

GPS-BASED DOCUMENTATION OF MANUAL SILVICULTURAL OPERATIONS

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Abstract

Herbaceous weed control and planting of southern pines share a common attribute in that they are both implemented using primarily hand labor in the southern US. Contractors providing these services have had problems documenting the amount and quality of work performed by individual laborers, and in providing auditable data to landowners of the extent of services provided. Electronic systems were developed to resolve these problems. The 'SmartPak' system recorded location while a worker sprayed herbicide and the 'SmartDibble' documented location when a tree was planted. Both systems had problems, but were also shown to provide value to the contractor using them.

Keywords: Herbicide, hand planting, electronic monitoring

Introduction

Temporary seasonal workers are commonly used in forest management in the US South, primarily in two specific tasks: regeneration planting, and herbaceous weed control. There are many reasons for this reliance on human labor, but the primary driver has been that costs tend to be lower. Mechanical alternatives are not available that provide as consistently good results across the broad range of conditions found in the region. In addition, a pool of non-resident labor is available and willing to work for wages lower than most native-born citizens, and at an acceptable level of productivity and quality.

There are questions, however, surrounding the employment of this temporary labor force, and the work they produce, that have caused some controversy. Large landowners, and the silvicultural contractors they employ, are seeking ways of improving the quality and accountability of work produced using seasonal laborers. This report will outline the authors' efforts to create information systems for documenting the output of manual labor in herbaceous weed control and hand planting.

Backpack Herbaceous Weed Control

Woodland Specialists, a silvicultural services contractor located in Chapman, AL, developed, in association with Auburn University Biosystems Engineering Department, a backpack spray system to reduce concerns with employee safety and quality assurance for clients. Design changes resulted in a new type of spray rig that addressed health concerns and added monitoring electronics to record spray system performance. Their objectives in creating the new system were:

1. Create a safer, healthier work place for their employees to reduce turnover and increase awareness of job performance standards, and
2. Develop a data collection system to document worker activity and chemical spray coverage over an entire tract.

The system they produced has been dubbed the 'SmartPak' and has been deployed in the field for one full season.

Worker safety concerns arose because of the nature of the work being performed. Herbicides are used extensively in forest stand management in the US, especially in the South, where an estimated 93 percent of silvicultural herbicides were sold (Shepard and others 2004). Their use in silvicultural stand management can be broken down into three primary objectives: site preparation, herbaceous control, and release (woody competition control). Site preparation and release treatments are typically broadcast applied using mechanized aerial or ground-based systems. Herbaceous weed control is usually applied a short time after planting to provide a window of time within which the seedlings can become established without competition. Applications are usually sprayed in bands directly over the seedlings,

saving chemical and providing equal benefit to broadcast application. Because no official statistics are kept on herbicide use in forestry, estimates of the acreage treated for herbaceous control are sometimes conflicting. Dubois and others (2003) reported estimates of usage from the four largest herbicide distributors in the South, who based their numbers on sales volume and presumed application rates. About 950,000 ha of pine plantation were treated with some form of herbicide in 2002, with nearly 25 percent representing herbaceous competition control. Shepard and others (2004) also reported herbicide use estimates. Based on survey data collected from member institutions of the National Council for Air and Stream Improvement (NCASI), primarily forest products companies, herbaceous competition control was found to represent 43 percent of the area treated in the South, the largest single use. The companies included in the NCASI report might have practiced a more intensive form of silviculture than the groups in the former survey, perhaps explaining the difference in values.

Regardless of the exact amount of herbaceous competition control being practiced, its use seems to be currently in favor, and one common means of implementing this type of prescription is through banded spraying using backpacks. Miller (1998) reported that, during the mid 1990's, only about one percent of herbicides used in the South for silvicultural purposes were applied using backpacks. That figure has certainly increased over the ensuing years. Dubois and others (2003) found in their survey that backpack application was used on about 16 percent of total pine plantation acres treated in 2002. The increase can be attributed to reduced chemical use compared to broadcast applications, lowering costs, plus a decrease in acreage mechanically site prepared, reducing the area on which spray machinery can subsequently operate cost effectively.

Chemical application by hand can be a risky business, for both the person carrying the backpack and that person's employer. For the worker, the risks are primarily associated with inadvertent contact with the chemicals being applied. In the past, backpack applicators consisted of a tank and a wand with which the worker sprayed the chemical. Spray pressure was typically maintained using a hand-powered pump, a significant physical burden. From a safety standpoint, this system forced the operator to walk through vegetation that had just been sprayed.

Shepard and others (2004) reported that 90 percent of herbaceous weed control chemicals used in the South were classified as imazapyr, metsulfuron methyl, or hexazinone. Toxicity of such chemicals is normally expressed in terms of an LD₅₀, the amount of the substance per kg of bodyweight that is toxic to 50 percent of subjects to which it is administered. Campbell and Long (1995) reported LD₅₀s for imazapyr and metsulfuron methyl as 5000 mg / kg, and for hexazinone 1690 mg / kg. By contrast, the LD₅₀ for caffeine is about 200 mg / kg. The amount of imazapyr ingested to be toxic to an average sized human, therefore, would be on the order of 375 g, an amount equivalent to the total active ingredient normally used in treating 0.4 ha of forest.

Although herbicides used in herbaceous weed control are relatively non-toxic, significant exposure of workers is possible because of the nature of the typical backpack sprayer and how it is used. Long-term exposure effects are not known, and

neither is the effect of inert ingredients used in commercial forms of the herbicides. Most herbicide manufacturers do not reveal exactly what additives their products contain, but enough is known to further discourage exposure of workers.

Besides having to control exposure of workers to herbicides, application contractors must provide their clients with evidence of the quality of the services rendered. Ideally, a contractor should be able to provide an auditable record of the amount of chemical applied at what locations. These data are useful for billing clients and in resolving disputes over efficacy of the treatment.

Modified Spray System Design

Spray system changes implemented by Woodland Specialists included mounting the tank on an ergonomic backpack frame to increase worker comfort, and conversion of the hand-powered spray system to use an electric pump, reducing physical demands placed on the worker. Spray nozzles were mounted in a fixed, rearward-facing direction so the worker was not constantly moving through chemically treated vegetation. These modifications reduced the level of exertion required while spraying and freed the worker's hands to help maintain balance when moving through thick vegetation and slash.

A spray monitoring system was used to record the state of the spray pump and location of the worker over time. The system itself consisted of an AMD 188 microcontroller that used a digital I/O port to track the state of the spray pump switch. The microcontroller sensed the pump being switched on and began recording position output from a global positioning system (GPS) attached through a serial port. Data were recorded at 1-s intervals on a compact flash card. Garmin model 18 and 16 GPS units have been used, and both have proved successful. The microcontroller extracted relevant data from a group of NMEA 0183 strings (RMA, GGA, VGA) output from the GPS unit.

Included in the monitoring system was an LCD screen through which the microcontroller could provide information to the operator. Output included updates on the state of switches and the GPS (satellite and WAAS availability), plus an error field that reported problems with data storage and other high-level system functions. The microcontroller also kept track of travel speed of the worker and gave constant updates via the LCD screen. The operator would typically be given a target speed at which to walk in order to apply the herbicide at the prescribed rate.

Figure 1 shows the spray systems in use. Note also the use of chemical resistant suits by the workers. Figure 2 shows details of the data recording and GPS systems, including the LCD screen.



Figure 1. Workers using SmartPaks to apply herbicide for banded herbaceous weed control.

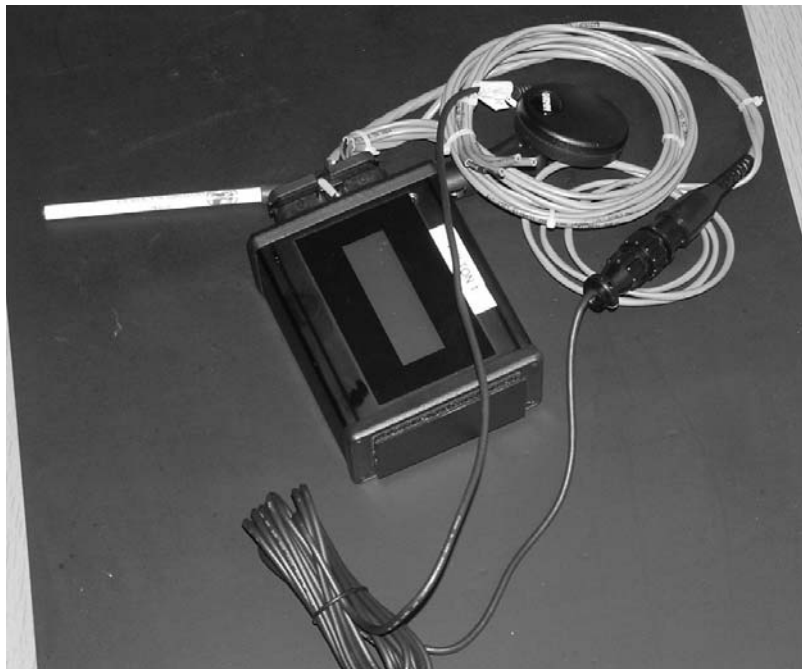


Figure 2. SmartPak electronics. The enclosure housed all electronics, including the memory card, which was accessed through the cover attached with Velcro on the side opposite the cable plug.

Field Experience Using the System

Woodland Specialists employed the SmartPak system in herbaceous competition control contracts on over 6000 acres during the 2005 spray season. About 20 total units were in use over that period, most on backpack units, but a few were used on mechanized spray equipment to track their application coverage. In general, the systems were deemed a success and plans are to use them again in the coming spray season.

Worker satisfaction with the SmartPaks was generally good, with the exception of a perception that, perhaps, productivity was not as high as desired. Wages were calculated on a linear distance application basis, so workers were very sensitive to any changes that affected their ability to cover ground. Although some spray system modifications enhanced productivity (the electric pump, hands-free operation), spray tank size had to be reduced in order to accommodate batteries, pumps, and other components. Most hand-powered spray units have a 19-liter tank. That volume was reduced by about 20 percent on the SmartPak, requiring additional trips to refill. The electronic components added 850 grams to the SmartPak, the battery about 3.5 kg more, but wet weight of the units (hand-powered and SmartPak) was roughly equivalent.

Operation of the SmartPaks required the workers to pay close attention to the feedback provided by the microcontroller, especially regarding battery status. They were motivated to do so, however, because of the link between the successful operation of the system and their pay. Workers typically monitored their speed while spraying, but they also looked for signs that the battery was beginning to lose its charge. When battery capacity was low, switching the pump on would drop the system voltage below a threshold required to run the electronics. In that case, the microcontroller would often power cycle and reinitialize the system. The initialization process would trigger the beginning of a completely new data record, which complicated an already too involved data management process.

There was some concern on the part of field technicians that the feedback given workers on speed did not have enough resolution. The speed data were extracted from the GPS information and were only available to the nearest 1/10th mph. The technicians, and presumably workers, felt this level of accuracy might not have been sufficient to ensure uniform spray coverage.

As one might expect, the SmartPak units deployed in the 2005 season proved not quite as durable as hand-powered units. Field technicians working with the spray crews felt the 2005 units would work reliably for about 3 to 4 months in the field. Spray season might last 6 months in that region of the country. Some of the failures observed had to do with the backpack carrier systems, which were essentially hiking pack frames that could not sustain the abuse suffered in field work over long periods of time. Units used later in the season were strengthened. Vibration and impacts during transport to and from the field was thought to decrease reliability of some of the electronics, but contamination from water or dirt was not a problem. Some of the components to be used in units for the coming spray season will be modified to increase the service life of the systems.

Workers were required to charge enough batteries every evening for the next day's work. The packs required at least two batteries per day in normal operation. Workers were not always happy with the responsibility of dealing with batteries, but seemed to accept it.

In the field, the SmartPaks worked about as well as could be expected for a prototype system. One area of operation that proved to be somewhat burdensome, however, was handling the constant stream of data being generated. This task required an estimated 30 to 40 hours per week for each of two technicians supervising seven spray crews. Over the course of the season, about 6 gigabytes of information were downloaded from the spray units, summarized, and transferred into a geographic information system (GIS). There was consensus among technicians that this process could be improved greatly.

The SmartPak controllers created a new output text file every time they were powered up. As work progressed, position information was logged into the file stored on a removable memory card in hour-minute-decimal second format. In the evening, files created for each worker were compiled then processed to convert the positions to decimal degree form. These data were exported into a dbf-type file for import into the GIS. Daily summaries of work activity were created for each laborer.

SmartPak Conclusions

After one season of extensive field testing, the management of Woodland Specialists felt the enhanced spray systems were worth the extra effort required to keep them operating. They cited the auditable documentation of work performed as the single greatest benefit of the systems. The data derived from the Smartpaks were used in settling accounts with landowners concerning number of acres treated and in resolving disputes over spray efficacy. Being able to show exactly where chemical had been applied proved a significant business advantage for the company. A map, such as that in figure 3, established a basis from which disputes could be resolved. The maps also provided a means of distinguishing Woodland Specialists from their competition and contributed to an atmosphere of trust with clients. When disputes arose over the level of herbaceous control in a particular tract, the company was able to show that they had in fact applied the chemical at the prescribed rate and that the prescription, or the chemical itself, must have failed.

Although other expected benefits, such as reduced chemical use through accurate application, were not as readily apparent, the SmartPak proved to be a useful tool in managing and educating workers. Maps of over sprayed and missed areas gave field technicians an unequivocal means of expressing concerns about poor performance to workers that most often did not speak English. Figure 4 shows detail of the data from figure 3. Areas of over- and under-spray, as well as the identity of the person responsible for the errors, are easily seen.

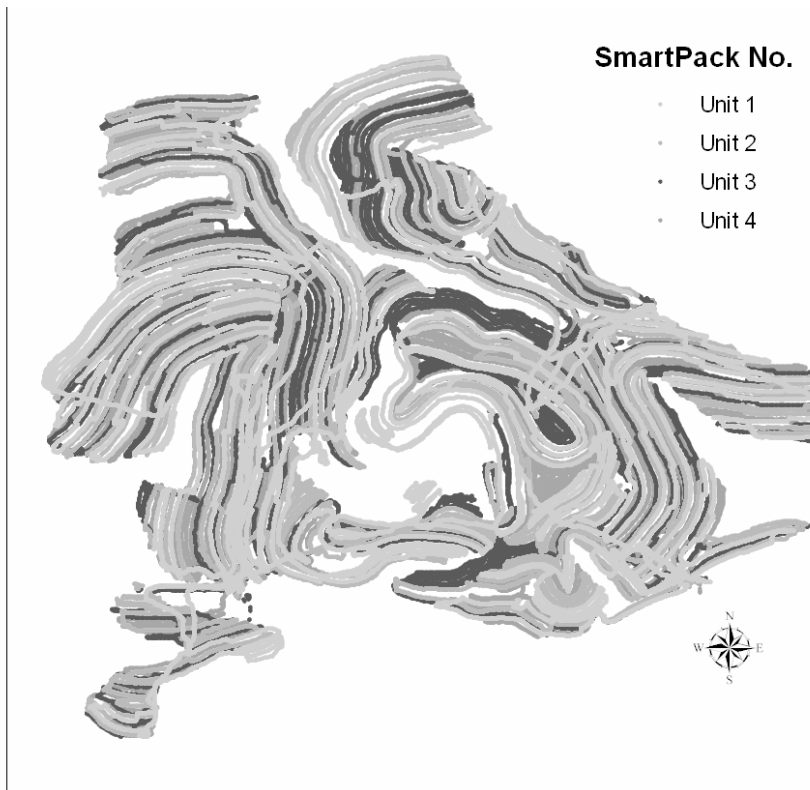


Figure 3. Map of herbicide spray coverage generated from data collected using the SmartPak. Color of the bands corresponds to which worker walked the given area.

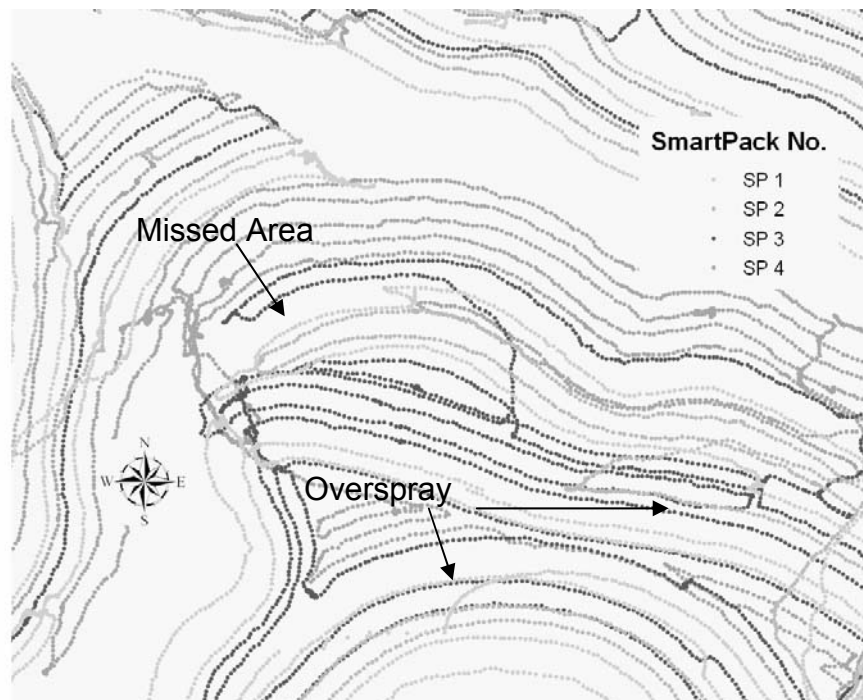


Figure 4. Detail of the spray coverage data from figure 3. The data illustrate gaps in spray herbicide application, and areas sprayed multiple times.

Hand Planting

Every year, US law allows issuance of 66,000 H2B guest worker visas to help companies involved in businesses other than agriculture hire workers they cannot recruit locally. In recent years, the majority (over 20 percent) of the visas issued have been for forest management activities (McDaniel and Casanova 2005). The program has been successful and Congress is considering upping the cap on visas to 200,000.

Regeneration planting of southern pines has been the largest single use to which H2B visas have been applied. McDaniel and Casanova (2005) reported that only about 8 percent of tree-planters working in the southern US were citizens, and about 84 percent were working with H2B visas. The remainder was on other types of visas, or undocumented.

A series of reports in the Sacramento Bee newspaper published in 2005 alleged serious mistreatment of workers hired for forestry work under H2B visas (Knudson and Amezua 2005). The articles reported many types of abuses, most involving taking advantage of the workers' dependency on the employer to maintain their status in the country. This publicity has focused a great deal of attention on the tree planting industry in the US. Some of the most critical has involved payment of planters. It has been alleged that workers were defrauded by unscrupulous employers that manipulated production figures, and the Southern Poverty Law Center of Montgomery, AL has filed a legal complaint on behalf of guest workers against the three largest contract planters in the country (Linn 2005) seeking redress.

These legal troubles have created to a tense atmosphere among companies involved in regeneration services. As in the case of herbaceous weed control, those companies that do their best to treat workers fairly and in compliance with laws feel they should be rewarded for the extra costs that effort entails. Unless they can fully document that compliance, however, their claims of unfair competition from other, less scrupulous, employers have no basis.

Woodland Specialists has, again working with Auburn University Biosystems Engineering, begun to investigate the use of electronic monitoring systems to document worker activity, this time involving tree planting. The concept, as in herbaceous weed control, was to create the technology to map all activity carried out by workers on a site. For planting, this meant showing placement of all trees across an entire stand. Such technology would form the basis of a fair piece-rate pay incentive program for workers, create an auditable record of work done for a landowner, and be a tool available to implement the concepts of 'precision forestry'. Given data on every tree in a stand, including its location, managers can focus attention and resources to the level of the individual tree, rather than the population. Managing for average conditions on a site will produce average results over time, but, as the technology becomes available, optimizing the growth potential of every individual should maximize the output of the entire stand.

The objectives of the work have been to

1. Create a wearable device that accurately records the location and time of a tree-planting event, and to
2. Use that device to map tree locations in hand planting operations.

A proof-of-concept version of such a device has been tested and prototype versions of a 'SmartDibble' are being assembled for use in the current planting season.

The SmartDibble

Trees are hand planted using one of two implements, a dibble or hoedad. Both are designed to create a hole in which the seedling is placed, the difference is in the motion required by the worker to use them. The hoedad uses an over-the-head swinging motion, much like an axe, while the dibble is an impact-type device, punched in a downward motion into the ground. While hoedads are used quite extensively in the southern US, dibles are recognized as being superior from a quality of planting standpoint and were the focus of this research.

The tree planting event 'sensor' developed for the project took advantage of the fact that every tree required a rather abrupt motion on the part of the worker to create a hole in the ground. An accelerometer was used to detect impacts of the dibble with the ground, and a microcontroller, when an impact was observed, recorded the event along with a time stamp and a position from a GPS.

The proof-of-concept system built used an Atmel Atmega-128 processor with integrated 10-bit analog-to-digital converter to monitor the output of a National Semiconductor ADXL150 accelerometer. When acceleration exceeded a threshold value, position was read from a Garmin model 18 GPS, interfaced through a Bluetooth connection. There was also an LED controlled through a microcontroller digital output port that provided a rudimentary type of operator feedback. Figure 5 shows the dibble system, with the GPS antenna affixed on the top of a hardhat and the monitoring electronics in the box attached to the dibble handle.

The system was tested under controlled conditions and figure 6 shows the results of one such test. An operator walked through a field and, at a prescribed distance interval, simulated a tree-planting event. Instead of a tree, the operator left a pin flag in the hole. The location of the pin flags was established using a real-time kinematic (RTK) GPS system and compared to the location reported by the dibble. In general, fixes of tree position were close to what could be considered a 'true' position from the RTK system. Differences could be reliably attributed to the relative inaccuracy of the GPS worn by the operator in these tests.



Figure 5. A prototype SmartDibble, a tool to collect information on tree location while planting. The system electronics are housed in the small box attached to the dibble handle. The electronics monitor received position information output from a GPS attached to the helmet the operator is wearing. The link between the controller and the GPS is established using a Bluetooth connection.



Figure 6. Map of planting locations established using two positioning systems: the SmartDibble, and an RTK GPS system.

Evidence has suggested that this, or a similar, system could be used in the field. A new prototype system has been developed for application in actual planting, but results have not been obtained as of yet. Plans are to test it over the first few months of 2006. The new SmartDibble incorporated several improvements over the previous version in electronics hardware, primarily in using a wireless connection between the accelerometer and the computer. The proof-of-concept system used a wireless link with the GPS to eliminate a physical connection between the operator and the dibble, but this meant there was quite a bit of additional hardware carried on the dibble itself, including the sensor, microcontroller, and batteries to power the entire system. In the newest version, only the sensor is carried on the dibble, while GPS, controller, and data storage hardware are carried on the person.

The hardware side of the SmartDibble has shown great promise, but, as in the SmartPak, data management will likely present the greatest obstacle in practice. One problem that has not been solved at this time is the issue of multiple impacts associated with a single tree-planting event. The hardware detects when an impact greater than a specific value occurs, but cannot discriminate if two or more impacts happen in the same location. It is most often the case when planting that multiple impacts are required to create the hole for the seedling, and that another impact is normally associated with closing the hole. Data from the SmartDibbles will therefore have to be filtered to arrive at a final list of legitimate seedling locations.

Conclusions

Manual operations are used widely in forest management in the southern US and likely will be in the future. Many concerns have been raised about the quality of work performed by hand and the systems presented in this report were developed to document the rate and spatial attributes of two forms of manual labor. The SmartPak system documented application of herbicides for herbaceous weed control, providing maps of where and when chemical was sprayed, as well as who performed the work. Although collecting the data was problematic, it has proved its value to contractors in documenting for landowners work performed and in resolving efficacy disputes. Although it has not been applied in practice as of yet, similar benefits should accrue from use of the SmartDibble system.

References

- Campbell, Paul; Long, Alan. 1995. Vegetation management in Florida's private non-industrial forests. SS-FOR-10. School of Forest Resources and Conservation, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. 11.
- Dubois, Mark R.; Straka, Thomas J.; Crim, Sarah D.; Robinson, Laura J. 2003. Costs and cost trends for forestry practices in the South. *Forest Landowner*. 62:3-9.
- Knudson, T. and Amezua, H., 2005. Forest workers caught in web of deception, Sacramento Bee, Sacramento, CA. November 13. pp. A1.
- Linn, M., 2005. SPLC sues forestry companies, Montgomery Advertiser, Montgomery, AL. August 27.

- McDaniel, Josh; Casanova, Vanessa. 2005. Forest Management and the H2B guest worker program in the southeastern United States: an assessment of contractors and their crews. *Journal of Forestry*. 103(3):114-119.
- Miller, J.H. 1998. Application variables and their influence on forest herbicide efficacy and selectivity: gaining understanding and control. In: Ed. Proceedings of the 51st Annual Southern Weed Science Society meeting; January 26-28; Birmingham, AL: Southern Weed Science Society. 120-133.
- Miller, K.V.; Miller, J.H. 2004. Forestry herbicide influences on biodiversity and wildlife habitat in southern forests. *Wildlife Society Bulletin*, 32(4): 1049-1060.
- Shepard, James P.; Creighton, Jerre; Duzan, Howard. 2004. Forestry herbicides in the United States: an overview. *Wildlife Society Bulletin*. 32(4):1020-1027.

