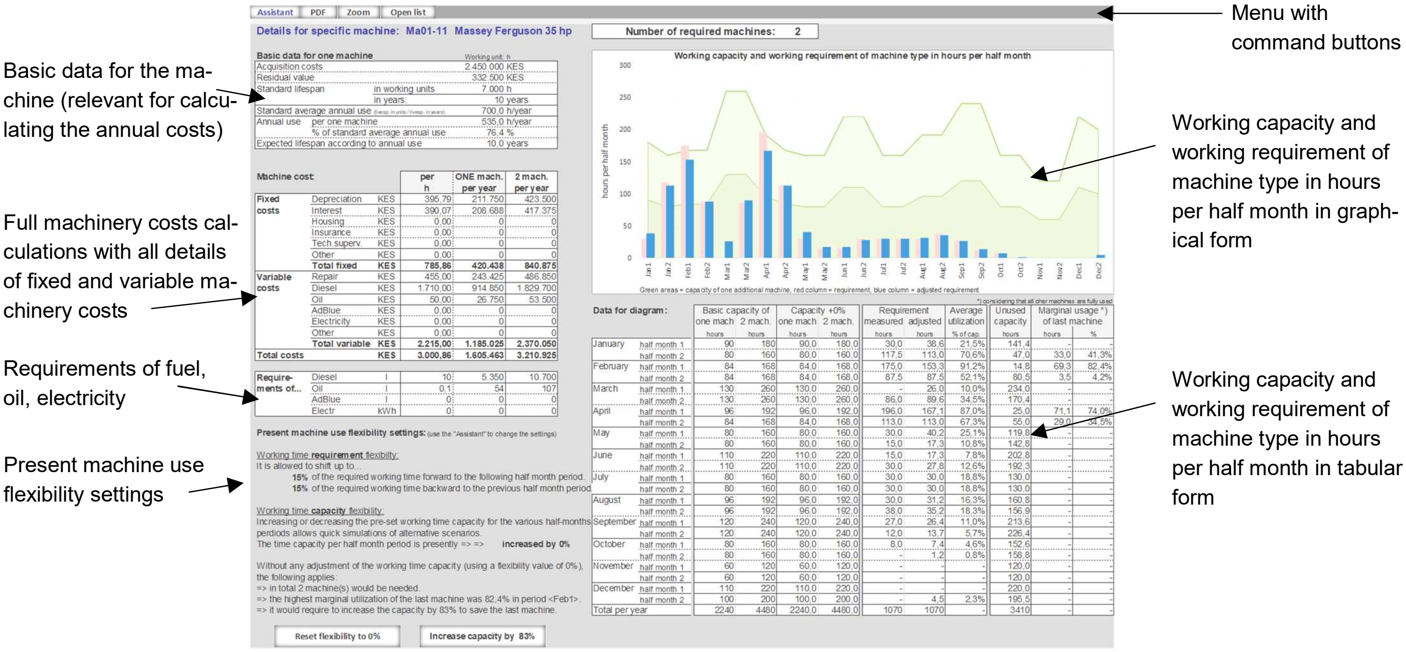
The ***variable*** costs include:
Repair, diesel, oil, AdBlue, electricity, other

The menu line contains the same command buttons as on the control board.

4.2.6 Details for individual machines (on sheet "Detail Ma")

The "Detail Ma" sheet of the front desk contains a table where the user can select any of the machines in the database to display the full machinery cost calculation, the use of the machine over the year (= working time requirement according to half months) and major technical coefficients of the machine.

Figure 19: Screenshot of the mask for details for individual machines



The machinery costs calculation for the selected machine displays the results for *one* machine as well as for the *total number of machines required*.

The ***total*** costs of the machine include:
Fixed costs of machines, variable costs of machines and labour costs

The ***fixed*** costs the machine include:
Depreciation, interest, housing, insurance, technical supervision, other

The ***variable*** costs the machine include:
Repair, diesel, oil, AdBlue, electricity, other

The menu line contains the same command buttons as on the control board plus a button for selecting the machine for the mask ("Open list").

4.2.7 Details for individual work processes (on sheet "Detail WP")

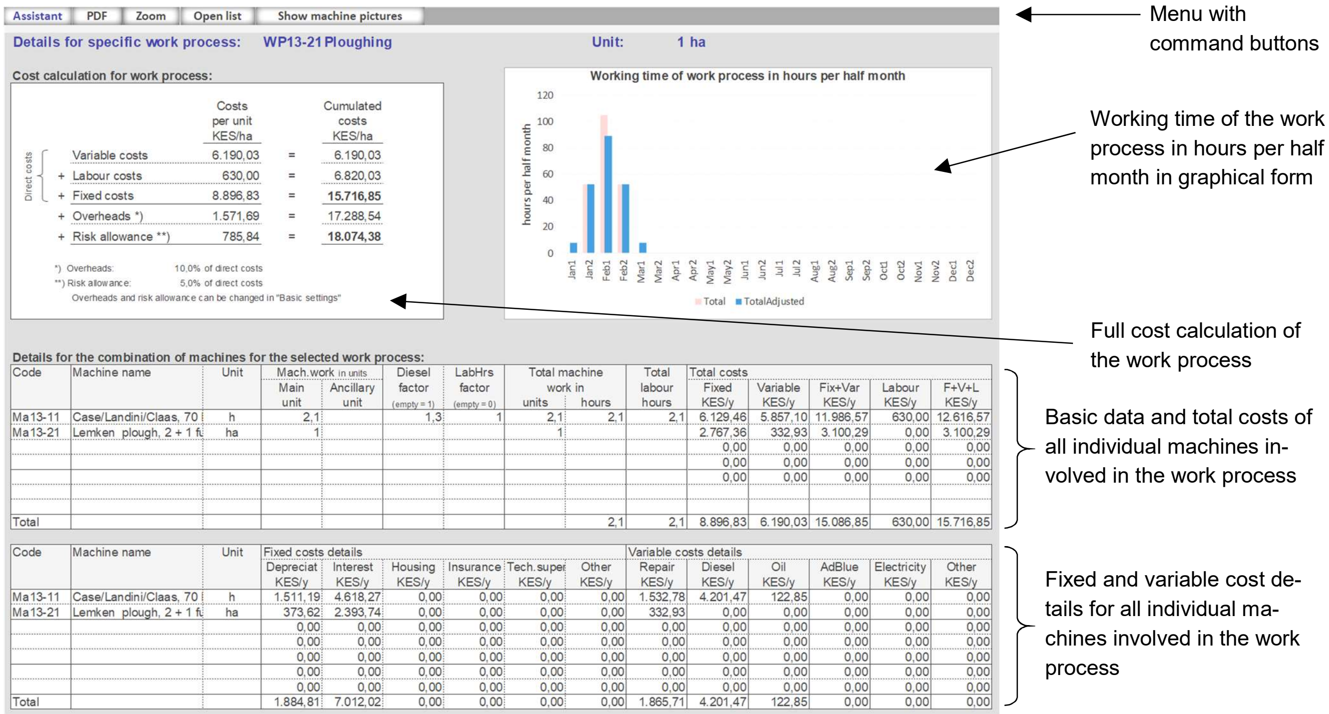
The "Detail WP" sheet of the front desk contains a table where the user can select any of the pre-defined work processes in the database to display the full cost calculation of the work process, the use of the work process over the year (= working time requirement according to half months) and the annual costs of all machines belonging to the selected work process.

The cost calculation of the work process includes the direct costs of the work process (= fixed and variable costs of the machines involved plus the labour costs) as well as additions for overheads and a risk allowance. Both additions can be determined as a percentage of the direct costs.

The ***fixed*** costs the work process include (for all machines involved in the process):
Depreciation, interest, housing, insurance, technical supervision, other

The ***variable*** costs the work process include (for all machines involved in the process):
Repair, diesel, oil, AdBlue, electricity, other

Figure 20: Screenshot of the mask for details for individual work processes



The menu line contains the same command buttons as on the control board plus a button for selecting the work processes for the mask and another button for displaying pictures (photographs) for the machine the user taps on in the list.

4.2.8 Basic data for machines and work processes (on sheet "Source table")

The "Source table" sheet contains a list of all pre-defined work processes in the IPS. In this list, the user can update/adjust basic data for machines and work processes. This is especially necessary, when setting up the IPS for a new region.

a) Data for machines:
   Acquisition costs (purchase price); Duration of use (in years and in working units like hectares or hours); Repair cost factor (Aquis.costs x factor = repair costs in mach. lifetime).

b) Data for work processes:
   Diesel demand (tractors: l/hour; process: factors); Working process time demand (hours per ha); Number of workers needed (incl. tractor driver); Prices for hired services per work process.

c) Time requirement calendar for each crop cultivation enterprise:
   For each crop cultivation enterprise the IPS requires to know *which working process* is carried out at *what time* period during the year for *how many times*. This information is entered in a calendar (based on half-month periods).

   Field operations can be entered alternatively

   - in one single half-month period using the value "1", meaning that the process is carried out once in the specified period;
   - spread over more than one half-month period, using values of less than "1" per period, but adding up to a value of "1", when summing up the values belonging to the one operation.

   In the example below (wheat production), all operations are spread over more than one period. The values entered for ploughing can (for example) interpreted as follows: ploughing takes place from January second half until February second half. 50% of the ploughing is carried out in February first half, while 25% is carried out in January second half and the same in February second half.

Figure 21: Screenshot of the mask for entering the time requirement calendar for wheat

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Wheat: How many times is the process carried out during a period?

			January		February		March		April		May		June		July		August		September		Octo
21	Ploughing	ha		0.25	0.5	0.25															
22	Stubble Cleaning	ha																			
24	Seedbed preparation	ha						0.25	0.5	0.25											
31	Sowing cereals	ha						0.25	0.5	0.25											
32	Planting maize/carrots, witl	ha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
33	Planting potatoes	ha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41	Fertilizer application	ha						0.25	0.5	0.5	0.5	0.25									
45	Spraying	ha	0.5	0.5				0.1	0.6	0.3			0.25	0.5	0.5	0.5	0.5	0.5	0.25		
51	Ridging maize	ha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
52	Ridging potatoes	ha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
55	Inter-row cultivation in mai;	ha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
56	Inter-row cultivation in pot;	ha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
61	Cereal harvesting (combin	ha																0.2	0.3	0.3	0.2

4.3 Back office

4.3.1 General aspects

In the back office, specially trained users can work on the data bases to add new machines and/or work processes. This is basically done in three tables subsequently building on each other:

List of machines: a database with all the machines, containing all planning-relevant data for each machine, in order to calculate the fixed and variable costs and to determine the use capacity over the year (according to half months).

List of work processes: a database with pre-defined work processes. A "work process" represents a combination of all machines required for a certain field operation (e.g. ploughing, sowing, ...) and includes a pre-determined working time requirement to carry out the operation.

List of farm enterprises: a database with pre-defined farm enterprises like cultivation of wheat, barley, etc.. For each farm enterprise, all necessary field operations are pre-determined and linked to a work process from the "list of work processes". When a work process is assigned to a certain field operation of a farm enterprise, the exact time period (half month) for carrying out the field operation needs to be pre-determined.

In all of the three mentioned database tables the elements (machines, work processes, farm enterprises) are grouped according to pre-defined machinery packages, representing different technology levels and different traction performance levels of the machines.

The remaining two tables of the *Back office* do not require any maintenance since they are used for the processing of the data entered by the end user via the *Front desk*.

All sheets are further described and explained in the following sub-chapters.

Users of the back office have full access to all Excel menus and functions and have, in addition, also VBA programmed command buttons available with assisting functions for the specific tasks necessary to maintain the databases with machines, work processes and farm enterprises.

Access to the back office is password protected.

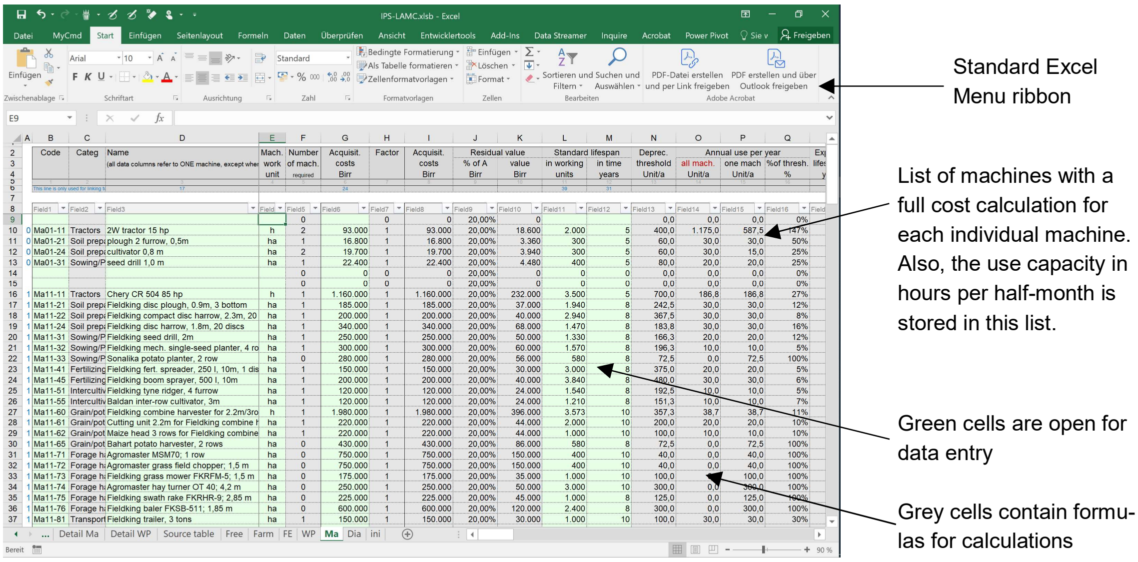
Since adding new machines and work processes is a complex process, video tutorials are available to demonstrate the procedure.

4.3.2 List of machines (on sheet "Ma")

The list of machines contains all planning-relevant data for each machine, in order to calculate the fixed and variable costs and to determine the use capacity over the year (according to half months).

Each machine is located in one individual row of the list and has a unique ID code.

Figure 22: Screenshot of the mask for the list of machines

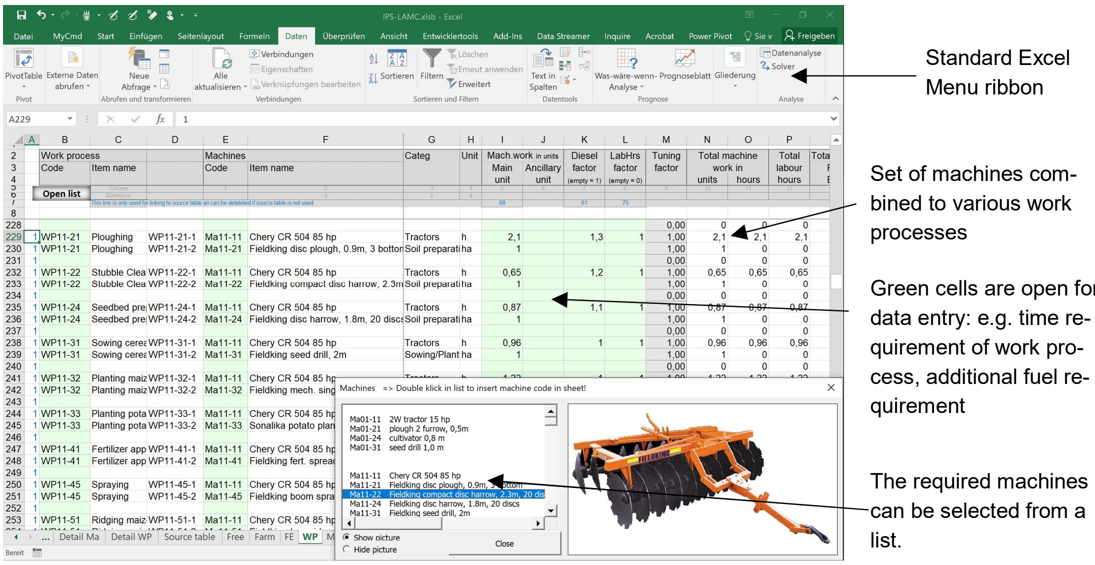


4.3.3 Combination of machines to work processes (on sheet "WP")

A "work process" represents a combination of all machines required for a certain field operation (e.g. ploughing, sowing, ...) and includes a pre-determined working time requirement to carry out the operation.

The costs for each work process are summed up in one individual row in the table, representing the totals of the work process and getting a unique ID code.

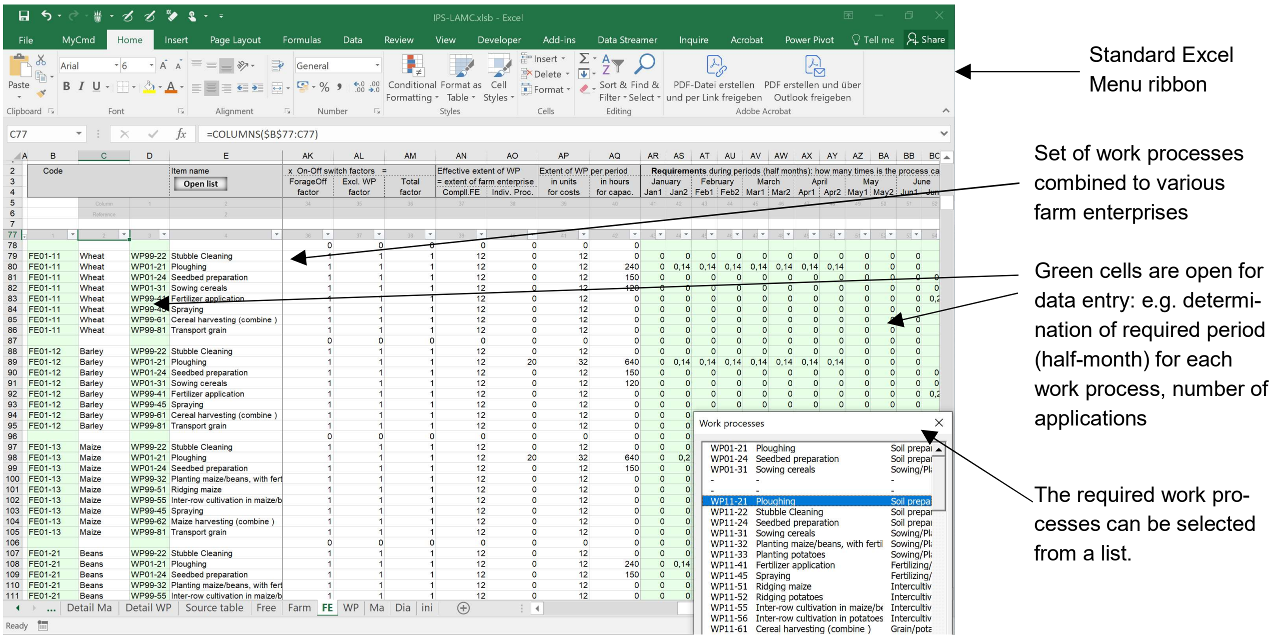
Figure 23: Screenshot of the mask for defining work processes



4.3.4 Combination of work processes to farm enterprises (on sheet "FE")

For each farm enterprise, all necessary field operations are pre-determined and linked to a work process from the "list of work processes". When a work process is assigned to a certain field operation of a farm enterprise, the exact time period (half month) for carrying out the field operation needs to be pre-determined.

Figure 24: Screenshot of the mask for combining work processes to farm enterprises



5 Direct and Indirect Agro-Ecological and Economic Effects

An example for direct agro-ecological effects of alternative mechanization packages is their different diesel consumption. In the IPS, the diesel consumption is displayed comparatively for:

- the different complete mechanization packages (on sheets "Control Board" and "Total costs),
- the different single work processes (on sheet "Detail WP")
- the different single tractors and self-propelled machines (on sheet "Detail Ma")

An example for indirect economic effects is the impact of different mechanization packages on the yield of the crops grown or on other costs related to the various farm enterprises. The following example may illustrate how to analyse such effects:

Let’s assume:

- a farmer grows 10 ha of wheat, 10 ha of barley and 10 ha of maize,
- the costs for mechanization package “80 hp, technology level low" is $30,000 per annum
- the costs for mechanization package “80 hp, technology level high" is $31,500 per annum

Since the annual costs for the high technology level are $1,500 above the costs for the low level, the high level would only be economically viable if other monetary advantages (which are not accounted for in the IPS => indirect effects) were to compensate for the higher mechanization costs.

Such other monetary advantages may be generated by higher yield or by saving costs for other inputs needed for crop cultivation e.g. saved crop protection costs or fertilizer costs due to high quality mechanization.

When related to the crop cultivation area, the cost difference between the two packages is

$ 1,500 divided by 30 ha = $50 per ha

Only if the higher yield and/or reduced cost for other inputs amount to at least $50 per hectare, the higher technology level of mechanization is economically viable.

If only related to the yield and assuming an average price for grain of $0.25 per kg, the minimum additional yield to be generated by using the high technology for being economically viable had to be:

$ 50 per hectare divided by $ 0.25 per kg = 200 kg per hectare

It is then up to the farmer (or his advisor) to judge whether it will be possible to reach this additional yield or not.