Forest Inventory, Lidar, and Patents

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Abstract

The goal for this paper is to increase awareness of patents for analysis methods that use airborne laser scanning (ALS) data in estimating forest inventories. US patents that have been applied for or issued are identified and critically reviewed. They are discussed in the context of the current controversy on whether methods patents, particularly software patents, are being granted too liberally. The patent process should promote innovation, but may sometimes discourage innovation and hinder scientific research. Some patent claims may overlap prior art (earlier public information), or may be obvious extensions of known methods. Actions are identified by which researchers may be able to help limit the scope of pending patents or to identify prior art that could be useful in re-examinations of existing patents.

Introduction

Walter Bitterlich (1908-2008) started working with sample observations of distances to trees, their diameters, and the subtended angles as early as 1931 (Bitterlich, 1984, p. 3). Some fifteen years later, a hand-drawn graph showed a remarkably strong relationship between numbers of trees subtending a fixed angle, and the total basal area of the trees in the plot. From this work arose the concept of angle-count sampling (ACS), also referred to as horizontal point sampling. The instruments used for ACS may include simple angle gauges, prisms, the relascope developed by Bitterlich, and a variety of electronic devices using laser technology; many of these instruments are patented.

"At the time when the author [Bitterlich] became aware of the great potential utility of the newly discovered ACS (this was in the summer of 1947) he was neither an official scientist in forest research, nor did he have any stable employment or other income. Intending to protect his new idea against interlopers, he tried to apply for patents; however, he was told by the patent office in Vienna that instruments could be the object of such protection but not a geometrical idea. So - having delayed the first publication of ACS for some months - he started developing different types of instruments." (Bitterlich, 1984, p. 69)

The method that Bitterlich developed can be stated as: basal area per unit area is estimated without bias as the product of a basal area factor (BAF) and a tree count obtained using an angle gage at a randomly selected location. This method was novel and non-obvious. Under current patent rules it would probably be patentable, i.e., at least if implemented in a computer program. By the mid-1960s ACS was being adopted internationally. If ACS had been patented, its implementation would probably not have been any faster, and other researchers might have been hesitant to build upon and expand the usefulness of Bitterlich's method.

Patents are being applied for and issued for uses of ALS within forest inventory. Many of these patents and patent applications are discussed here, as is the broader question of whether patents will advance or retard development of ALS methods for forest inventory.

Patents

"A patent is a property right granted by the Government of the United States to an inventor 'to exclude others from making, using, offering for sale, or selling the invention throughout the United States or importing the invention into the United States' for a limited time in exchange for public disclosure of the invention when the patent is granted." (United States Patent and Trademark Office (PTO), 2009). Patent procedures differ between countries; however the similarities are greater than the differences.

Most US patents are now published by the US PTO eighteen months after the earliest effective filing date. Each patent contains a patent number and class, date of patent, title, list of inventors, filing date, background, a description of the invention, claims, and disclosure of prior art. "Prior art" is prior public knowledge, often from dated publications. Patents may deal with processes, machines, article of manufacture, composition, or new uses. Patents must be useful, novel (with regard to prior art) and unobvious. Patent "claims" are definitive descriptions of the methods or objects for which patent protection is granted. The "named inventors" on a patent must include all the true inventors and may not include anyone who is not a true inventor. Each of the named inventors has an individual right to use or license the patent. The date of invention can be an important factor. Self-help books such as Pressman (2008) suggest simple ways to prove invention date. The "priority date" is generally the date that material was first filed with any patent office. Provisional applications disclose an invention and are filed so as to establish an early priority date, before the applicants have had time to fully develop a regular patent application. US patent applications must be made within one year of any public disclosure. Many European countries, including Finland, do not allow prior disclosure. After a patent application is filed in one country, there is a time window for filing in other countries to obtain the benefit of the earlier priority date.

US patents and regular patent applications may be searched and downloaded at no cost on several web sites. One of the easiest sites to use is Patent Storm (**www.patentstorm.us**). The PTO has expanded offerings, including downloads of image file wrappers: all the correspondence and actions concerning a patent application. File wrappers are

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freely available from the PTO "eBusiness" page (**http://www.uspto.gov/ebc/indexebc.html**) using the "status and view documents" button. An international site for patent searches is Patent Lens (**www.patentlens.net**); this site shows the full international "patent family" associated with any individual patent.

Controversies on business method patents and software patents regularly make the front pages of newspapers. The abstract nature of software makes it difficult to establish bounds on what is claimed, leading to excessively high numbers of patent disputes. The problems were apparent to Bill Gates in 1991: "If people had understood how patents would be granted when most of today's ideas were invented, and had taken out patents, the industry would be at a complete standstill today." (Boldrin and Levine, 2008, p. 16). Several organizations including End Software Patents (**www.endsoftwarepatents.org**) are participating in court cases hoping to significantly reduce the scope of what is patentable. Other organizations are finding ways to call attention to prior art, so as to reduce the numbers of patents for minor variations on known methods. Further background on patent controversies is in Bessen and Meurer (2008) and Jaffe and Lerner (2004).

Patents and Patent Applications Related to Forest Inventory and ALS

There are numerous patents for image processing methods and equipment. The discussion here is limited to the few patent applications and issued patents which involve ALS and methods to estimate forest inventories (Table 1). All but one of these patents attempt to identify individual tree crowns (ITC). Within the literature an ITC is usually represented by the spatial extent that a tree detection algorithm has identified as probably being associated with the crown of a single tree. Hence, an ITC could be thought of as an "inferred tree crown."

Canopy Height Model and Crown Segmentation

The earliest patent application for the use of lidar in forest inventory was filed in Finland in 1999, and is now a US patent (Hyyppä, 2004) retaining the Finnish priority date of 28 October 1999. The patent's first claim seems to cover many uses of ALS that result in a three-dimensional presentation of stand height which in turn is used to determine attributes of individual trees or groups of trees. Lidar data are used to develop a crown surface model, a digital terrain model (DTM), and a canopy height model as the difference between the former two. ITCs and their boundaries may be analyzed with "pattern recognition methods," which may include filtering for local maximum heights. The derived crown data are coupled with "generally known formulas" to "determine" diameters, volume and other characteristics. An example of such a formula would be a simple linear regression between tree diameters and crown diameters; coefficients would be "determined" by calibration with inventory data, possibly by species. The methodology is partially described by Hyyppä *et al.* (1999) and Hyyppä and Inkinen (1999).

Stand and Crown Segmentation from Digital Images

The next patent application involving crown segmentation was filed on 03 May 2002 and is also now a US patent (Rousselle *et al.*, 2007). The claims cover the use of digital images for forest stand delineation, individual crown segmentation, and the inferences necessary to obtain a forest inventory. Stand delineation is based upon a gradient image analysis, whereby small homogeneous regions around seeded points are expanded and sometimes merged with adjacent regions. Crown segmentation is carried out within each of the delineated stands with a similar seeded region technique. Tree species classification uses a training procedure to assign species to unidentified tree crowns based upon a set of assignments made by an operator. An example of a classification technique is the nearest neighbor method based upon ITC color, shape, and texture. Tree attributes such as diameter are to be estimated through correlation models fit to individual tree data. The data would require field measurements of tree diameter, crown diameter, tree height, and other characteristics. The resultant species-specific models are applied to the full set of ITCs so as to obtain a forest inventory. The patent cites work on crown segmentation including that by Gougeon and Leckie (2001) and Hyyppä *et al.* (2001a). It is stated that the invention uses a higher resolution input and produces more accurate results compared to other contemporary methods. An overview of the method and its history is by McCrystal (2003).

Probability Modeling for Individual Tree Crowns

A series of patent applications were filed as "continuations-in-part" to Rousselle *et al.* (2007). The series started with a provisional application filed on 19 June 2006 (Kelle *et al.*, 2007). The remotely sensed data may include combined digital imagery and lidar data. Earlier photo-based methods of crown segmentation are extended to work with pixelized lidar data. Sample field plots and the trees on the field plots are precisely matched with the remotely derived data including ITCs. Matched tree and ITC data are used to develop empirical models which are then applied to all the

TABLE 1. PENDING AND ISSUED US PATENTS BY PRIORITY DATE. ASSIGNEE CODED AS FGI IS THE FINNISH GEODETIC INSTITUTE (GEODEETTINEN LAITOS); CSIRO IS THE AUSTRALIAN COMMONWEALTH SCIENTIFIC AND RESEARCH ORGANIZATION; BLOM KARRTA OY IS A FINNISH COMPANY; WEYERHAEUSER, AND IMAGETREE ARE US COMPANIES. ASTERISK INDICATES REASSIGNMENT TO AN AFFILIATE OF GEODIGITAL INTERNATIONAL (CANADA).

Priority date	Reference	Application	Patent No.	Title or Key Phrase	Assignee
1999.10.28	Hyyppä (2004)	10/111145	US 6,792 684	Determination of Stand Attributes	FGI*
2001.02.09	Jupp *et al.* (2007b)	10/467607	US 7,187,452	Lidar System and Method	CSIRO
2002.05.03	Rousselle *et al.* (2007)	10/139001	US 7,212,670	Feature Identification and Analysis	ImageTree*
2003.03.31	Hyyppä and Yu (2006)	10/803966	US 7,013 235	Determining Growth of Trees	FGI
2004.03.15	Savolainen *et al.* (2008)	10/598322	pending	Determination of Stand Attributes	Blom, FGI
2006.06.19	Kelle *et al.* (2007)	60/814715	provisional	Feature Identification and Analysis	ImageTree*
2006.06.19	Kelle *et al.* (2009)	11/728099	US 7,639,842	Probabilistic Sampling Based Inventory	ImageTree*
2006.06.19	none	12/618321	abandoned	Unknown. Filed on 2009.11.13	ImageTree*
2006.08.16	Bortolot and McTague (2008)	11/505189	abandoned	Method for Estimating Forest Inventory	none
2007.06.22	Welty *et al.* (2009)	11/767050	US 7,474,964	Vegetation Attributes from Lidar	Weyerhaeuser
2007.06.22	Welty *et al.* (2010)	11/767084	US 7,720,605	Vegetation Attributes from Lidar	Weyerhaeuser
2007.12.20	Kelle *et al.* (2010)	12/340217	pending	Carbon Dioxide Volume of a Forest	ImageTree*

ITCs. The empirical models may include probability predictions for tree - ITC matching and species assignment. This use of probability models may be the motivation for the phrase "probabilistic sampling based inventory" used in the patent titles. The patent includes an "Example of Probabilistic Sampling Based Predictions;" details of those probability models and related regressions are in Flewelling (2008). The use of such models within a design-based estimation process is described by Flewelling (2006 and 2009). An advance over the method of Rousselle *et al.* (2007) is that the prediction models are fitted using ITC characteristics as independent variables; previously the primary independent variables were field-measured tree heights and crown widths. One of the related patent applications, 12/618321, was filed on 13 November 2009, but has not yet been published. The original application has been granted a patent (*Kelle et al.*, 2009). A daughter patent application (Kelle *et al.*, 2010) combines the method for estimating stand tables with a previously published allometric relationship for carbon estimation (Hansen, 2004). The title and objective of the patent both refer to the estimation of the "carbon dioxide volume of a forest." The commercial context of the application is that of carbon sequestration accounting. Possibly the authors are confusing carbon dioxide volume with the mass of carbon in standing trees.

Localized Setting of Parameters for Crown Segmentation

Bortolot and McTague (2008) is a patent application filed on 16 August 2006; the PTO declared the application "abandoned" on 08 October 2008. The method uses lidar data at densities too low for good ITC recognition, but adequate for recognizing groups of trees. It requires the matching of ground plots with corresponding remotely sensed data. The data from each plot-sized region are processed so as to calculate several lidar metrics as functions of threshold parameters. The parameter values are set so as to maximize the correlation between the metrics and the plot yield statistics. In the presented example, most stands in the inventory would have some sample plots, allowing for the application of unbiased estimators for individual stands. A novel feature is the specific feedback between the sample plot data and the processing of the remotely sensed data. An uncommon feature of the patent application is the explicit use of standard sampling survey estimators. The method, originally presented at SilviLaser 2005, is described by Bortolot (2006).

Determination of Tree Growth

Hyyppä and Yu (2006) is a US patent, with a priority date of 31 March 2003 from an original Finnish application. The general concept is that crown segmentation methods will be applied to lidar data sets taken at two points in time. The ITCs from the two points in time are aligned with one another using distance or other criteria so as to find pairs of ITCs that are presumed to represent a single tree at both points in time. Pairs that fail to meet all criteria are excluded. The remaining pairs are used to calculate average height growth for some region of interest. Hyyppä *et al.* (2003) and Yu *et al.* (2008) provide further details.

Combined ALS and Terrestrial Lidar

Jupp *et al.* (2007b) is a US patent with a priority date of 09 February 2001 based on an Australian filing. The patent describes the use of terrestrial lidar to determine the spatial statistics of shrubs and trees and to characterize multi-layer canopy structures. Technical features include the use of calibrated reflectances and inferences based on varying the beam width and shape for the ECHIDNA® ground-based lidar system. Included in the patent are brief descriptions of two other inventions which had been considered for additional patents. Those other unpatented inventions combine the use of ground-based lidar and airborne lidar. Details of the methods are in Jupp *et al.* (2007a), Jupp *et al.* (2009), and Jupp and Lovell (2007). The latter reference used data from the SLICER airborne system with an 8 m footprint. Statistics derived from the airborne lidar, including cover fraction as a function of height, can be mapped over large landscapes. Sample plots combining data from terrestrial and airborne lidar are used to construct relationships that in turn can be used to predict detailed canopy structures across the landscape.

Supplementing Lidar Data with Stereo Photo Images

Savolainen *et al.* (2008) is a US patent application with a priority date of 15 March 2004 obtained from a successful Finnish patent application. It differentiates itself from Hyyppä (2004) in that *x-y-z* points from airborne lidar are supplemented with *x-y-z* points derived from sets of overlapping photo images. The photo images may be from airborne cameras or ground-based cameras.

Three-dimensional Crown Segmentation

Welty *et al.* (2009) is a US patent filed on 22 June 2007 for a crown segmentation method which allocates lidar returns to individual items of vegetation including understory. Welty *et al.* (2010) is a US patent describing the same invention under a different patent classification. The methodology differs from most current crown segmentation methods in that crowns of individual trees can overlap. Each segmented crown is bounded from above by a concave curve; lidar returns are associated with the curve immediately above them. Since the curves may themselves overlap, multistoried stand structures can be described in detail.

Discussion

The foregoing patents and applications might all be of a patentable nature, novel, non-obvious, and useful. They are more than "abstract ideas" or pure mathematical algorithms, which are not patentable subject matter under 35 U.S.C. Sec. 101. However, patents are sometimes granted for inventions which seem to be abstract, trivial or obvious; such patents and are often upheld by the courts (Bessen and Meurer, 2008, pp. 212-214). In what is commonly referred to as the "Bilski case," the US Court of Appeals held that a patentable "process" must be tied to a particular machine or apparatus, or transform a particular article into a different state or thing. The US Supreme Court reviewed that case and has ruled that the "machine or transformation test" is important but inconclusive. The narrow ruling did not signal a major change in the patentability of software (Mullin, 2010); the flood of expensive litigation over individual patents will continue. A few issues which could arise in examinations of pending patents or re-examinations of issued patents are presented, along with comments on several technical limitations of the patented methods. Legal determinations on the validity or scope of any particular patent claims, or the legal relevance of any prior art, are beyond the the expertise of this author.

Relevant prior art is often the best evidence that can be used against a patent in its re-examination, particularly if that prior art has not been cited by the patent applicant or the patent examiner. Prior art can be formal publications or public presentations, such as seminars at universities. Prior art could possibly include grant proposals, progress reports, and confidential disclosures (Cortina, 2007). Patent applicants are not obligated to search diligently for prior art.

Possible Defects in Pending and Issued Patents

Canopy Height Model and Crown Segmentation

Hyyppä's (2004) major advance over most earlier ITC modeling efforts was the use of lidar as the basis for crown segmentation and height estimation. However, by the date the patent application was filed, other researchers in Europe, Canada, Australia, and the US were actively working on similar methods. More importantly, some of the work by other researchers, and some of Hyyppä's own results, had already been published. A challenge to the patent might assert that the patent methods were not novel, or were obvious extensions of known methods. The patent includes a discussion of the current state-of-the-art and provides references for some relevant prior publications. Publications mentioned within the patent include Nelson *et al.* (1988), Hyyppä *et al.* (1999), and Borgefors *et al.* (1999).

Initially, the US patent examiner rejected most claims because they had been anticipated by Hyyppä *et al.* (1997). The applicant's response shown in the file wrapper states that the patent is differentiated from prior art in that it teaches that the lidar beam sweeps perpendicular to the flight path, that individual trees are detected, and that a three-dimensional presentation of stand height is made. It was further asserted that neither Hyyppä *et al.* (1997) nor any of the other cited references teach those features. However, prior art that was not cited does disclose or anticipate major features of the patent. Nilsson (1996) stated "If airborne laser data could be given both height and planimetric coordinates with high accuracy, single trees or groups of trees could be identified and detailed terrain models could be generated." Brandtberg and Walter (1999) proposed using scanning lasers to obtain tree heights for ITCs delineated from digital photography. Hyyppä *et al.* (1999) noted that " . . . TopoSys laser-scanner enabled detection of single trees. A high pulse rate guarantees enough ground hits to model the DTM and the tree crowns . . . ,"and they also showed good accuracy in using the lidar data to obtain heights of individual trees. Borgefors *et al.* (1999) used scanning lidar to build canopy height models, delineated individual crowns as sets of adjacent pixels within the canopy height model, and noted that "tree heights can be found by referring back to the corresponding segment areas" in the canopy height model. Neither Hyyppä *et al.* (1999) nor Borgefors *et al.* (1999) were considered by the US patent examiner. Though those two works are discussed in the patent, their importance is marginalized; for example "the real heights of individual trees were not analyzed in [Borgefors *et al.*, 1999]." These works of prior art seem to have fully anticipated the major claims in the patent. If these works were to be considered in a future re-examination, some of the broad claims might be disallowed, leaving only those narrower claims with elements not present in prior art.

Other prior art may be found outside of formal publications. The work reported by Hyyppä had been part of a European-wide attempt to derive single-tree information from lidar data (Hyyppä *et al.*, 2001b). That European-funded project had participants in Austria, Finland, Germany, and Switzerland. Project proposals and interim reports submitted before the patent's priority date might be used to show that the patented claims were not novel. This may be the case even if those proposals and reports had not been widely available. Similarly, proposals, reports, and seminar presentations from other contemporaneous projects for ITC extraction from lidar data may be relevant; two such projects are described by St-Onge (1999) and Young *et al.* (2000).

Stand and Crown Segmentation from Digital Images

Rousselle *et al.* (2007) has examples of stand and crown delineation using digital color photography. The claims refer to digital images, which possibly could be interpreted as including pixelized lidar data, even though the patent does not mention lidar. The broadest claim includes nine different elements; prior art that would be needed to refute the claim might have to contain all nine elements. However, most of the elements in the various claims have strong similarities to contemporaneous research reviewed by Gougeon and Leckie (2001 and 2003).

Probability Modeling for Individual Tree Crowns

The application for Kelle *et al. (2009)* had been filed on 23 March 2007 with thirty-five claims and four named inventors. The fifth-named inventor notified the original applicants that the inventorship was in error, and sent them an abstract for a presentation (Flewelling, 2006) with overlapping material. The presentation was made on the same date as the provisional filing; for that reason it is not prior art. The earlier-distributed abstract may be prior art; most of its text is repeated verbatim in the provisional filing. The applicants' attorney subsequently petitioned the PTO to add the newly identified inventor to the patent. On 17 June 2009 the applicants' attorney canceled all but three claims, reserving the right to file a continuing application with one or more of the cancelled claims at a later date. He also unsuccessfully sought to limit the inventorship to the originally named four persons. It is possible to correct unintentional errors in inventorship while a patent is pending or after it has been granted. Hence the inventorship of this patent and other related patents or patent applications might be subject to further change. Some of the named inventors have refused to sign new or updated declarations of inventorship.

The sampling terminology used in the patent is misleading. The key term "probabalistic sampling" seems to refer not to sampling, but instead to the generation of probability models of outcomes for ITCs. The actual sampling techniques receive minimal discussion. Another critically important concept, the sample frame, seems to take on two contradictory meanings. In parts of the patent, the usage is consistent with the usual definition: "a list of members of the population" (Upton and Cook, 2005, p. 347). Elsewhere in the patent, sampling frames are randomly selected, apparently with each sample plot being in a separate sample frame. If the patent examiner was searching the literature for terms such as "probabalistic sampling," he would be unlikely to encounter any literature describing probability models similar to those in the patent. The imprecise use or misuse of statistical and sampling terminology make the patent claims difficult to understand. In turn, the imprecise language may lead to much uncertainty as to what has actually been patented.

Determination of Tree Growth

The Hyyppä and Yu (2006) method of growth determination might seem to be an obvious extension of already known methods. Most or all elements of the tree growth patent are similar to earlier developed methods. For example, Kovats (1997) demonstrated that large scale aerial photographs can be used to accurately estimate heights of individual trees within progeny tests at multiple dates. In a progeny test, maps exist for all the trees of interest; typically rows of trees are tagged and spacing is rigorously controlled. Thus for Kovats, the population of interest is precisely known. Any tree whose height growth can not be reliably estimated due to obstructions can be measured by someone on the ground. Moreover, any method of estimating average height or top height from ALS data could be used to estimate growth.

A technical limitation of the patented method is that the estimated growth applies to a set of trees whose selection is controlled by the processing of the lidar data. Sets of trees selected in that manner are unlikely to be of as much interest as trees selected by a repeatable on-the-ground procedure chosen to be useful for growth monitoring or modeling. The height metric which biometricians find useful for growth modeling is top height. Top height may be defined as the sampling expectation of the mean height of the largest-diameter 100 trees per hectare as determined on plots of a fixed size. Increment in top height would be a worthwhile quantity to estimate. Estimation techniques based on a top height estimator calibrated at each point in time, or a calibrated estimator for change in top height, would seem to be more promising than the paired ITC approach in the patent. Similarly, change in Lorey height might be closely correlated with change in crown-area weighted mean height of all ITCs. The patent does not address temporal calibration, the importance of which has been shown by Næsset and Gobakken (2005) and Véga and St-Onge (2008). Regardless of the patent's merit for change in top height, the idea of differencing heights or crown sizes for ITCs will be important when crown segmentation methods and temporal fusing methods are improved. However, the obvious operation of height differencing is now patented in some contexts.

Three-dimensional Crown Segmentation

The methods developed by Welty *et al.* (2009) appear to be substantively different from techniques developed or proposed by other researchers. For the upper-most canopy layer, Welty's methods bear some similarity to those of Wack *et al.* (2003), in that the individual crowns are delineated through the use of non-overlapping shells or caps. Welty *et al.* (2009) then go on to process the returns at lower heights, whereas Wack *et al.* (2003) do not. Other researchers use substantially different methods to detect and describe overlapping crowns. Andersen *et al.* (2002) do so with Bayesian models of crown shape and lidar reflectance; Morsdorf *et al.* (2003) use statistical clustering algorithms to assign returns to individual crowns.

Impacts upon Future Research

Patents issued for analysis methods or sampling methods related to ALS and forest inventory will affect the deployment of such methods and the course of ongoing research. On the deployment side, some companies and agencies engaged in forest inventory may be reticent to deploy technologies which have been patented or which might be patented. Persons working for US government agencies have limited rights to use patented technologies without the consent of the patent holder; compensation may be required. Others, including university researchers in the US and some other countries, may require licenses from the patent holders (Dent *et al.*, 2006).

In the short term, the presence of patents may have a larger effect upon on-going research than upon commercial deployment. The companies or institutions owning the patent rights have an increased incentive to do follow-on research that can enhance the value of their original patents. Those same companies and institutions also have an incentive to pursue other competing methods, even inferior methods. If they can expand their suite of patents, it lessens the likelihood that other new methods will enter the public domain. Researchers and institutions who do not wish to pursue patents are also affected. Their on-going research related to ALS and forest inventory may build upon and improve existing methods, some of which could be covered by existing or pending patents. Hence, the benefits of their new research may accrue to the holders of the patents. That potential result, in spite of substantial uncertainty, may be a major disincentive to undertake research, particularly research related to ITC segmentation. Many researchers, including those with no interest in acquiring patents, may feel compelled to expend time and effort in understanding the patent process and patent developments in their fields. Corporate researchers may become less communicative so as to avoid becoming targets of infringement suits, to avoid helping the patent seekers, or to become better positioned to file their own defensive patents.

Obligations of Inventors and Institutions

The legal obligations of inventors, attorneys, assignees, and others are summarized by Moatz (2007). A primary obligation is that of candor; information relative to patentability, inventorship, and known prior art must be disclosed to the PTO. Intent to deceive the PTO, either through misstatements or failure to report known relevant facts, can cause a patent application to be voided. Willful false statements and the like on a declaration of inventorship are punishable under 18 U.S.C. 1001. Obligations may also be imposed by funding agencies and governmental cooperators. Grant recipients may be required to affirm that the design, conduct, and reporting of research will not be biased by any conflicting financial interest. Most employers now require an assignment of intellectual property (IP) rights as a condition of employment. Inventors may also have the normal scientific obligation to recognize properly the other researchers whose work and ideas contributed to the inventions.

Agencies that provide research grants have obligations to ensure that their primary goals are not compromised by the patenting efforts or the financial interests of the researchers or host institutions. Much of the ongoing research in ALS for forestry is government funded. Some government agencies view the acquisition of patents by research organizations as being useful. Usually the agencies' primary goal is to promote the rapid development and deployment of useful technology. The funding agencies should be proactive in deciding whether patents will aid or hinder research innovation and dissemination, and they should make funding and IP policy in accord with their determinations. They can require that IP rights for funded projects be turned over to the funding agency, or can require that such rights enter the public domain.

Universities and non-profit research institutions often have some of the profit-retention goals of private corporations, while also having some of the knowledge dissemination goals of the funding agencies. Universities and research institutions usually acquire the IP rights of their employees, but sometimes will share resultant financial rewards with those employees. Managers in such institutions must deal with the issue that their employees may prefer to work on projects with patent potential to the detriment of equally important projects without patent potential.

Conclusions

Patents have come to ALS and forest inventory. These patents will presumably affect widespread usage of ALS unless Congress or the courts tighten current restrictions on patenting abstract methods or obvious extensions of known methods. Some in the software industry are actively seeking such restrictions, or are attempting to assist the patent offices in identifying prior art, or are developing public licensing schemes that will promote sharing of intellectual property.

For those researchers who are not interested in acquiring and enforcing patent rights, some actions are available which may lessen the impact of patents in their subject areas. Foremost among these is to publish quickly and to include comments on extensions or variations of the methodology which they can "foresee." Distribution modes for such defensive publications are critiqued by Adams and Henson-Apollonio (2002); a newer venue is Scribd (**www.scribd.com**), a document sharing service that is free, indexed and provides evidence of publication date. It may be possible to have proceedings and abstracts registered with the PTO so that they are included in the relevant field of search in the same way journals are included. It may also be possible to ensure that one or more of the scientific citation services, such as Scirus, index the proceedings; this increases the likelihood that the PTO will discover the prior art. More expensive and time consuming, individual inventions may be filed with the PTO as "statutory invention registrations." Other possibilities are to file and then abandon regular patent applications, or to obtain defensive patents which could be used to counter-sue parties claiming infringement on their patents. Pending patents may be checked to learn whether they cite all relevant prior art. Any omissions can be brought to the attention of the attorney prosecuting the patent. The attorney is obligated to disclose that information to the PTO in a timely manner, but only if the attorney agrees that it is relevant. The US PTO may allow the public to submit prior art in the sixty days following the publication of an application. The European Patent Office (EPO) allows the public to make observations concerning the patentability of pending patents or the omission of prior art. Researchers who do acquire patents may choose to issue unrestricted public licenses for the use of their patents, or may issue restricted public licenses, such as GPLv3 (Free Software Foundation, 2007). Some industries create IP pools to encourage such practices (Boldrin and Levine, 2008, p. 248). The SilviLaser community could facilitate challenges to patents by sponsoring on-line forums to assemble prior art references relevant to specific patents.

Walter Bitterlich, the inventor of ACS and the relascope, had originally been concerned that someone else might patent ACS. However, methods of using geometry and sampling theory for forest inventory were not patentable at the time. In that atmosphere forest biometrics has flourished with a free and open exchange of ideas and innovations, with credits being appropriately shared. "Courtesy and appreciation of the work of others are the two reliable hallmarks of those in the top ranks of our profession" (Iles, 2003, p. 261). The patent system does little to encourage these characteristics. However these admirable characteristics can be exhibited by inventors who properly limit their patent claims to innovations that are truly their own and that their colleagues will consider to be unique, new and non-obvious.

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