Evaluation of the influence of topography and the structure of vegetation upon the success-rate and the precision of the GPS-telemetry in the Palatinate Forest (Pfälzerwald, Südwestpfalz district, Germany)

(Source: EBERT 2006)

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Abstract

In the regional natural park of the Palatinate Forest, as in most parts of Western Europe, the population of wild boar (*Sus scrofa L.*) has increased tremendously. The GPS and VHF telemetry are technical means at scientists' disposal to follow these populations. The precision and reliability of these methods have already been evaluated by many researches, but the scientists who made them recommend doing them again for every type of GPS receiver, as well as for every kind of environment.

In the FAWF's study domain (Rhineland Palatinate, Germany), tests have been made with two GPS collars in different vegetation structures. The goal being to evaluate the influence of the different vegetation components (trees' height, basal area, canopy cover and tree density) upon the location errors. The collars have been left 24 hours in every type of vegetation and GPS fixes have been made every hour. For every site tested, several vegetation parameters have been collected.

The mean location error collected within all the tests is of 10m. The values collected for the vegetation components have each been correlated with the location error (R > 0,5 and P < 0,05). The factor that has the most influence on this location error is the basal area (R = 0,739 and P = 0,001). The canopy cover also has a significant influence, but it is not as high. The vegetable species didn't have any influence on the location error.

Parallel to the above, six wild boars have been followed with both WHF and GPS telemetry. The VHF fixes, effectuated at the same time as the GPS fixes, have been used to compare the two methods. The GPS fixes are significantly more successful on the plateau than in the valley. But the comparison method is difficult to operate in the valley, where the topography has probably a great influence upon the success rate of both GPS and VHF fixes.

Finally, a comparison of the two telemetry methods has demonstrated that the GPS system is quite more accurate (location error of about 20m) and asks a lot less time for making a fix than the VHF system (location error of about 200m). A priori, the GPS is one of the most effective instruments for evaluating the moving of big fauna.

3. Methods and material

3.1. Capture and marking of the boars

In order to carry out the research on the telemetric methods (cf. chapters 3.2 and 3.3) on the fauna, it has been necessary to first capture and mark the animals with different transmitters. There are several capturing techniques, depending on the animals to be captured. The WAWF utilises the techniques the most adapted to the capture of wild boars. The ones that are described here are the ones that were utilised during the period of this diploma study.

3.1.1. The capture of boars with a hypodermic gun

To be able to capture an animal with a hypodermic gun, the first thing is to prepare an baiting site. Corn grains (used since they are appetising for the boars) have to be disposed regularly on a site which could be potentially visited by the boars, so to lure them and to get them accustomed to feed themselves there. The grains are put in wooden boxes with a lid, so to prevent small rodents and birds to eat there (cf. Appendix 2). The boars can easily lift this lid. The fact that the lid has been lifted or that the grains have been eaten allows generally to affirm that boars have visited the site.

It can happen that due to time reason, it is not possible to fill up regularly the corn boxes. In this case, the FAWF uses some automatic dispensers, which are suspended on the trees on the baiting site. These automats release a predetermined quantity of corn, at defined time.

The setting up of a photographic detector of movements (Bushell TrailScout Pro, 2.1mp NV Camera, Bushnell, USA) is an additional measure to verify whether the site is visited and allows to determine the number, the age, the weight and the gender of the boars which visited the site (cf. Appendix 2).

A hut (mobile or not) is installed on the site, in order to hinder the boars to smell or to hear the shooters (cf. Appendix 2). If the site has been regularly visited, a capture group is organised. The shooter lies <u>in the wait</u> in the hut and the rest of the group waits with the marking tools at a minimum distance of 500m, so to avoid the <u>flight</u> of the boars.
The lookout is generally organised at dusk or at night, during the active phases of the wild boars (HUCKSCHLAG, personal communication, 2007).

Before installing himself on the lookout, the shooter estimates the weight of the target boar by observing the pictures taken by the photo trap. Some wooden poles with height marks are disposed in front of the photo trap on the site of the baiting site so to facilitate the determination of the size and the weight of the boar. The concentration of the hypodermic product, which serves to the immobilization of the boar, is prepared in accordance to the weight of the animal: about 13 mg are injected per kilo (HUCKSCHLAG, personal communication, 2007). The hypodermic product used by the FAWF for the capture of boars is the Zoletil®100 (Virbac, France), constituted by two active elements: the Tiletamine and the Zolazepan.

The product is prepared before the lookout so the shooter avoids the maximum of noises when the boars appear on site. The disadvantage of this method is that the shooter cannot aim but on the boars of the same weight as predetermined. If the product is injected in a lighter boar, the risk is death of the animal (HUCKSCHLAG, personal communication, 2207).

The fire power of the gun (JM Standard, Dan-Inject, Denmark, cf. Appendix 2) must be adjusted to the distance between the shooter and the boar. In order to avoid being constantly regulating the gun and to make as little noise as possible when on the lookout, the gun is pre-adjusted to a distance of 10m. The wooden poles to determine the weight are planted at 10m of the hut so to allow the shooter to know when the boar is within shooting range. Once the boar is located in vicinity of the wooden poles, the shooter can fire the gun.

The touched boar can run for as several hundred meters before being under the effect of the narcosis. The hypodermic arrow has a small VHF transmitter (cf. chapter 3.2.1) which allows the capture group to find the animal in an easier way.

This technique needs to apply to the services of a licensed shooter for a hypodermic gun and at the same time needs time for the lookout. This is why it is used solely when there is enough time and the chances of a capture are relatively high.

3.1.2. Capture of boars with cages or corrals

The cages or corrals are often different from one research centre to another, as far as dimensions and used material go. Their functioning remains nonetheless the same.

The FAWF owns two cages, 2,5m long, 1,5m large and 1m high, as well as two corrals, made out of 10 elements each, 2,5m in height and 2m large. The cages and the corrals have two trap doors integrated in the elements, a small one of 1m high and 0,5m large, and a bigger one, 1m high and 1,5m large. The walls are constituted of wire netting 4mm thick and 4cm in gap (cf. Appendix 2).

The cages or corrals are constructed or dropped on sites potentially or already frequented by boars, like for the capture with a hypodermic gun. The baiting site is also identical.
It is simply done inside the cages or the corrals instead of being done in the open. A photo trap is generally also hung up, to so confirm that the cage has been visited.

When regular visits of boars have been established, the capture system is activated. The capture systems used by the Institute are various: first of all, there is the system using an autonomous trigger. The trigger (Fangschloss, Kieferle GmbH, 78244 Gottmadingen, Germany) is fixed on one side to the cable, keeping the big portal, and on the other side to a rope stretched across the cage. If the boar touches the rope, the trigger that releases the cable and releases the trap door (cf. Appendix 2). This system has the disadvantage that any animal or object putting a pressure upon the rope can trigger the device. That is why it can sometimes be slightly modified: the rope, instead of being tightened, is rolled out on a longer distance (minimum of 40m) and is directly pulled by a person. The advantage of it is that the person can select the animal to be captured, since he can control the trigger. The disadvantage is that the boar can potentially detect the presence of this person and in that case might not enter the corral. Furthermore, the rope must be easily moved about.

Another system in use consists of hanging up a video camera (Mobotix-M10 Digital Network IP, Mobotix AG Security-Vision-Systems, Germany) connected to portable computer situated in a vehicle (in a maximum distance of 300m, due to the length of the video cable). This camera can be coupled to some small infrared light projectors (Model 84/30-880, Universe Company, Germany) as to be able to film at night. The person in the vehicle can see in real time what happens in the cage or the corral and can release the device thanks to an electronic trigger. Again, the advantage is that the person can select the animal to be captured. The camera can also play the role of a video trap. It can be activated by movements and register the sequences on an external hard disk, which is located in a tight box. The whole device being supplied by batteries.

The cages and the corrals are systematically controlled when the autonomous capture system is active. When the boar is captured, the capture group is called upon. A smaller box beam is fixed to the small portal to isolate a boar, in the case that several have been captured at the same time. If the boar is too big and weighs more than 50kg, it is put to sleep with the help of a compressed air blowpipe (Jab-stick, Dan-Inject, Denmark, cf. Appendix 2). The hypodermic product is the same as the one used with the gun (cf. chapter 3.1.1), but the concentration is smaller: about 9mg are injected per kilo (HUCKSCHLAG, personal communication, 2007). If the boar weighs less than 50kg, a net in the form of a tunnel is fixed on the small box and the boar is attracted in it. The animal is then immobilised "bare-handed" by the capture group.

3.1.3. Marking of the boars

When a boar has been captured and immobilised, the capture group goes to the capture site with the marking material. When the capture is done with the hypodermic gun, the boar being able to move at times for over a hundred meters before the narcotics is effective, the material is stored in several bags and cages so to be brought swiftly on the immobilisation site.

In the capture group constituted by a minimum of 4 people, one person is in charge of the immobilisation of the head and the front of the animal, another one the back. The third person is in charge of transcribing the protocol of the capture, and the last one overlooks several manipulations (installation of transmitters and to take all the samples needed).

For security reasons, the first step in marking is to attach the legs and the muzzle of the boar. In order to calm it down, a cloth is put around its eyes.

Since the boar could at any time struggle and escape, the following steps are ordered by priority: the absolute priority for the FAWF is to equip a maximum of boars with GPS collars (GPS Pro-3 Plus Collar, Vectronic Aerospace GmbH, Germany). Therefore, the next step is to put the GPS collar on the neck of the boar (cf. Figure 9). The GPS collars are only put on adult boars, since the piglets cannot bear the weight of them and since they are still growing.

An auricular VHF transmitter (C-1 / ER1733[A], Wegener, Germany) and a plastic auricular marking (cf. Figure 6) are fixed on the ears of adults and juvenile boars. The double equipment, both GPS and VHF, allows following the animal in case one of the system breaks down.

Then a passive transponder, identical to the one used with domestic animals, is injected under the skin in the neck region, with the help of a syringe. This will allow, in case of the loss of the two external markings, to identify the animal when captured or if it is found dead. The functioning of the chip is tested by passing a chip-reader over the animal's neck. The identification number is then written down on the capture protocol.

If the boar is still immobilized, the next step consists of taking a small piece of the ear's cartilage, so to be able to send it to a lab, in order to add the DNA information to the data bank. This data bank is then used by the FAWF to evaluate and improve a non-invasive capture-mark-recapture (CMR) system. "Non-invasive" means that there is no direct contact with the boars. It is about (after EBERT, personal communication, 2007) to cover pre-established transects to collect the boars' dung (this corresponds to the capture phase), to determine the DNA of the boar which defecated (this corresponds to the marking phase) and to look for further droppings in the same transects (this corresponds to the recapture phase). The ratio between the captured marked and recaptured animals and the ones captured for the first time during a recapture action, allows determining the size of the boars' population (OTIS et al. 1978 and WHITE et al. 1982).

When all the steps are concluded and the boar is still calm, its weight is measured. This allows the shooter (or to the person who has approximately evaluated the weight of the animal in order to determine the quantity of narcotics to be used) to verify whether the estimate was correct. A picture of the teeth is also taken in order to be able to evaluate the animal's age later on.

Finally, if the other steps have not lasted too long and that the boar does not show any signs of waking up, several other measurements are taken: the size of the withers, the largeness of the chest, the size of the feet and of the ears, as well as the length of the body with the head but without the tail (which is measured separately).

When the marking phase is ended, the boar is released or laid down in a place where the risks of injures following the waking up or the releasing are limited (on a more or less even ground without any roads in the vicinity). The follow-up or the fixing phase can hence start (cf. chapter 3.2).

3.2. Evaluation of the GPS telemetry via the VHF telemetry

A total of six boars have been followed with both the VHF and the GPS telemetry. The used data come from the fixes collected during the diploma work and the fixes made by other diplomandi, doctorandi or trainees or civil servants before the beginning of this study. The period of collection spread from Oct. 17th, 2006 to Sept. 19th, 2007.

3.2.1. The fixes with the VHF telemetry

The VHF fixes have been done at the same time (hours) than the GPS fixes (cf. chapter 3.2.2), so to be able to compare the data. The frequency of these fixes could not be done as often as the GPS ones; it has thus been decided to collect them about three times a week during day time and about two times a week at night. The choice of the boars which have been fixed was randomly made every night and every day. The goal being nonetheless to get an identical proportion of data for each boar.

The different telemetric tools which have been used for the fixes are the following (cf. Figure 6):

- Transmitters: auricular transmitters, C-1 / ER1733[A], Wagener, Germany.
  The GPS collar having as well a VHF transmitter, it has also been used for the VHF fixes when the signals from the auricular transmitter was not as good or when the latter was lost, GPS Pro-3 Plus Collar, Vectronic Aerospace GmbH, Germany.
- Antenna on telescopic pole fixed on the company bus: 5 Element – Yagi, Biotrack, England.
- Handheld antenna: 3 Element Folding – Yagi Antenna, Wildlife Materials International Inc., USA (only used for the "home in").
- Receivers: TRX 1000S, Wildlife Materials International Inc., USA.

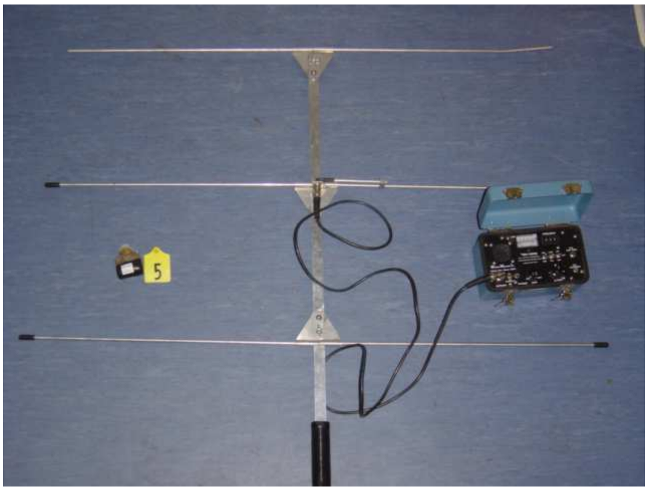

Figure 6 : Tools used for the VHF telemetry (on the left the auricular transmitter, in the middle the handheld antenna and on the right the receiver)

Figure 7 : The bus used for the VHF telemetry with the telescopic pole deployed

All the VHF fixes have been made in the company bus with the antenna on the telescopic pole. The advantages of this technique are that, when the weather conditions are bad, fixes can be made quicker then by foot as the tracker can stay in the shelter.

The method used for the fixes and described here is issued from my own experience acquired during the present diploma work and during a training effectuated in August and September 2003 with a research group on the wild boar of the "Département Nature et Paysage du Canton de Genève" DNP (Department of Nature and Landscape of the Canton of Geneva, Switzerland, formerly "Service des Forêts, de la Protection de la Nature et du Paysage" SFPNP, Service of the Forests and the Protection of the Nature and Landscape).

The principles of this method have of course been described earlier in different scientific books. In order to support the description of the method, the work of KENWARD (2001) has been used.

The VHF telemetry method is quite simple, but the rapidity and the precision often depend on the experience of the tracker. In order to determine a position, it is first of all necessary to find the boar. The frequency that identifies him is chosen on the receiver which is linked to the antenna. The study domain in then scoured through, while halting often to perform a 360° scanning with the antenna (FISCHER, personal communication, 2003 and EBERT, personal communication, 2007). The receiver is provided with a gain which allows lowering or heightening the reception's strength. By setting it to its maximum, one enhances the chances to find the animal (KENWARD, 2001).

Once a sufficiently strong signal is found, one has to make sure to be on a known point on the reference map. This map allows reporting on it the directions found by the antenna. To do this, one has to regulate the gain so to get an adequate signal strength that allows to determine the direction from where the signal comes (KENWARD, 2001). A sweeping with the antenna is then executed to find the directions from where a signal is obtained. The angle gained with these two directions represents the receiving angle. If one takes the middle of this angle one should theoretically get the direction from which the signal is the strongest (cf. Figure 8). A second sweeping around this direction with a slightly diminished gain allows getting the direction from where the signal is the strongest (FISCHER, personal communication, 2003 and EBERT, personal communication, 2007).

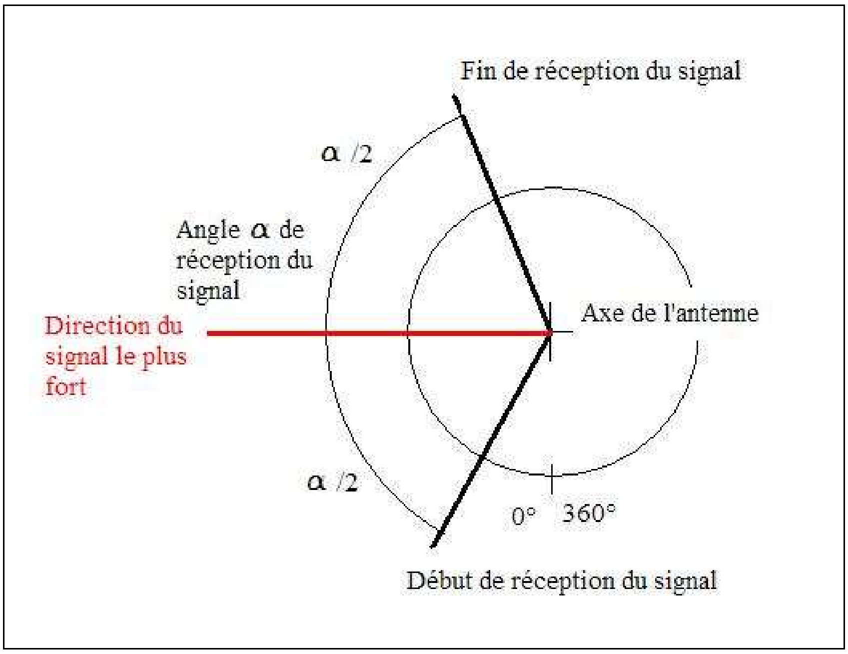

Figure 8 : Figure to show how to find the direction of the strongest signal

Once the direction is established, it is necessary to get out of the vehicle and get the direction with the help of a compass. To avoid reading errors, due to the vehicle's magnetism, the direction must be taken at least 5m from it (EBERT, personal communication 2007).

To read the direction on the compass, it is needed to be placed behind the antenna and to aim in that direction in which the antenna points. The needle indicating the North must be positioned between the two red lines representing the North on the compass. The digit of degrees indicated by the direction is reported on the fixing report. The direction is reported on the reference map. For this, the two red lines representing the North on the compass must be directed towards the North of the map (generally, the upper part of it). The compass is now directed in the right direction. It is then enough to shift the compass, whilst keeping its North directed towards the top of the map, in order to match one of the compass's sides with our location, and then trace a line representing the direction of the signal (FISCHER, personal communication, 2003 and EBERT, personal communication, 2007).

According to KENWARD (2001), this action repeated three times in three different places enables to get a triangulation. The three lines meet on one point or form a triangle on the map. The intersection point or the centre of the triangle thus formed represents the position of the transmitter and hence of the animal (cf. Appendix 3). Two directions could suffice to get a position, but the reliability of the data thus collected is mediocre. That is why it is always better to get at least three directions. When more than three directions have been collected, one must at best estimate the probable location of the boar via the intersections of the directions and the force of their signal.

In the fixes' protocols are registered the date, the name of the fixed boar, the transmitter's frequency and the weather. In addition to this data, are also registered for each collected direction: the time, the degrees indicated by the compass, the received signal's maximum force (between 0 and 1), the number of the used elements on the telescopic pole which have been used and the remarks concerning the fixing or the boars, for instance if other boars are present in the same sector (EBERT, personal communication, 2007).

3.2.2. The GPS fixes

The frequency of the GPS fixes is predetermined. Generally, the GPS collar (GPS Pro-3 Plus Collar, Vectronic Aerospace GmbH, Germany) is set to perform fixes every 15 minutes at night as well as in the day right after the boar's capture and release. Once the correct functioning of the collar is established, it is set to perform fixes every hour at night (from 7 p.m. to 8 a.m.), when the animal is active, and set to perform three fixes during daytime (10 a.m., noon and 3 p.m.), when the animal is less active. These fixing times are set for the Summer time. In winter, the boars' activity lasts longer due to the shorter days, hence the fixing times are adapted accordingly (EBERT, personal communication, 2007).

The kind of GPS collar used by the FAWF as well as for this study is the GPS Pro-3 Plus Collar of the firm Vectronic Aerospace GmbH in Germany (cf. Figure 9). This model has 12 channels and utilises the satellites' civil codes (C/A) passing the L1 wave (SCHULTE, personal communication, 2007). The data collected by the collars are: the date at the coordinated universal time (UTC) and at the local time (Local Metric Time, LMT), the fixe's UTC and LMT hour, the latitude and longitude coordinates, the German reference system's coordinates (Gauss-Krüger), the altitude, the Dilution of Precision (DOP), the type of the fix (failure, 2D or 3D), the validation, the indications on the two batteries (a main and a reserve battery), the external temperature(not totally exact, because influenced by the body’s temperature) (Vectronic Aerospace, 2005).

Figure 9 : The GPS collars used for the tests and put on the wild boars

According to Vectronic Aerospace (2005), this data is stored in the collar's memory and sent out whenever it reaches a certain quantity. Since the GPS collar owns SIM card (Subscriber Identity Module), the sending takes place via the GSM (Global System for Mobile Communications) mobile telephone network by sending an SMS (Short Message System). This data is received by a station (GSM Ground Station, Vectronic Aerospace GmbH, Germany) linked to a computer provided with a data receiving program (GPS Plus Collar Manager, Vectronic Aerospace, GmbH, Germany). This computer works 24 hours a day and can receive the messages at any time.

The computer and the station allow sending out orders via SMS to the collar as well (for instance, the times it has to perform some fixes).

The data is stored in the program as GPS data files (in the GDF format) and a transformation is directly made into a simple text file (in the TXT format).

3.2.3. Treatment of the data

The positions collected during the VHF fixes are introduced directly into a project of the software ArcGIS© of the firm ESRI. The positions' points are placed via the maps that are included in the project. The points' coordinates are then calculated by the program.

The data collected by the GPS collars must first be transformed into database spreadsheets (dBase, in the DBF format). It is then introduced into the ArcGIS© software project. The positions' points are shown directly after having chosen the adequate geodesic coordinates system.

In order to be able to compare the VHF and the GPS data, we had to determine beforehand the periods during which we have tried to fix or to follow the boar with the two methods. When a test fix has been carried out by both, the data is entered on a same line into an Excel sheet. The information added to the sheet are: the name of the boar, the date, the time of the VHF fix, the time of the GPS fix, whether the fix has succeeded or not, the DOP, the type of the fix (2D or 3D), the topographical place of the VHF position, the topographical place of the GPS position, whether the VHF is accepted or not, the names of the boars wearing transmitters and thus being available to perform some fixes at the same period, the GPS coordinates after the German system, the VHF coordinates following the same system, the distance between the two positions.

An example for one of the boars is found in Appendix 4. The VHF fixes taken for this comparison have all succeeded in order to be able to determine in which topographical place the GPS fix has succeeded or not. So to be sure of the reliability of the VHF fixes, they have been analysed with the help of some selection criteria. According to the number of criteria fulfilled, they were accepted or rejected.

The selection criteria - by order of importance - are the following:

- the distance between the two fixes, when the fixes have succeeded, is less than 50m;
- the signal's force coming from a minimum of three directions is equal or greater than 1;
- five or more directions cross themselves in a restraint range;
- the distance between the tracker and the boar is smaller than 100m;
- the boar's position has been confirmed by other means than the fix ("home in", seen or heard, etc);
- the topography is reasonably flat, allowing to say that the signal has not been reflected;
- despite the fact that there was no successful GPS fix at the same time, there exist some at the same place of the VHF fix the hour before or the hour after;
- the fix has been collected by daytime when the animal was inactive.

The topographical place of each fix entered in the spreadsheet has been determined via the contour maps within the ArcGIS© software. At the beginning, three place categories have been chosen: valley, hillside and plateau. But in order to allow the statistical analysis of the results, only two categories have been used: valley and plateau. The "valley" category represents all the environments that are located in the valley and in the lower part of the hillside; the category "plateau" represents all the environments on the plateau and in the upper part of the hillside.

The data accepted after the selection criteria has then been analysed by means of the statistical software SPSS 14.0. A Chi-square test has been effectuated on the frequency of successful or unsuccessful trials by the GPS collar.

3.3. Evaluation of the GPS transmitting collars' precision under different vegetation structures

3.3.1. Setting up of the tests and field readings

For the tests, the GPS collars have been fixed on a mounting. In order to be as close as possible to the real using conditions, the mounting has to resemble as much as possible to a boar. In order to achieve this, a water jerry can of 25l has been used. This jerry can has been fixed on a stand, so that its height would correspond to one of an adult boar (cf. Figure 10).

Figure 10 : A GPS collar fixed on a jerrycan of water on the support in wood with a camouflage net on it

Two collars with their supports have been used for the tests. In order to determine the tests' sites, some types of vegetations that represent at the best the domain of the study have been chosen (cf. Table 4). Eight categories have been chosen and two tests have been carried out for each of them.

Once these eight categories determined, we had to choose the sites for the tests. The choice has been made based on several parameters. The site had to be located on a plateau or somewhere up, so to be able to eliminate the topographical factors that influence the precision. Furthermore it had to be close to a path crossing, so to be able to determine the exact spot of the test. Finally, the vegetation type had to be the most homogenous possible within a minimum of a 30m range. The appropriate sites have been found by striding along the forest paths of the study ground.

During each test, the following measures are collected:

- the date;
- the beginning and the end time of the test;
- the vegetation type;
- the total and the strated canopy cover;
- the predominant plant species;
- the trees' average height;
- the trees' basal area;
- pictures of the vegetation in the direction of the four cardinal points (north, south, east and west) and towards the sky, so to represent the canopy cover;
- the presence of a mobile telephone network used by the GPS collars;
- the weather at the beginning and the end of the test;
- the approximate GPS location of the test site;
- the distance and the direction of the nearest path intersection;
- the precise GPS position of the test site.

The total cover represents the percentage of the sky covered by the vegetation and the strated cover represents the part of each stratum in percentage of the total cover. These values have not been measured but only estimated, as well as the average height of the trees.

The basal area has been measured with the help of a dendrometre (Dendrometer, Institut für Forstenrichtung und Ertragskunde der Universität Göttingen, Germany). The diameter of the trees used to calculate the basal area has been measured with a periphery ribbon. The tree density per hectare has been calculated with the values of the basal area and with the trees' diameter by using a mathematical formula taken out of a forestry course of the University of Freiburg (Abteilung für Forstliche Biometrie, Universität Freiburg, 2002).

The presence of a network of mobile telephone has been detected via the firm mobile telephone of the FAWF, which uses the same operator than the GPS collars. The weather has been collected by using the VHF fixing criteria (cf. Appendix 5).

The first GPS position has been collected with a handheld GPS (etrex, Garmin, USA) in order to determine approximately the site of the test, since the former was too imprecise to be used as a reference of the real test site. The distance and the direction from the path crossing have at the beginning simply been measured with a decametre and a normal compass. In order to improve the precision of the measurements, the decametre has been replace by a device for distance measurements (Vertex III, Haglöf, Sweden) and the normal compass has been replaced with an optical aiming compass (Suunto KB-14/360, Suunto, Finland).

Theoretically, the values of the directions and the distances, via the software ArcGIS©, should have given the exact location of the GPS collar. But, again, the precision was not enough. That is why the exact position has been measured later on via a differential GPS (GEOmeter 24, GEOsat, Germany).

In all, 16 tests have been carried out with eight types of vegetation. Each test has measured a position every hour during 24 hours. The principle of the data collecting is the same as for the GPS fixes (cf. chapter 3.2.2).

3.3.2. Data processing

The data has been typed in the software ArcGIS© the same way as the GPS fixes. The number of available satellites for each position collected by the collars has been determined by the software Planning version 2.7 from the firm Trible Navigation Ltd.

The distances between the position displayed by the GPS collar and the collar's real location has been calculated. It corresponds to the location error or to the dissemination in regards to the exact site. Its mean has also been calculated. Furthermore, an average point has been calculated by taking the mean of all the coordinates of a same test. The distance between this mean point and each position revealed by the collar has been taken to calculate the global dissemination of the positions. All this data has been brought together in an Excel spreadsheet for each test (cf. Appendix 6).

Some statistical tests have then been effectuated with the software SPSS 14.0. The locations' errors of each test have been compared to the locations' errors of the other test by means of the statistical Kolmogorov-Smirnov test (non-parametric test of two independent samples) in order to show whether there could exist some significant differences between the tests.

The average measures of the factors that could influence the location error (tree density, canopy cover, etc., cf. Table 4) have been compared with help of the statistical Spearman's Rho test (non-parametric correlation test) to determine whether there are some correlations between certain factors as well as with the average location error.

Parallel to Spearman's Rho test, a linear regression test has been effectuated, in order to see whether the elements of the vegetal structure have an influence upon the location error and if yes, to what extent. Several linear regression methods have been used. First of all, each element of the vegetation's structure has been tested individually. Then a regression has been effectuated by adding progressively each independent variable (Forward regression). In another regression, the opposite has been done, e.g. by removing progressively the variables that have the less influence (Backward regression). Finally, a regression step by step has been made: where one variable is added to another and that the other ones are not significant any more, because of this introduction, they are pulled out (Stepwise regression).

4. Results

4.1. Results of the evaluation of GPS telemetry method's via VHF telemetry

The total number of locations done due to the VHF telemetry, over the collecting period, amounts to 125. These 125 locations have been compared to the locations done through the several GPS collars at the same moment. The GPS collar locations can either succeed or fail. Out of these 125 locations, collected through the VHF telemetry, 91 have been accepted after they passed the selection criteria (cf. chapter 3.2.3). Out of these 91 locations or positions, 74 can be found on the upper part of a hillside or on a plateau (category "plateau") and 17 are situated on the lower part of a hillside or in a valley (category "valley"). 21 positions out of the 74 in the "plateau" category could not be collected by the GPS collar, and the same for 11 out of 17 for the "valley" category (cf. Table 1).

Table 1 : GPS and VHF location fix

		GPS and VHF[a]		VHF[b]	
	All	n	%	n	%
Accepted	91	53	58.2	38	41.8
Refused	34	22	64.7	12	35.3
All	125	75	60.0	50	40.0

		GPS and VHF[a]		VHF[b]	
	All accepted	n	%	n	%
Plateau	74	47	63.5	27	36.5
Valley	17	6	35.3	11	64.7
All	91	53	58.2	38	41.8

[a] Location succesfull for both GPS and VHF telemetry
[b] Location succesfully performed for the VHF telemetry but failure of the GPS collar

As far as the 34 refused locations go, 20 are located in the "plateau" category and 14 in the "valley" category. On the 20 location attempts in the "plateau" category, 7, respectively, 5 out of 9 the "valley" category could not be collected by the collar.

The mean distance between the validated GPS and VHF locations, when the two methods have succeeded to detect a position, is of about 120m, with a maximum distance of 360m and a minimum one of 6m.

The fact that we dispose of only a small data set for the 'valley' category, does not allow us to say that the fixes have been more or less successful in the valley. Altough, there a slight tendency visible indicating that the values are higher in the valley for the average distance, the maximum distance and the minimal distance, than on the plateau (cf. Table 2).

The statistical analysis on the frequency of the accepted fixing attempts with a test of Chi square indicates that the GPS collars have a significantly greater success rate than failure rate on the plateaus (P = 0.020) Concerning the valleys, the statistical analysis does not indicate any significant differences between the observed and the expected success rate (P = 0.25), probably because of the few data available for this category. Although, one can observe a slight tendency. The success rate is slightly lower than the failure rate (cf. Table1).

The GPS collars, when they are succesful to determine a position, also collected additional data. Among these, the most interesting are the type of fix (3D or 2D) and the validation or not, by the collar himself, of the GPS fix (cf. Table 2). For the fixes obtained in the category 'plateau', we can observe a clear predominance of 3D fixes (80%) and of validated fixes (70%). In the valleys, the ratio of 3D fixes is lower (60%), as is the ratio of validated fixes (60%).

Table 2 : Number of fixes accepted and succesfull for the GPS and theVHF telemetry

		Validated [a]		Non validated [a]		Location				Distance between GPS and VHF positions [m]		
						3D		2D				
	All	n	%	n	%	n	%	n	%	Average	Max	Min
Plateau	47	32	68.1	15	31.9	36	76.6	11	23.4	116	327	6
Valley	6	4	66.7	2	33.3	4	66.7	2	33.3	136	358	31
All	53	36	67.9	17	32.1	40	75.5	13	24.5			

[a] Validation of the fix by the GPS collar according to the DOP and according to the location type (2D or 3D) (Attention: the validation does not correspond to the acceptation of the VHF fix which is in the tableau1)

During the period of data collection, it happend height times that the tracker did not find the boars he was attempting to track. In four of these eight cases, the GPS collar succeeded to take a position. These four positions are located in the 'plateau' category.

4.2. Results of the evaluation of the precision of a GPS collar in different structures of vegetation

The statistical analysis to determine whether the values of dispersion of each testing situation of the GPS collars differ from one to the others (statistical test of Kolmogorov-Smirnov) has demonstrated that the values of the tests performed under a same vegetation condition do not differ significantly from one another (P > 0,05). The values of the tests that have taken place in shallow wooded areas (prairie and bushy areas) differ significantly from those effectuated in densely wooded areas. "Densely wooded" means here a large value for the basal area of the vegetation in combination with a high percentage of canopy cover (cf. Table 3)

Table 3 : Results of the statistical analysis (Kolmogorov-Smirnov test).

			Vegetation [b]	M1	M2	B1	B2	CO1	DO2	DD1	MO2	CD1	DD2	DO1	MO1	MD2	CO2	CD2	MD1
			Basal area [m2/ha]	0	0	0	0	20	24	24	28	28	28	32	32	36	44	52	56
			Canopy cover [%]	0	0	75	100	40	80	100	75	95	100	75	80	100	30	100	100
			Dis1[a]	5.4	4.8	5.1	5.6	5.7	13.5	11.0	7.3	12.1	6.9	11.5	12.4	19.5	9.3	17.1	13.3
Veg.[b]	B.a.	C. c.	Dis1[a]																
M1	0	0	5.4	\	S	S	S	S	D	S	S	S	S	D	D	D	S	D	D
M2	0	0	4.8	S	\	S	S	S	D	D	S	D	D	D	D	D	D	D	D
B1	0	75	5.1	S	S	\	S	S	D	S	S	S	S	D	D	D	D	D	D
B2	0	100	5.6	S	S	S	\	S	D	S	S	S	S	D	D	D	D	D	D
CO1	20	40	5.7	S	S	S	S	\	S	S	S	S	S	S	D	D	S	D	D
DO2	24	80	13.5	D	D	D	D	S	\	S	S	S	S	S	S	S	S	S	S
DD1	24	100	11.0	S	D	S	S	S	S	\	S	S	S	S	S	S	S	S	S
MO2	28	75	7.3	S	S	S	S	S	S	S	\	S	S	S	S	D	S	D	S
CD1	28	95	12.1	S	D	S	S	S	S	S	S	\	S	S	S	D	S	S	S
DD2	28	100	6.9	S	D	S	S	S	S	S	S	S	\	S	S	D	S	S	S
DO1	32	75	11.5	D	D	D	D	S	S	S	S	S	S	\	S	S	S	S	S
MO1	32	80	12.4	D	D	D	D	D	S	S	S	S	S	S	\	S	S	S	S
MD2	36	100	19.5	D	D	D	D	D	S	S	D	D	D	S	S	\	S	S	S
CO2	44	30	9.3	S	D	D	D	S	S	S	S	S	S	S	S	S	\	S	S
CD2	52	100	17.1	D	D	D	D	D	S	S	D	S	S	S	S	S	S	\	S
MD1	56	100	13.3	D	D	D	D	D	S	S	S	S	S	S	S	S	S	S	\

[a] Average distance between the positions performed by the GPS collar and the real position

[b] Vegetation type classified according to the basal area and then to the canopy cover

D = significant difference (P<0,05) between the tests

S = no significant difference (P>0,05) between the tests

Vegetation type : M = meadow, B = bush, CO = conifer open, DO = deciduous open, MO = mixed open, CD = conifer dense, DD = deciduous dense, MD = mixed dense

Table 4 : Values performed by the GPS collars and values performed on every tests sites

	Structure of vegetation					GPS fix				DOP			Location error 1[b]			Location error 2[c]		
N°	Type of vegetation [a]	Canopy cover [%]	Density [tree/ha]	Basal area [m²/ha]	Average height of tree [m]	n	3D	2D	No fix	Ave.	Min	Max	Average 1	Min 1	Max 1	Average 2	Min 2	Max 2
N2	Meadow 1	0	0	0	0.5	24	24	0	0	4.7	2.4	16.4	5.4	0.4	11.6	5.3	0.6	12.0
N12	Meadow 2	0	0	0	0.5	24	23	1	0	3.2	1.8	6.2	4.8	1.1	11.4	4.6	0.3	12.2
N8	Bush 1	75	0	0	1.5	24	21	2	1	4.3	2.2	14.8	5.1	0.4	23.5	5.1	0.5	22.5
N15	Bush 2	100	0	0	2	24	24	0	0	4.1	2.2	9.6	5.6	0.0	18.6	5.5	0.4	19.7
N4	Conifer open 1	40	233	20	25	24	23	1	0	3.5	2.2	6.6	5.7	0.7	15.1	5.7	0.4	14.3
N10	Deciduous open 2	80	223	24	25	24	23	1	0	4.1	1.8	8.2	13.5	0.5	43.5	12.8	1.9	46.9
N6	Deciduous dense 1	100	178	24	15	24	21	3	0	4.6	2.4	10.2	11.0	1.2	32.1	10.7	0.3	30.9
N11	Mixed open 2	75	132	28	25	24	23	1	0	4.5	1.8	21.6	7.3	0.5	22.9	6.5	1.7	19.2
N5	Conifer dense 1	95	751	28	15	24	11	10	3	4.6	2.4	12.0	12.1	0.4	80.7	12.1	2.5	76.7
N14	Deciduous dense 2	100	892	28	5	24	18	6	0	5.7	2.0	14.4	6.9	0.9	15.5	6.7	0.9	16.3
N1	Deciduous open 1	75	456	32	20	24	20	4	0	5.2	2.0	16.0	11.5	0.7	28.5	10.4	1.7	33.2
N7	Mixed open 1	80	145	32	25	24	24	0	0	4.5	2.6	9.2	12.4	1.7	35.6	11.7	1.7	37.7
N9	Mixed dense 2	100	945	36	15	24	11	10	3	5.2	2.0	17.0	19.5	1.4	81.9	19.2	2.2	81.9
N13	Conifer open 2	30	206	44	25	24	19	5	0	5.0	1.8	13.4	9.3	1.6	50.3	9.2	1.1	47.3
N16	Conifer dense 2	100	669	52	20	24	21	2	1	6.4	2.2	24.8	17.1	0.9	74.7	17.3	2.2	75.0
N3	Mixed dense 1	100	1001	56	20	24	16	3	5	5.8	2.4	14.6	13.3	1.0	56.0	10.1	2.8	44.5
				Total		384	322	49	13	4.7	1.8	24.8	10.0	0.0	81.9	9.6	0.3	81.9

[a] Types of vegetation are classified according to the basal area and then to the percentage of canopy cover

[b] This error represents the distance between the coordinates of the positions calculated by the GPS collar and the coordinates of the real position

[c] This error represents the distance between the coordinates of the positions calculated by the GPS collar and the coordinates of the average position calculated using all the positions

The most important data, collected by the GPS collar and collected directly in the field, is gathered in Table 4. There we can observe that the relation between the different elements of the vegetation's structure and the various GPS data. The most important value of this research is the scattering of the GPS's position in regard of the exact location. This error of location is due to the difference of measurement between the coordinates collected by the collar and those of the real location. The comparison of this value with the different characteristics of the vegetation structure could allow to determine if the vegetation has an influence on the precision of the GPS's collar fixes.

This comparison has been made with a non-parametrical correlation statistical test, the R of Spearman. The results show that each element of the structure of vegetation is more or less correlated (R > 0,5 and P < 0, 05) with the error of localisation (cf. Table 5).

Table 5 : Results of the statistical test of Spearman-Rho made with the programm SPSS

		Error 1	Error 2	Basal area	Canopy cover	Tree density	Tree height
Location error 1 (with the real position)	Correlation coefficient	1,000	,962(**)	**,790(**)**	**,575(*)**	**,723(**)**	**,535(*)**
	P	.	,000	,000	,020	,002	,033
	N	16	16	16	16	16	16
Location error 2 (with the calculated position)	Correlation coefficient	,962(**)	1,000	,692(**)	,576(*)	,679(**)	,472
	P	,000	.	,003	,019	,004	,065
	N	16	16	16	16	16	16
Basal area	Correlation coefficient	,790(**)	,692(**)	1,000	,404	,748(**)	,555(*)
	P	,000	,003	.	,121	,001	,026
	N	16	16	16	16	16	16
Canopy cover	Correlation coefficient	,575(*)	,576(*)	,404	1,000	,556(*)	-,009
	P	,020	,019	,121	.	,025	,973
	N	16	16	16	16	16	16
Tree density per hectare	Correlation coefficient	,723(**)	,679(**)	,748(**)	,556(*)	1,000	,321
	P	,002	,004	,001	,025	.	,225
	N	16	16	16	16	16	16
Average tree height	Correlation coefficient	,535(*)	,472	,555(*)	-,009	,321	1,000
	P	,033	,065	,026	,973	,225	.
	N	16	16	16	16	16	16

** The correlation is significative on 0,01 niveau.

** The correlation is significative on 0,05 niveau.

Besides a correlation between the elements of the vegetable structure, one can observe an important correlation between the basal area and the density of trees per hectare. This can be explained by the fact that the density of trees per hectare has been calculated with the same gross data collected on the field as the basal area (measurement of the trees that satisfy the criteria of the dendrometer). The relation between the error of location and the elements of the vegetation structure is also visible graphically. The more the elements of the vegetation structure increase, the more the location's error gets higher (cf. Figure 11, 12, 13 and 14).

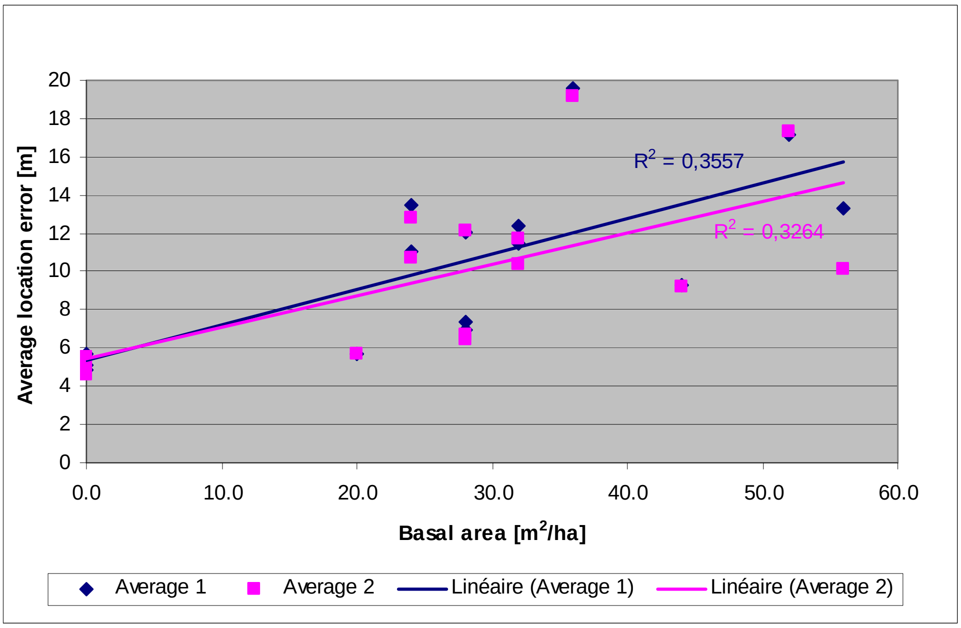

Figure 11 : Location error in relation to basal area

(Average 1 = average of the distances between the coordinates of the positions calculated by the GPS collar and the coordinates of the real position ; Average 2 = average of the distances between the coordinates of the positions calculated by the GPS collar and the coordinates of the average position calculated using all the positions)

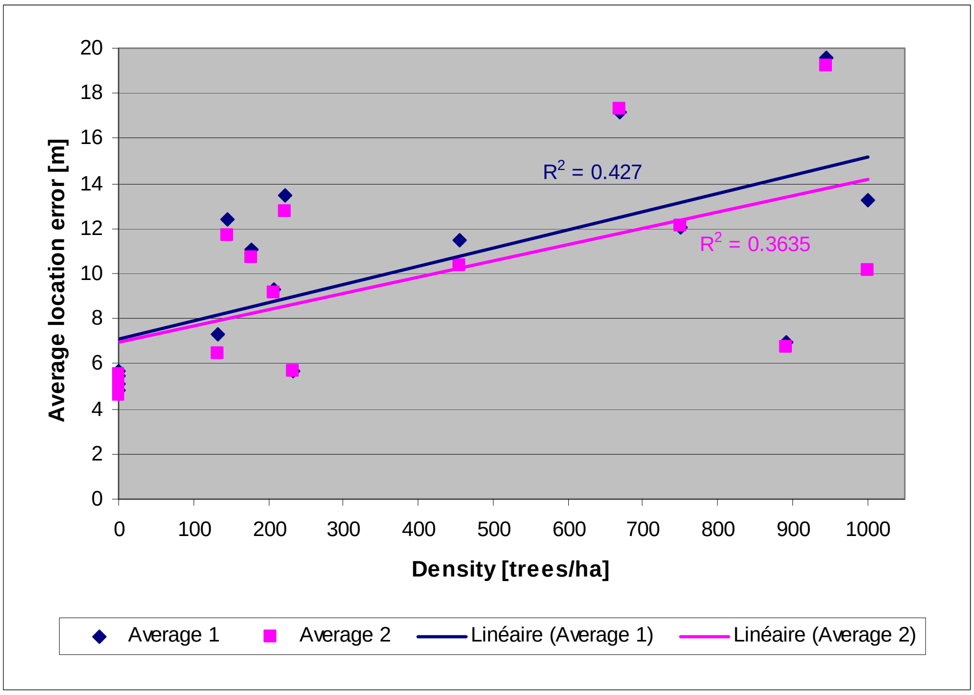

Figure 12 : Location error in relation to tree density

(Average 1 = average of the distances between the coordinates of the positions calculated by the GPS collar and the coordinates of the real position ; Average 2 = average of the distances between the coordinates of the positions calculated by the GPS collar and the coordinates of the average position calculated using all the positions)

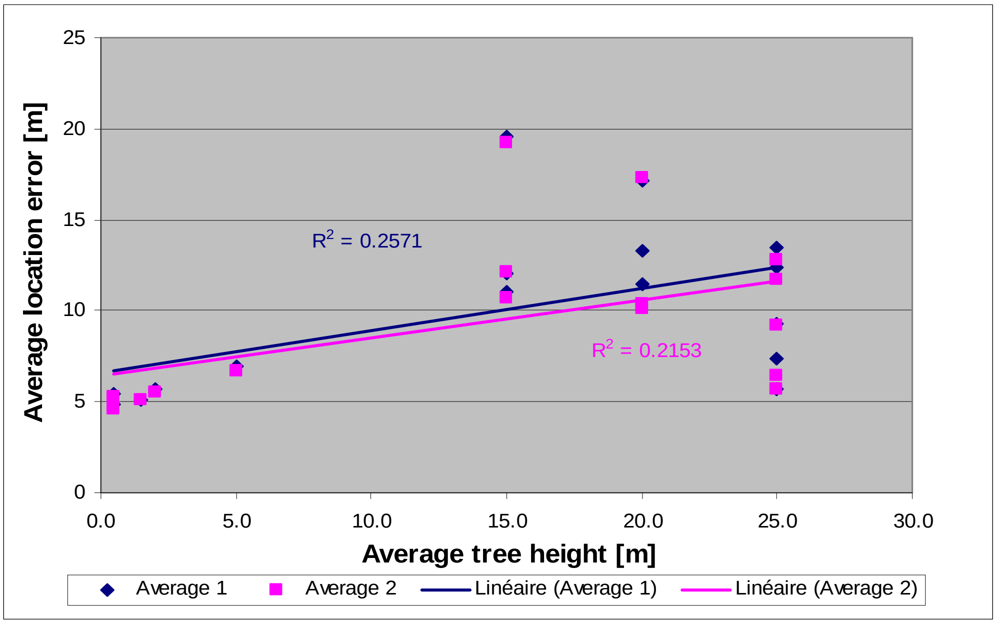

Figure 13 : Location error in relation to average tree height

(Average 1 = average of the distances between the coordinates of the positions calculated by the GPS collar and the coordinates of the real position ; Average 2 = average of the distances between the coordinates of the positions calculated by the GPS collar and the coordinates of the average position calculated using all the positions)

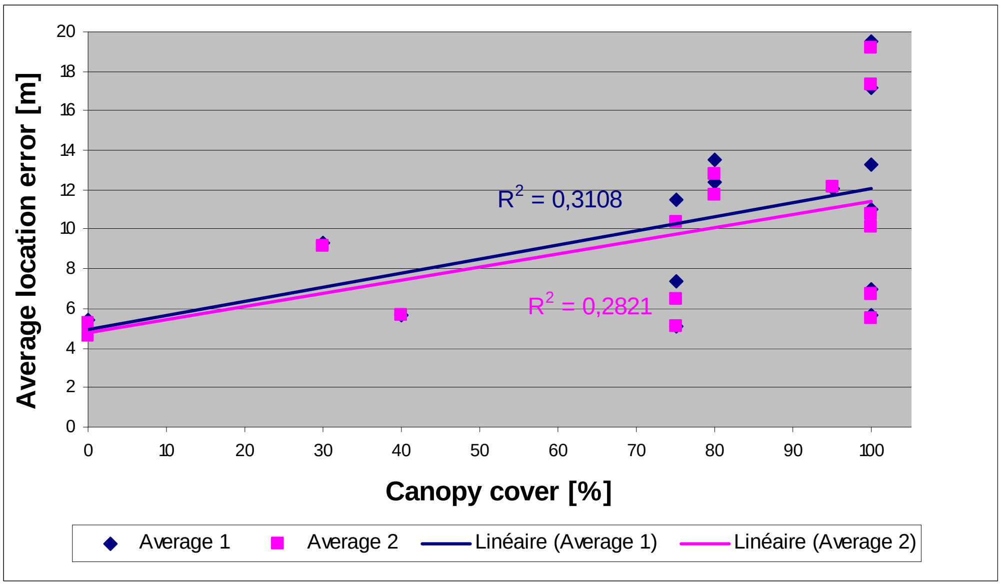

Figure 14 : Location error in relation to canopy cover

(Average 1 = average of the distances between the coordinates of the positions calculated by the GPS collar and the coordinates of the real position ; Average 2 = average of the distances between the coordinates of the positions calculated by the GPS collar and the coordinates of the average position calculated using all the positions)

From a general point of view, location errors have very different values for certain types of vegetation. Even when two types of vegetation of the same category (for instance: mixed open forest 1 and 2) have not presented significant differences in the statistical test, location errors can differ in an important way (cf. Figure 15). On the other side, the kind of fixes (3D, 2D or failure) done by the GPS collars has shown a significant correlation with the density of trees by hectare (R3D = -0,788, R2D = 0,728 and Rfailure = 0,550).

This means that the more the density of trees increases, the more the ratio of 3D fixes will decrease, and hence the more the ratio of fixes 2D as well as the failures will increase (cf. Figure 16).

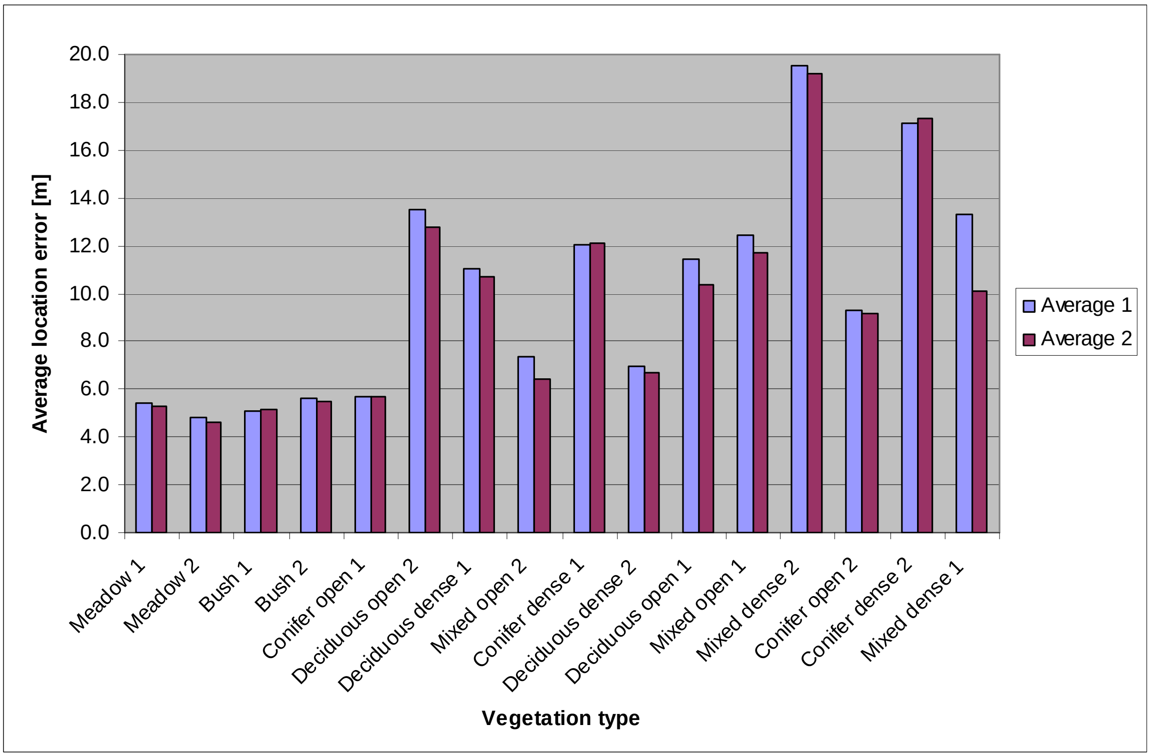

Figure 15 : Location error for every vegetation type

(Average 1 = average of the distances between the coordinates of the positions calculated by the GPS collar and the coordinates of the real position ; Average 2 = average of the distances between the coordinates of the positions calculated by the GPS collar and the coordinates of the average position calculated using all the positions)

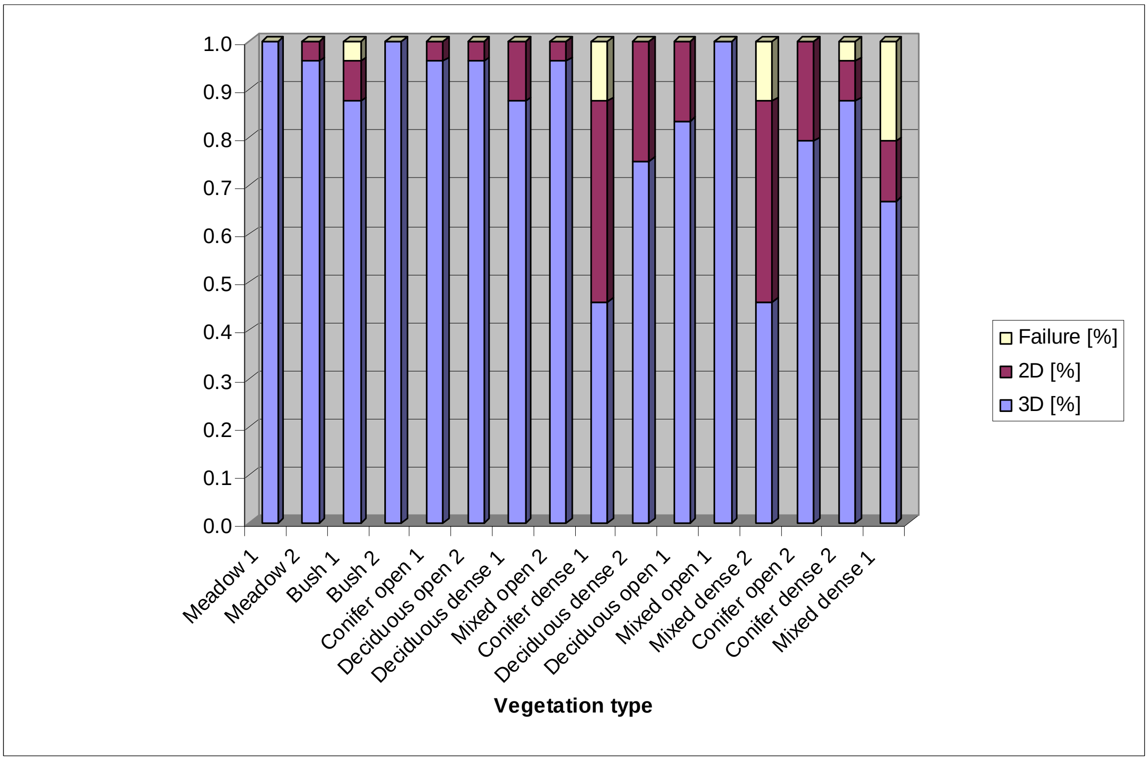

Figure 16 : Percentage of the different types of position for every vegetation type

What is worthwhile noticing in the graph of Figure 16, is that the four types of vegetation that have the highest rates of failure and 2D fixes are dense (e. g. they have a high ratio of canopy cover) and at the same time they show the four highest values of tree density by hectare.

The statistical tests to determine which is the element of the vegetation structure which has the most influence on the location error (multiple linear regression) have shown identical results. Each regression (Forward, Backward and Stepwise) has shown that the element of the vegetation that has the most influence on the location error is the basal area (R = 0,739 and P = 0,001). That is why the types of vegetation have been classified after the value of the basal area. If the basal area increases of 1 m2/ha, the location error increases of 0,186m.

The second element which also has an influence on the results is the canopy cover (R = 0,557 and P = 0,025). The tree density by hectare and the tree's height also have a significant influence whenever they have been tested individually (Rdensity = 0,654, Pdensity = 0,006 and Rheight = 0,509, Pheight = 0,044), but they have been systematically eliminated by the Forward, Backward and Stepwise regressions.

In the light of these results, it has been found interesting to deepen the comparison between the basal area and the location error. To do so, the values of the basal area have been categorized (from 0 to 15, from 15 to 30, from 30 to 45, from 45 to 60 m2/ha). The result is even more evident then in the Figure 11: the more the basal area increases, the more the location error increases as well (cf. Figure 17).

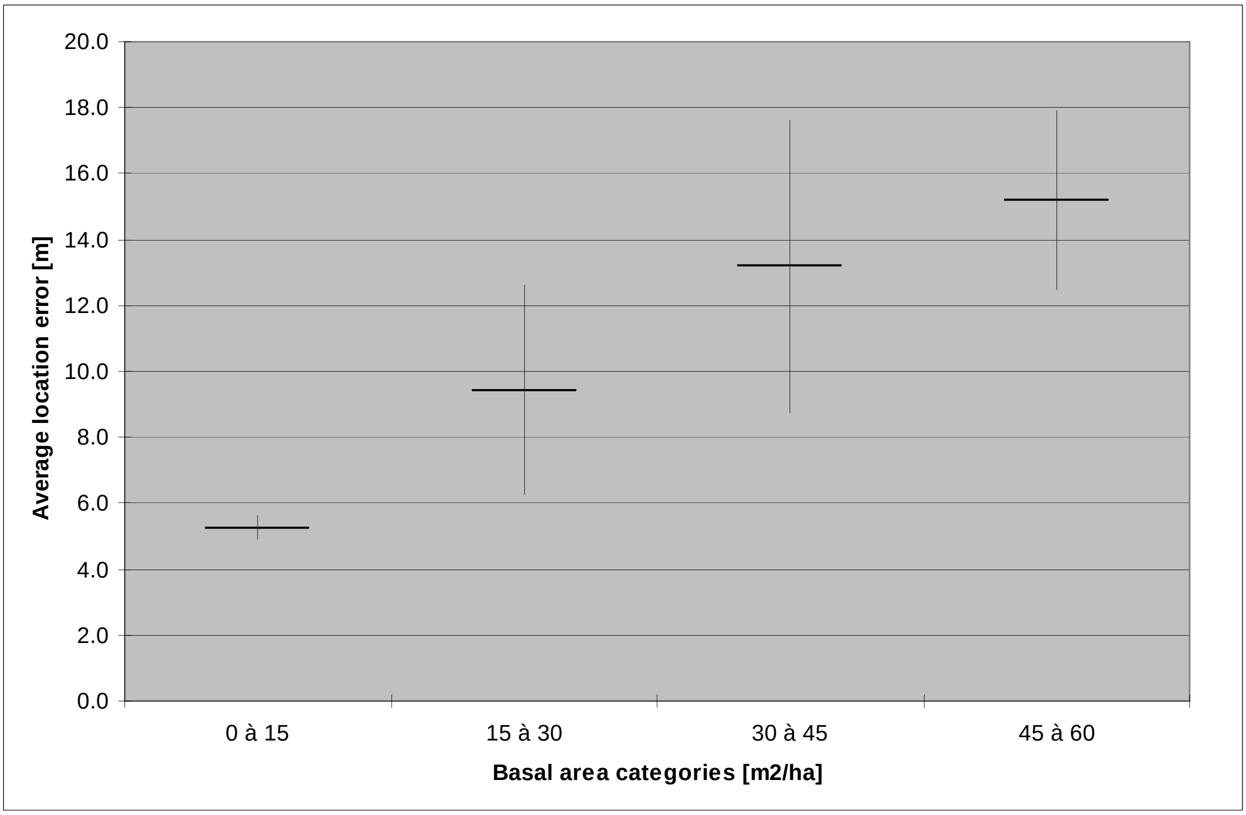

Figure 17 : Location error in relation to the basal area categories
(the vetical line represents the ecartype and the horizontal line represents the average value)

5. Discussion and perspectives

5.1. Evaluation of the GPS telemetry method via the VHF telemetry

The evaluation of the GPS telemetry method has demonstrated that the topography can play an important role on the success rate of fixes, as well as on their localization in three or two dimensions (3D or 2D). The fact that less data, both GPS and VHF, has been collected in the valley does not necessarily mean that the boars were less roaming around there. Indeed, a possible explanation could be that with the boars in the valley, the GPS collars have a lower success rate because of the conditions, which are worse than those on the plateau. In the valleys, the satellite's signals penetrate much less, since they are blocked out by the topography. The latter could be one of the reasons of the weak success rate collected by the GPS collars in the valleys. If this is true, one of the consequences is a bias when evaluating the use of space by the wild boar, in the sense of an underestimation of the presence of boars in the valley environments.

In order to determine the distribution between the valleys and the plateaux for all the fixes done, the complete GPS data set of each of th collared wild boars should furthermore be analysed. We could thus obtain a much larger sample, which in turn could allow much broader results with the statistical analysis. This study has not been undertaken, since, with more than a thousand results, the thorough analysis would have taken too much time.

The GPS telemetry is not the only one being influenced by the topography. Indeed, according to KENWARD (2001), the VHF telemetry also becomes less precise and more difficult to realise when the topography is more uneven. The risk of collecting a reflected VHF signal increases when the tracker is located in a valley or near a cliff. I have been able to make this observation myself during the different telemetry sessions.

In the case where the VHF telemetry would have a just as low rate of success in the valley than the GPS telemetry, the evaluation of the success rate of the GPS fixes via the VHF telemetry would not yield to any useful results and would not make any sense altogether. If we consider the few results obtained, this hypothesis is not unlikely to be consistent.

The last hypothesis to explain the lower location rate in the valley could be to consider that the boars simply stay less in the valley than they do on the plateaux. Collecting signs of presence (traces, dung, rooting, etc.) could constitute a method to test this hypothesis. If indeed we could observe less traces of presence in the valleys than on the plateaux, this hypothesis could be confirmed.

5.2. Evaluation of the GPS collars in different vegetation structures

The evaluation of the GPS collars in different vegetation structures has demonstrated that the GPS fixes, despite a clear influence of the vegetation, are very precise information in the places without any marked topographical elements. If we observe the global values collected on the fixes, only 13 (3,5 %) out of 384 have failed. Among the 371 fixes having succeeded to determine a position, 70% have a location error of less than 10m and 95% have an error of less than 30m. The mean location error for all the fixes is of 10m.

There has not been a difference of precision between the fixes collected in conifer vegetation and those collected in deciduous vegetation. In other words, the vegetal species do not have any influence on the location errors in this study. On the opposite, the marked influence of the basal area allows to say that the obstruction of the signals is greater when the obstacles are rigid elements, like the wood of the trees' trunk.

These results are similar to those published by DI IORIO et al. in 2003, where they tested the precision of two GPS collars of two American firms wa tested in different habitats that are comparable to the habitats tested in this study. 88% of their fixes had a location error of less than 25m (less than 19m for this study here). The mean location error is similar (14m for the Latek Inc. collar and 16m for the Advanced Telemetry Systems Inc. collar), as well as the failure of fixes (4%).

As far as the vegetation parameters that have an influence on their fixes, their results are partly different. They have observed that the more the canopy cover is important, the less the collars have succeeded and the less they had 3D fixes. Their basal area was slightly and negatively correlated with the location error ($R2 = 0,57$, $P < 0,01$), as opposed to the canopy cover which did not correlate at all. The linear regression they have done with the basal area explains slightly the location error variation for the 3D fixes.

These differences between the two studies in the vegetation influence could be explained by the fact that the elements of the vegetation structure were not the same at all, or else, they were analyzed in a different manner.

The comparison of the results observed in this study with those published by REMPEL et al. in 1995 and those published by MOEN et al. in 1996 shows the great influence of the *Selected Availability (SA)*, since these studies have been made before the abolition of the SA in 2000.

The location errors obtained by REMPEL et al. have a median of 60m with a minimum of 3m and a maximum of 650m. 95% of the fixes have an error between 3 and 242m. The location errors observed by MOEN et al. were three times as big (50% of the fixes have an error of less than 40m and 95% have less than a 100m error) than those found in this study. The SA has also a great influence on the success rate and the 3D fix rate (only 30% of 3D fixes and 3% failure in an environment totally open for the two studies).

These results, whencorrected differentially, become much more precise and hence correspond more or less to the results which can be obtained today without the SA. This demonstrates the gain in precision obtained since the suppression of the SA.

In the present study, the evaluation of the GPS collars has been conducted with tests only located in environments without major topographic elements. It has demonstrated that the precision is influenced by the vegetation, but the location errors remain within acceptable values for an analysis of the movements of wild boars in an environment without major topographic elements.

In order to determine the impact of topographic elements which can block out the reception of satellite signals, another study should be done in environments like valleys or near cliffs. By comparing the results with those obtained in this study, it will be possible to determine the impact of topography. At the beginning of this diploma research, such tests have been performed. However, in order to determine the influence of the vegetation without any other influential factor, these tests have been continued only on plateaux, where the topography could not have any influence anymore. Moreover, these preliminary tests, because of lack of information, have not been properly effectuated (very little standardised, effectuated during 5 hours instead of 24 hours and configured to collect a fix every 30 minutes instead of every hour).

An evaluation of the topography's influence on the location error of the GPS collars has already been realised by D'EON et al. in 2002. It has demonstrated that topography does not have any influence when vegetation is absent, but interacts with it when the former becomes more dense.

Likewise as the influence of vegetation, the influence of topography should be measured for the study area of FAWF. Because the results could differ from the results of the other studies in a significant manner.

5.3. Comparison of the GPS telemetry with the WHF telemetry

The scientists working on the monitoring of fauna choose generally one of the two telemetry methods in order to collect useful data for their research. The comparison between the two methods as for costs, precision and time needed for the collection of data will ease the choice.

In Table 6 below, the two methods have been compared. The parameters (costs, precision, etc.) are specific to the methods used by the FAWF and can differ with those used by other research centres. For example, the VHF telemetry could cost much less if the fixes were realized with a hand antenna instead of one mounted on a vehicule.

VHF telemetry	**GPS telemetry**
Material cost : - 215 € : Auricular transmitters (C-1 / ER1733[A], Wagner, Germany) - 540 € : Receivers (TRX 1000S, Wildlife Materials International Inc., USA) - 180 € : Antenna (5 Element – Yagi, Biotrack, Angleterre) - 1800 € : Telescopic pole (ST55-4-TC, Clark Masts, Angleterre) - 22'000 € : Bus (Transporter T4 2,5 TDI, 1998, Volkswagen, Germany) - 40 € : Compass (DS 50, Recta, Swiss) Total : 24'775 € Utilisation cost : - Diesel for the bus - Different supplies (paper, pencil, etc.)	Material cost : - 3'575 € : GPS collar (GPS Pro-3 Plus Collar, Vectronic Aerospace GmbH, Allemagne) - 1'500 € : Ground station for the data reception (GSM Ground Station, Vectronic Aerospace GmbH, Allemagne) with SIM cards for the collars and the rights for using the data manager programm (GPS Plus Collar Manager, Vectronic Aerospace GmbH, Allemagne) Total : 5'075 € Utilisation cost : - Electricity 24h on 24 for the computer
Average precision : - Lower than 200m (BERGER, 2006)	Average precision : - Lower than 20m (DI ORIO et al., 2003)
Time required for one fix : - Between 30 and 60 minutes (plus 40 minutes for driving to the study area)	Time required for one fix : - 3 minutes
Operating time of the transmitters : - about 1,5 years (WAGENER, personal communication 2007)	Operating time of the transmitters : - about 18'500 fixes (Vectronics Aerospace, 2005) which correspond to 2,5 years if 20 fixes are made every 24 hours

One can observe that the costs of the VHF telemetry are five times higher than the ones for the GPS telemetry, if we count the acquisition of a vehicle for moving around. Time investment is also much more important. The longevity depends, for the GPS telemetry, from the frequency of the fixes. The precision, as stated in this study, is clearly better with the GPS telemetry. However, if several transmitters have to be bought, the costs will be lower with the VHF telemetry.

It is with use of comparisons like the one in this study and other comparable ones that future research works in big fauna will be able to base their choice for a telemetric system.