FHP TECHNOLOGY DEVELOPMENT PROJECT PROPOSAL

PROJECT STATUS: New, not previously funded.

PROJECT NUMBER: R05-1999-02

PROJECT TITLE: Development of remote sensing technology for detecting vegetational change of Schinus terebinthifolius and other non-indigenous weeds undergoing biological control in Hawaii.

SUBJECT: Technical Committees: Survey, Evaluation, and Monitoring; Vegetation Management. Keywords: survey and monitor invasive non-indigenous weeds; evaluating weed biological control agents; remote sensing; Schinus terebinthifolius; Christmasberry; non-indigenous plant invasions

PROJECT OBJECTIVES: 1) Develop remote sensing methodology capable of identifying the distribution and rate of spread of invasive introduced vegetation, primarily Schinus terebinthifolius, Christmasberry. 2) Evaluate and compare the accuracy of several remote imaging technologies for detecting and delineating S. terebinthifolius. 3) Establish baseline vegetation distribution and density information on S. terebinthifolius to provide the foundation of a landscape monitoring system for the biological control of this plant species.

BRIEF DESCRIPTION OF PROJECT: This project will employ remotely-sensed image data in developing algorithms and methods for detecting the non-indigenous plant species S. terebinthifolius in Hawaii. This methodology will be used in monitoring biological control efforts on this plant species. We propose to develop technology that detects this plant using sub-pixel classification techniques of SPOT data, multi-spectral satellite imagery, and IRS 4m. We will compare these three methods in accuracy and cost. The resulting methodology will be useful in the documentation of vegetation changes resulting from a biological control program against S. terebinthifolius.

FHP PERSON WHO WILL LEAD PROJECT: Duane Nelson, Institute of Pacific Islands Forestry (IPIF), USDA Forest Service, Volcano, Hawaii.

JUSTIFICATION: Classical biological control of weeds in Hawaii has a long, rich history. However, recent concerns have been expressed about biological controls' safety and efficacy for Hawaii's environment (Howarth 1991; Menard 1998). Many of the criticisms of biological control can be attributed to a lack of: 1) baseline data for target plants; and 2) little, if any, monitoring after release of biological control agents. However, for many non-indigenous plant species in Hawaii biological control offers the only feasible possibility to manage these invaders (Tunison 1992). Therefore, it is imperative that increased effort be given to better planning and monitoring of biological control projects in Hawaii. The purpose of this project is to implement such planning and monitoring in the biological control of one of the most aggressive, noxious weeds in Hawaii: Schinus terebinthifolius Rabbi, commonly called Christmasberry or Brazilian

peppertree. We propose to develop remote sensing technology - specifically, algorithms and methodology - that details distribution information on this target weed. This information will allow monitoring of the impact on this plant from biological control agents over a landscape level. Protocols developed in this study will be applicable to other invasive plants in Hawaii and lead to a more favorable acceptance and increased use of biological control of weeds.

To date, no detailed mapping of invasive S. terebinthifolius populations has been conducted on the islands of Hawaii or any other location (e.g., Florida Everglades or eastern Australia). Distribution of S. terebinthifolius on the Big Island was estimated from personnel contacts and a limited, 30- year old survey on non-native weeds (Yoshioka & Markin 1991; Hawaii Dept. Agric. 1962). This proposal develops the powerful technology of remote sensing to accurately determine distribution of S. terebinthifolius not only on the island of Hawaii but anywhere this invasive weed occurs.

URGENCY: Schinus terebinthifolius is an introduced perennial plant that has become established throughout the Hawaiian Islands (Yoshioka & Markin 1991). This species is native to South America and was brought to Hawaii as an ornamental before 1900. In Hawaii, S. terebinthifolius has become an aggressive, rapidly spreading weed that displaces native vegetation (Bennett & Habeck 1991; Cuddihy & Stone 1990). Hawaii Department of Agriculture (Morton 1978) recognized the plant as a noxious weed. Conservation organizations consider this plant a high priority target in Hawaii because it is already widespread and has great potential to increase its range (Randall 1993). The U.S. Fish and Wildlife Service (1998) identified S. terebinthifolius as one of the most significant non-indigenous species currently threatening federally listed threatened and endangered native plants throughout the Hawaiian islands. No control method is currently available against the large and dense populations of S. terebinthifolius. A biological control program has been initiated against this plant in Hawaii. An urgent need exists for a viable and low cost remote sensing technology to monitor S. terebinthifolius vegetation before and after biological control agents are released into the environment.

LINK TO NATIONAL FHP TECHNOLOGY DEVELOPMENT PRIORITIES: Develop or refine biocontrol methods for established species (native and non-native) and established pest populations. Developing a landscape scale monitoring system of populations of non-indigenous S. terebinthifolius will be vital in the current biological control program of this plant. This technology will help determine under what conditions biological control agents are successful and quantify the impact of agents against the target weed.

Develop or improve detection, analysis, and management of exotic pests .... Remotely sensed vegetation data provides vital resource information on non-indigenous plant species. Developing technology that utilizes less expensive remote sensing data will save money and make this technique more exceptable to others with similar invasive S. terebinthifolius problems. Correlating present distribution of S. terebinthifolius with various climatic, elevational, and soil substrate parameters will allow extrapolation for potential spread of this weed.

SCOPE OF APPLICATION: This project will be applicable to all islands and atolls in the State of Hawaii where this weed is a serious invader. U.S. territories (Guam, America Samoa) and affiliated Pacific islands (e.g., Kosrae and Pohnpei) where the plant threatens to invade will also benefit. Regions where this weed has invaded and caused environmental damage, including Florida Everglades (Bennett & Habeck 1991) and eastern Australia (Panetta & McKee 1997), can directly benefit from this research. In addition, the technology developed in relation to monitoring a biological control target is not limited to this specific weed but is relevant to theory and development of biological control programs in Hawaii, as well as worldwide.

RESEARCH BASIS: A new project has been initiated by IPIF on biological control of Schinus terebinthifolius in Hawaii. That project will evaluate the undocumented status of previously released biological control agents, their effect on non-target plants (if any), and collect detailed information on the target weed. In addition, a potentially new biological control agent against this plant, Brazilian schinus sawfly, will undergo host specificity testing in Hawaii. Release of the sawfly is predicted to reduce the density, distribution, and spread of S. terebinthifolius (Habeck & Medal 1996).
Tools for vegetation remote sensing have evolved significantly over the past few decades. This technology has allowed for ecological applications including vegetation mapping, land-cover change detection, and disturbance monitoring (Asner 1998). Remotely sensed data are highly cost effective for analysis of large areas. LANDSAT and SPOT imagery are the least costly of available imagery types that are suitable for vegetation classification. However, due to their relatively large pixel sizes (³ 20 m), small areas of ground cover such as individual plants will be ``mixed' with other unrelated cover types within a given pixel. This produces pixel data that are not readily assignable to any single cover type using standard techniques of supervised and unsupervised classification. Hyper-spectral imagery can provide very high spatial and spectral resolution, but is too expensive at present for extensive areas. Fortunately, new algorithms such as linear spectral unmixing, when combined with detailed hyper-spectral data collected for small sample areas, are capable of detecting small fractions of constituent cover types within individual pixels (Adams et al. 1993; Johnson & Greenfield 1997; Smith et al. 1990). This greatly enhances the classification potential of the more economical LANDSAT and SPOT imagery (Adams et al. 1995).
Viability of sub-pixel classification of SPOT multi-spectral data and LANDSAT multi-spectral data versus higher resolution and costlier IRS 4m multi-spectral data for identifying non-indigenous vegetation (specifically S. terebinthifolius) will be tested in this proposal. If sub-pixel vegetation detection techniques are shown to work then there is great potential for using these techniques over large areas to monitor future vegetational changes due to biological control agents. Cost savings in time and resource expenditure to accurately characterize and monitor non-indigenous vegetation would be substantial.

METHODS: The southern region of the island of Hawaii (known as Southpoint) has been chosen as a pilot project area for comparison of remote sensing data and methodology regarding the identification of S. terebinthifolius vegetation. Various vegetation and substrate types are found within the Southpoint area including large, dense

stands of S. terebinthifolius, mixed S. terebinthifolius and native vegetation, relatively intact native vegetation, and variously aged lavaflows (some with colonizing S. terebinthifolius). Schinus terebinthifolius is a compound-leaved, evergreen tree that reaches heights of nearly 13 m. The proposed study will involve acquiring a variety of recent and new remote sensing data for approximately 600 km2 in the Southpoint region. Imagery will include SPOT (available), LANDSAT Thematic Mapper (to be acquired), and IRS 4m multi-spectral data (to be acquired) in order to compare effectiveness of each imagery type for S. terebinthifolius detection. In addition, airborne hyper-spectral imagery will be collected over small sample areas to obtain detailed spectrographic reflectance data (signatures) for S. terebinthifolius and other vegetation types. These signitures will be used with algorithms, such as linear spectral unmixing, to provide subpixel detection capabilities within the large pixels of LANDSAT and SPOT imagery. Ground truthing data will be collected for use in identifying ``pure' pixels containing only one cover type, and for assessing accuracy of classifications derived from each algorithm and image type used. Multiple discrete patches of S. terebinthifolius and other native and alien plants will be mapped using military-grade Global Positioning System (GPS) units. Half of the sites for each cover type will be selected at random for use in developing image-specific spectral profiles for each cover type; the remaining half will be reserved for testing accuracy of each classification attempt. Comparison between the various methods and remotely sensed imagery data will determine the reliability of these techniques in detecting S. terebinthifolius. Of primary interest will be the ability of lower cost imagery to approach the accuracy and precision of more expensive hyper-spectral imagery.

MEASURE OF SUCCESS: 1) Develop a remote sensing methodology for detecting S. terebinthifolius that maximizes accuracy and minimizes cost. 2) Produce GIS data layers showing distribution and extent of S. terebinthifolius in study area on Hawaii. 3) Extend technology developed by project to areas currently invaded by S. terebinthifolius (e.g., major islands of Hawaii, Florida Everglades, and eastern Australia).

COOPERATORS:
Stephen Hight - USDA, Forest Service, IPIF, and University of Hawaii at Manoa, Cooperative Parks Studies Unit (CPSU). Scientist responsible for project and will conduct all phases of technology development, independently and cooperatively. Estimated time to be expended on project is 30%.
Brian Farm - USDI, Biological Resources Division (BRD) of USGS. Furnish on-island remote sensing expertise, develop algorithms and method for S. terebinthifolius detection, make available computer hardware and software to analyze GPS and remotely-sensed data, and assist in application to GIS. 25% time investment.
Jim Ellenwood - USDA, Forest Service, FHTET-Fort Collins. Review and technical assistance. 5% time investment.
Linda Pratt - USDI, BRD, Hawaii Volcanoes National Park. Assist in design of study and
vegetation identification. 5% time investment.
Tim Tunison - USDI National Park Service, Hawaii Volcanoes National Park. Assist in study

design, site selection, and GPS ``ground truthing'. 5% time investment.

PRODUCTS: 1) Digital maps of the study area identifying S. terebinthifolius vegetation will be completed using three different remote sensing data; SPOT, LANDSAT Thematic Mapper, and IRS 4m. 2) Compare the SPOT, LANDSAT, and IRS outputs, and analyze the significance of the differences between the three. 3) Algorithms for sub-pixel image analysis will be adapted/modified for use in conjunction with remote sensing imagery of invasive, non-indigenous vegetation. 4) Develop ``base-line' biological measurement of S. terebinthifolius to which impact and success of biological control agents can be evaluated. 5) Publications documenting efforts and results for this technology.

PUBLICATION: At least three peer-reviewed publications are anticipated from this project. One publication would consist of technological details for detecting S. terebinthifolius in Hawaii using remote sensing data. A second publication would address past and present distribution of the plant, its rate of spread, and potential range that S. terebinthifolius may reach. At least one additional publication would identify the importance and applicability of this technology for monitoring biological control of weeds projects, including the target plant and potential impact from classical biological control agents. In addition, a report detailing this study and outlining the methods for transferring these techniques to other locations with invasive populations of S. terebinthifolius will be prepared.

TECHNOLOGY TRANSFER: This project will have both specific and general applicability to weed biological control by successfully quantifying a monitoring protocol. This technology can be used directly by others with current S. terebinthifolius invasions to monitor biological control efforts against this plant, but also by the larger biological community in developing monitoring criteria and programs for any biological control project.

PROJECT DURATION: Remote sensing technology will be developed in FY 1999. Follow-up monitoring of biological control against S. terebinthifolius will be conducted through contributed services of USFS-IPIF and UH-CPSU.

LONG TERM BUDGET: One year project. See below for annual budget.

FY1999 BUDGET REQUEST:
Item
Requested FHP STDP Funding $
Other Sources
Amount $
Organization Name
Admin Items:
Salary

10,500 (20% B.F.)
13,700 (30% S.D.H.)

2,500 (5% B.F.)
7,500 Field Assistant (0.3 FTE)
IPIF & CPSU
BRD
IPIF
Overhead
None

Travel

2,500
IPIF
Procurements:
Contracting

None

Software
7,000 (Image processing software)

Equipment
1,600 (High-capacity hard drive and recordable CD-ROM)
5,000 (GPS hardware)
3,000 (Computer)
IPIF
BRD
Supplies
1,000 (color printer paper and ink, plotter paper and ink, misc. computer supplies)

Data
28,000 (LANDSAT Data)
4,400 (IRS image data)
6,000 (Hyper-spectral data)

Publication charges
1,000
1,500
IPIF & CPSU
Total FY 99 Budget
59,500
35,700

BENEFIT AND COST: See Enclosure 2a.

LITERATURE, CITATIONS, ATTACHMENTS:

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U.S. Fish and Wildlife Service. 1998. Draft Recovery Plan for Multi-Island Plants. U.S. Fish and Wildlife Service, Portland, OR.
Yoshioka, E.R. and G.P. Markin. 1991. Efforts of biological control of Christmas berry (Schinus terebinthifolius) in Hawaii. Pp. 377-387. In T.D. Center, R.F. Doren, R.L. Hofstetter, R.L. Myers, and L.D. Whiteaker (eds.), Proceedings of the Symposium on Exotic Pest Plants, Miami, FL, Nov. 2-4, 1988. USDI, National Park Service, Washington.

Enclosure 2a

STDP PRODUCTION FUNCTION

PROJECT NUMBER: R05-1999-02

PROJECT COST:

Requested STDP $	Other Sources $	PROJECT TOTAL $
Totals		
59,500.00	35,700.00	95,200.00

PROJECT OBJECTIVE: Overall objective of this project is to develop remote sensing technology for identification of non-indigenous vegetation, specifically Schinus terebinthifolius. A biological control program has been initiated against this invasive weed in Hawaii. A need exists to develop a viable, low cost, monitoring system capable of detecting vegetation changes on a landscape scale before and after biological control agents are released. Benefit of this project used in the economic analysis is cost savings with newly developed remote sensing technology in place (with project) versus aerial photography and extensive ground delineation of vegetation (without project). Without remote sensing capabilities, vegetation mapping on a landscape scale is both too costly and incomplete to monitor impact of biological control agents on S. terebinthifolius.

ASSUMPTIONS:
With Project:
a) new and refined algorithms and methodology will be developed that improves sub-pixel classification of low cost spectral imagery
b) sub-pixel vegetation detection techniques will allow for monitoring of vegetation over large areas
c) benefits and applicability of this technology will be permanent, i.e., subsequent vegetation monitoring will require purchase only of low cost remotely sensed imagery and minor ground truthing

Without Project:
a) vegetation analysis of study area would be accomplished with aerial photography and extensive ground surveys
b) each subsequent vegetation monitoring will require new photos and ground surveys

BACKGROUND DATA:
General:
a) technology will initially be developed over area of 600 km2
b) economic assessment with and without project is based on total Hawaiian land area of 2490 km2
c) 20 year economic assessment based on methodology developed to monitor vegetation every 5 years: first monitoring on 600 km2; second through fifth monitorings on 2490 km2

Conventional Vegetation Delineation:
a) Cost of aerial photography is $150 per km2
b) Cost of ground truthing is $238 per day and takes 40 days: salary & expenses=$7,500; travel=$2,000
c) Cost of interpretation is $10,000; georectification and image analysis specialist 2 months

Remote Sensing with New Methodology:
a) Cost of remote sensed imagery is $4 per km2
b) Cost of ground truthing is $100 per day for 40 days
c) Cost of interpretation is $5,000; remote sensing specialist 1 month

EXPENDITURE & OUTPUT VALUES (EOV) WITHOUT PROJECT:
= sum[(1 monitoring on 600 km2) + sum(4 monitorings each on 2490 km2, discounted 4%)]
= [(conv. mapping/km2*600 km2)] + [(conv. mapping/km2*2490km2)/1.04)$1-19]
= $1,298,875

EXPENDITURE & OUTPUT VALUES (EOV) WITH PROJECT:
= project cost + sum(4 monitorings each on 2490km2, discounted 4%)
= $95,200 + [(remote sensing imagery/km2*2490km2)/1.04)$1-19]
= $218,656

BENEFIT (CHANGE IN EOV) ATTRIBUTABLE TO PROJECT:
= (cost without project) - (cost with project)
= $1,080,219

BENEFIT/COST RATIO:
= (benefit attributable to project)/(total project cost)
= 11.35

BENEFIT ATTRIBUTABLE TO STDP:
= (STDP fund request) * (benefit/cost ratio)
= $ 675,137

PNV OF PROJECT:
= (benefit attributable to project) -- (total project cost)
= $ 985,019

PNV OF STDP:
= (benefit attributable to STDP funds) - (STDP request)
= $ 615,637