PROCEDURES FOR POST-BORDER WEED RISK MANAGEMENT

SECOND EDITION

Plant Production and Protection Division
Food and Agriculture Organization of the United Nations
Rome, 2011

CONTENTS

BACKGROUND

Weeds have significant economic, environmental and social impacts across a wide range of agricultural, natural and urban land use systems. The most cost-effective means to manage weeds is to prevent their arrival, and procedures for predictive weed risk assessment to screen plant imports at a country's border have been developed (FAO 2005) and implemented (see Pheloung *et al.* 1999). At the Post-border level however, there are often a wide range of weed species at various stages of invasion (Williams 2003). For example, the total number of introduced plant species in USA, UK, Australia, South Africa and Brazil is more than 73 000 species (Pimentel *et al.* 2001). Weed species differ in their impacts and there are limited government and community resources to target individual species in a coordinated manner. Hence weed species need to be prioritised for coordinated control programs by identifying those that pose the greatest future threats and which are most feasible to control.

Weed scientists in Australia and New Zealand have developed a post-border weed risk management protocol (HB 294:2006), based on the Australian/New Zealand Standard for risk management (AS/NZS 2004). This FAO Procedures document follows the example of the Australian/New Zealand protocol.

Post-border weed risk management (WRM) consists of six distinct stages:

- Stage 1 is establishing the WRM context in which goals, scope, stakeholders, resources and methods of analysis are determined.

- Stage 2 is identifying alien or exotic weed(s) recently detected in any territory of the country or the region. It may also be a plant intentionally introduced, which have started to spread fast to areas where it is unwanted. Recent data from plant monitoring or inventory revealing the presence of the new invader is necessary.

- Stage 3 is gathering all the information about the behaviour of the new invader, this can also be done retrieving the data from previous weed risk assessment (WRA) if done.

- Stage 4 is analysing the spread of the plant and choosing technically-feasible control measure (e.g., preventing entry, eradication, containment).

- Stage 5 is to evaluate the economical feasibility of chosen coordinated control.

- Stage 6 is implementing weed management actions, based on the decisions taken.

Overarching these stages is the need for effective communication and consultation throughout the process. Monitoring and reviewing is essential to measuring the effectiveness of the WRM process and to allow for future improvements and reassessments as new information arise.

Post-border WRM can provide a decision framework for regulatory management of weeds within countries (e.g., legal restrictions on sale and movement of declared/noxious weeds and legal requirements for their control), for selecting species priorities for research into improved control techniques and for choosing species targets for eradication. However, the new revised procedures give advice to the developing countries on how to proceed with WRM when a new plant (invader) is detected in a country or in a region.

This procedure was previously developed by Dr John Virtue of the Cooperative Research Centre for Australian Weed Management and recently revised by FAO to make it more adequate to the conditions of developing countries.

REFERENCES

AS/NZS 2004. Risk management. Australian Standard/New Zealand Standard 4360. Third Edition. Standards Australia International Ltd, Sydney and Standards New Zealand, Wellington.

FAO 1999. SD Dimensions Global Climate Maps. www.fao.org/sd/EIdirect/climate/EIsp0002.htm

FAO 2002. International Standards for Phytosanitary Measures, Glossary of phytosanitary terms. *Publication No. 5*. Rome, Secretariat of the International Plant Convention of Food and Agriculture Organization (FAO) of the United Nations.

FAO 2005. Procedures for Weed Risk Assessment. Plant Production and Protection Division, FAO, Rome, 16 p.

Groves, R.H.; Panetta, F.D.; Virtue, J.G. 2001. Weed risk assessment, Melbourne, CSIRO Publishing.

HB 436:2004 Standards Australia/Standards New Zealand 2004. Risk management guidelines companion to AS/NZS 4360:2004. (Standards Australia International Ltd: Sydney and Standards New Zealand: Wellington).

HB 294:2006. National Post-Border Weed Risk Management Protocol (Cooperative Research Centre for Australian Weed Management: Adelaide and Standards Australia International Ltd: Sydney).

Morse, L.E., Randall, J.M., Benton, N., Hiebert, R. 2004. An Invasive Species Assessment Protocol: Evaluating Non-Native Plants for Their Impact on Biodiversity. Version 1. NatureServe, Arlington, Virginia.

Myers, J.H., Savoie, A. and van Randen, E. 1998. Eradication and pest management. Annual Review of Entomology 43, 471-91.

Pheloung, P. C.; Williams, P. A., Halloy, S. R. 1999. A weed-risk assessment model for use as a biosecurity tool evaluating plant introductions. Journal of Environmental Management 57: 239–251.

Pimentel D., S. McNair, J. Janecka, J. Wightman, C. Simmonds, C. O'Connell, E. Wong, L. Russel, J. Zern, T. Aquino & T. Tsomondo. 2001. Economic and environmental threats of alien plant, animal, and microbe invasions. Agriculture, Ecosystems and Environment 84:1–20.

Randall, R.P. 2002. A Global Compendium of Weeds. RG and FJ Richardson, Melbourne, Victoria. 906 pp.

Richardson, D.M., Pysek, P., Rejmanek, M., Barbour, M.G., Panetta, F.D. and West, C.J. 2000. Naturalisation and invasion of alien plants: concepts and definitions. Diversity and Distributions 6, 93-107.

Williams, P.A. 2003. Guidelines for weed-risk assessment in developing countries. Chapter 1. Research and risk-assessment techniques for improved weed management. In Weed Management for Developing Countries Addendum 1 (Ed. R. Labrada). FAO Plant Production And Protection Paper 120 Add.

DEFINITIONS AND ABBREVIATIONS

Note: As post-border WRM is not restricted in scope to regulated pests, some definitions listed below differ from those of the International Standards for Phytosanitary Measures (FAO 2002). Unless otherwise indicated, definitions below are from the previous handbook produced in 2006 (HB 294:2006).

area — An officially defined country, part of a country or all or parts of several countries (FAO 2002).

consequence — The outcome or impact of an event (AS/NZS 2004). Note that there may be a range of possible outcomes, ranging from positive to negative, associated with an event. In WRM, the overall consequences of a **weed** are a function of its **impacts** and **potential distribution**.

containment — Application of phytosanitary measures in and around an infested area to prevent **spread** of a pest (FAO 2002). A **weed management** approach that aims to prevent an increase in the **current distribution** of a **weed**, by using **weed control** procedures to reduce the density of existing infestations and limit the **dispersal** of **propagules.**

coordinated control — A strategic, usually government-led, **weed management** program that takes into consideration all occurrences of a **weed** and involves the application of **weed**

	control procedures towards a specific end (e.g., **eradication** or **containment**).
current distribution	The geographic area over which a **weed** can be found at present.
dispersal	The movement of **propagules** across the landscape.
eradication	The elimination of every single individual of a species, including **propagules,** from an area to which recolonisation is unlikely to occur (Myers *et al*. 1998).
establishment	The perpetuation, for the foreseeable future, of a pest within an area after entry (FAO 2002).
exotic	Not native to a particular country, ecosystem or ecoarea (applied to organisms intentionally or accidentally introduced as a result of human activities) (FAO 2002).
feasibility of coordinated	The ease with which effective **coordinated**
control	**control** of a **weed** may be achieved. The higher the feasibility the lower the resources required.
habitat	Part of an **ecosystem** with conditions in which an **organism** naturally occurs or can establish (FAO 2002).
impacts	The (usually negative) economic, environmental and/or social effects of a **weed**. Impacts are considered on a per

	unit area basis (the overall **consequence** of a weed is a function of impacts and **potential distribution**). For the purposes of this document, impacts of a weed are considered to be distinct from the utility obtained from the same species when it is deliberately grown.
incursion	An isolated population of a **pest** recently detected in an **area**, not known to be **established**, but expected to survive for the immediate future (FAO 2002).
invasiveness	A relative index measure of the likely rate of **spread** of a naturalised plant species, being a function of the species' establishment, reproductive and **dispersal** abilities. Akin to the **likelihood** of spread.
invasive plant (also called **invader**)	**Naturalised plants** that produce reproductive offsprings, often in large numbers, at considerable distances from parent plants, and thus have the potential to **spread** widely (Richardson *et al*. 2000). Note that this definition does not include any potential **impacts** (hence the term invasive plant is not necessarily synonymous with **weed**).
introduction	The **entry** of a **pest** resulting in its **establishment** (FAO 2002).

land use	The principal land management objective. In broad terms an objective may be primary production (e.g., agriculture), conservation, or human services (e.g., residential, water supply).
likelihood	Used as a general description of probability or frequency (AS/NZS 2004).
monitoring	A process to verify pest situations in an area.
naturalised plants	Exotic plants that sustain self-replacing populations without direct intervention by people (or in spite of human intervention), usually close to parent plants, by recruitment from seeds or vegetative propagules (e.g., tillers, tubers, bulbs, fragments) capable of independent growth (Richardson *et al*. 2004).
noxious weed	A **weed** declared under government legislation which landholders have a legal requirement to control and/or which cannot be legally propagated, harvested, imported, sold or otherwise moved.
pest	Any species, strain or biotype of plant, animal or pathogenic agent injurious to **plants** or **plant products (**FAO 2002).
plant	Living plants and parts thereof, including **seeds** and **germplasm (**FAO 2002)

potential distribution The geographic area that a **weed** could occupy if allowed to **spread** unhindered.

propagules Discreet units of reproduction, including both sexual (e.g., seeds) and vegetative (e.g., corms, bulbils, fragments) means.

restriction A **phytosanitary regulation** allowing the importation or movement of specified **commodities** subject to specific requirements [CEPM, 1996, revised CEPM, 1999].

risk The chance of something happening that will have an impact (positive or negative) upon objectives. Risk is measured in terms of a combination of the **consequences** of an **event** and their **likelihood of occurrence.** (AS/NZS 2004).

risk analysis A systematic process to understand the nature of and to deduce the level of **risk** (AS/NZS 2004).

risk assessment The overall process of **risk identification**, **risk analysis** and **risk evaluation** (AS/NZS 2004).

risk evaluation The process by which judgements are made on the tolerability of the **risk** on the basis of **risk analysis** and taking into account factors such as socio-economic, legal and environmental aspects (AS/NZS 2004).

risk identification The process of determining what, where, when, why and how something could happen (AS/NZS 2004). For this document, this relates to identifying which species should be considered as candidates for weed **risk analysis**.

risk management The culture, processes and structures that are directed towards realising potential opportunities whilst managing adverse effects (AS/NZS 2004).

risk treatment The process of selection and implementation of measures to modify **risk** (AS/NZS 2004). For WRM this relates to the analysis of **feasibility of coordinated control** and the implementation of an appropriate **weed management** strategy for each **weed** species considered.

spread Expansion of the geographical distribution of a pest within an area (FAO 2002). The extent to which infestations of a **weed** move across the landscape, measured on a distance or area basis.

stakeholders Those people and organizations who may affect, be affected by, or perceive themselves to be affected by a decision, activity or **risk** (AS/NZS 2004).

surveillance An **official** process which collects and records data on **pest occurrence** or absence by **survey**, **monitoring** or other procedures (FAO 2002).

survey	An **official** procedure conducted over a defined period of time to determine the characteristics of a **pest** population or to determine which species **occur** in an **area (**FAO, 2002).
weed	A plant that is growing where it is not wanted by humans (FAO 2002). Plants (not necessarily non-native) that grow in sites where they are not wanted and which usually have detectable, negative economic, environmental and/or social effects (Richardson *et al.* 2000). Hence weeds are plants that cause negative **impacts**.
weed control	Application of any of a number of methods (e.g., mechanical, chemical or biological) that are designed to reduce the density and reproductive output of **weed** infestations, so that **impacts** are reduced or mitigated through suppression, containment or eradication.
weed management	A strategic, planned, long-term combination of a range of preventative hygiene procedures and active **weed control** tactics to minimise the **spread** and **impacts** of one or a range of **weed** species.
WRA	weed **risk analysis.**
WRM	weed **risk management.**

PURPOSE

This FAO post-border WRM procedures document complements and extends the previous document "Procedures for Weed Risk Assessment" (FAO 2005), which discussed resourcing and technical issues for predicting weed risk to enhance border quarantine. This document provides a generic guide to the development of a post-border WRM decision framework.

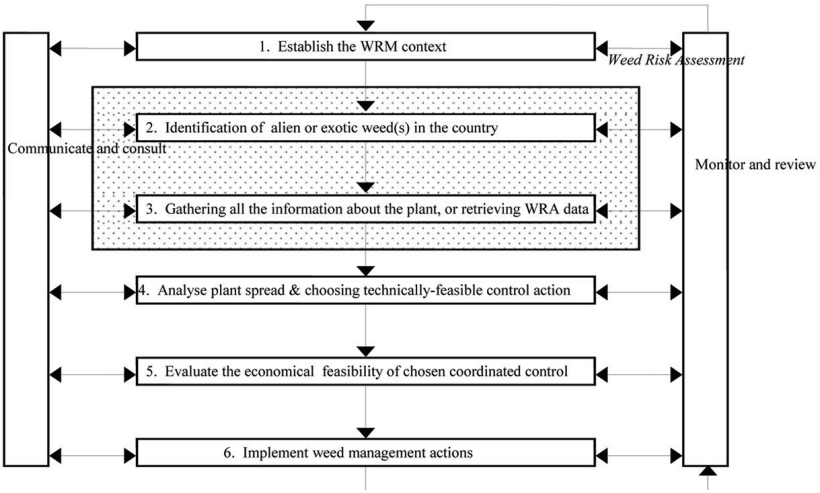
It includes the key criteria that should be considered in assessing and comparing:

(i) weed risks posed by different plant species established in a geographic area, or likely to become so, and
(ii) the feasibility of managing these species through coordinated control programs.

This document is focused on the weed risks of newly introduced plant species and does not take into account the potential benefits from deliberately growing such plant species. Objective procedures for resolving such conflicts of interest, often between economic uses of a species as a crop versus its environmental impact as a weed, are still at an early stage of development. Nonetheless, species should not be excluded from WRM procedures on the basis of their usage or perceived value.

WEED RISK MANAGEMENT OVERVIEW

Figure 1 gives the basic elements of post-border weed risk management. There are six distinct stages in determining weed species priorities.



ESTABLISH THE CONTEXT OF WEED RISK MANAGEMENT

WRM is to be applied when a new plant species has been detected and it is necessary to establish a programme for preventing its further spread in a territory.

The first step in any WRM is to bring all stakeholders to define the basic parameters within which weed risks must be managed and

to agree on the expected outcomes and level of complexity for the process. The assessment processes to be used need to be agreed upon and a project steering committee formed.

The **stakeholders** will be largely determined by the goal and management area. They need to be engaged throughout the WRM process, but their input is particularly important in establishing the context. Potential stakeholders include governments and their weed management authorities, agricultural industries, community groups, scientific organizations and land managers (e.g. farmers, rangers). In developing countries landowners and leaseholders should actively participate, and landowners should also provide support for any planned action.

Existing **policy and legislation** relating to pests provide opportunities, constraints and obligations for weed management. Managing weed risk successfully may, for example, involve establishing a legal requirement to control a species using pest laws, or developing and implementing a code of practice for hygiene measures.

If in any country there is no phytosanitary law to support the action for the control of a new invasive plant it is necessary that the authorities of the village or county request the government for a special decree compelling all stakeholders to participate and support the planning and implementation of the control action.

The level of **resources available** for both the WRM process and subsequent weed management programmes need to be planned. Resources include funding, data, literature, expertise, time and commitment/support from stakeholders.

The above considerations will enable the definition of clear and achievable **outcomes and outputs** expected from undertaking the WRM process.

The various values and perspectives that different stakeholders bring to the WRM process need to be identified, broadly acknowledged and considered in choosing methods. A clear separation between the development and routine use of an analytical system minimises the potential for inherent bias.

Establishing a representative steering committee provides for effective WRM **project management**. In addition to adequate stakeholder representation, the steering committee should also have technical expertise in weed ecology, control and risk management, and if not available, expertise in plant protection will be required. Roles, responsibilities, tasks, milestones and completion dates should be formalised.

1. The invasive plant to control

Detecting new weeds present is vital if the goal of WRM is to eradicate new weed threats. Investment in surveillance activities to detect new weeds is an integral part of effective weed risk management. This also involves reviewing records of recent naturalisations and also seeking anecdotal observations by local persons with recognised expertise in identifying native and exotic plant species. In both cases the true identities of the species should be confirmed by a qualified botanist so that appropriate literature searches for weed risk analyses be undertaken.

While WRA is mainly used for preventing the introduction of a new plant, a **review of likely incursions** is needed to prevent the establishment of a new weed in the area. The required technical information is about the behaviour of that plant in other countries where it has been recorded as an invader.

The main goal of WRM is to decide what coordinated action should be implemented and whether the resources and funding available enable this implementation, and this fully complies with the third step of Pest Risk Analysis (FAO 1996), i.e. managing the risk . This approach is different from the Australian standard which advises to prepare a list of important weed species, exotic and/or naturalized, for their categorization, prioritisation and subsequent control.

2. Weed risk assessment (WRA)

Weed risk assessment (WRA) is the use of standard, technical criteria to determine the relative weed threats posed by different plant species (Virtue and Panetta 2002). This process firstly identifies the weed that may qualify as a quarantine pest in a defined area (usually a country) and secondly, determining the likelihood of its entry, establishment, spread, and economic importance of its impacts. This may also include plant species already growing in a country that have not yet been classified as pests (FAO 2005).

If the new detected plant has been previously assessed using the WRA standard, it is just a matter to see whether the plant is in the so-called 'non permitted list of plants'. Technical information available from this assessment will be useful for WRM, particularly for the assessment of its potential spread, effective strategies for its control and prevention of its sexual or asexual reproduction taking into consideration land uses and/or ecosystems. All these data will be also useful for the assessment of the feasibility of a coordinated control.

It is important when retrieving the existing information from WRA to determine, if possible, the **Invasiveness criterion,** which gives a relative index of the rate of spread of a weed. Here three factors are to be considered:

- Establishment ability of the plant to establish amongst a dense vegetation, such as an advanced crop or closed forest, and considered as a higher weed risk. However, those that mainly establish after significant vegetation disturbance events, such as fire, cultivation, drought or extreme grazing pressure, are considered a lower weed risk.
- Reproductive ability which depends on the rate of reproduction. Highly invasive species are those which mature early, have high seed or other propagules (e.g., bulbs, tubers, root suckers, rhizomes, stolons) production
- Dispersal ability. Species with propagules (seed and/or vegetative) that are regularly moved long distances from parent plants pose a higher weed risk. Dispersal ability depends on the number of dispersal modes for a weed, their frequency of occurrence and the distance moved. The dispersal modes that should be considered are wind, water, flying animals, ground animals (including native, pests and livestock), deliberate human dispersal (i.e., species grown as crops, pastures and/or ornamentals), accidental human dispersal (e.g., attachment to clothing), vehicles (e.g., cars, farm machinery, boats) and produce contaminants (e.g., hay, grains, gravel).

The **Impacts criterion** considers the economic, environmental and social effects of weeds, these being the basis for such plant species being called 'weeds'. It is difficult to value such impacts in monetary terms, due to the limited availability of data for many weeds and due to difficulties in economic valuation where natural ecosystems are concerned. Hence it is simpler to focus on the types of impacts a weed can have, and the magnitude of these. Impacts in this criterion are considered on a per unit area basis, and the magnitude of these impacts will often be related to the weed's density or abundance. Total potential impacts are then a function of Impacts and Potential Distribution (at its simplest; impacts per unit area × total area). Six key factors are:

- Competitive exclusion of other plants. Weeds that, through competition or allelopathy, significantly reduce establishment

of desired plants (i.e. crops, pastures, indigenous vegetation) are a greater risk. In extreme cases certain weed species can form monocultures.

- Reduction in yield/biomass of other plants. This considers the weed's competitive effects on sizes of desired plants at harvest or maturity. This may be a reduction in grain, pasture, fruit or timber yields, or a reduction in biomass of native vegetation.
- Reduction in quality of products/services. Examples of this impact include tainting of meat or milk, colouration of drinking water, weed seed contamination of grains, hay or wool, and structural damage to roads and buildings. For natural ecosystems the main impact of concern is a decline in indigenous plant species diversity, reducing nature conservation, recreational and tourism values.
- Restriction of physical movement. This could include restrictions on movement of water (in natural and man-made systems), of people (e.g., walking or using vehicles, machinery, boats) and animals (e.g., livestock access to pasture and water, native animal access to breeding sites). Weeds that form tall, dense, spiny thickets rate highly for this risk factor.
- Human and/or animal health. This considers the likelihood of poisoning, allergic reactions and/or physical injuries from thorns or spines.
- Altered ecosystem processes. Ecosystem processes that may be significantly changed by high weed densities include fire regimes (through various effects upon fire frequency and intensity), levels of nitrogen fixation, water supply and use, soil sedimentation or

erosion and salt accumulation. In addition, weeds may provide habitats and/or food sources for pest animals or act as alternate hosts for plant pests and diseases.

The **Potential Distribution** criterion considers the total area that a weed could occupy if it were to spread uncontrolled. The greater the Potential Distribution the greater the weed risk. It may be described in

terms of area at risk (e.g., hectares), proportion of a region at risk (%) or proportion of a land use at risk (%).

Potential distribution is ideally predicted using climate modelling overlaid with soil and land use tolerances in a Geographic Information System (GIS) framework:

- Climate matching. Climate modelling software such as CLIMEX can give good estimates of areas favourable for a weed, provided input data is based on a representative set of point locations of the current occurrence of the species in both its native and naturalised world range. At a minimum, potential distribution can be ranked by visually matching known overseas distribution to similar climatic zones within the management area using maps (FAO 1999). Climate modelling can be quite variable in the accuracy of predictions, due to limits of distribution data, the models themselves and whether factors other than general climate place significant limits on a species distribution (e.g., plant competition, pests and diseases). Potential distributions can also be significantly overestimated for species that are normally restricted to areas that remain damp, such as riparian and swamp habitats. However, this method is not possible to be used in several developing countries due to the lack of necessary equipment and data. At this point the best solution is to retrieve available information from the literature about the influence of climatic condition on the behaviour of the plant.
- Soil tolerance. Overlaying soil tolerance with climate-based predictions can significantly refine weed potential distributions. However, this is dependent on the availability of soil maps for the region of interest, and on knowledge of weeds' soil tolerance.
- Susceptible land uses. Different weeds invade and impact in different land uses/ecosystems, due to differences in resource availability and disturbance regimes. When maps of these land uses are available then these can be overlaid with the climatic and soil tolerance to further refine potential distribution.

For aquatic weeds rainfall is generally irrelevant in predicting potential distribution, so only temperature parameters should be used in climate analysis although plants believed to be tropical and sub-tropical are now found in temperate areas. Soil tolerance are similarly mostly irrelevant for water weeds.

A **weed risk category is calculated** by combining the above three criteria into a decision framework, usually a semi-quantitative weed risk analysis system that calculates a relative score. The application of the scores should be based on the available information and with minimal subjectivity to ensure repeatable results. For example, each criterion can be scored as follows:

1- Low
2- Medium
3- High

Multiplying the scores of evaluated criteria will give products of 1-2-3-4-6, 8, 9, 12, 18 and 27. Just for giving an idea, some examples are given below:

Invasiveness (1) X Impacts (1) X Potential distribution (1) = 1

Or

Invasiveness (2) X Impacts (2) X Potential distribution (1) = 4

Or

Invasiveness (3) X Impacts (1) X Potential distribution (1) = 3

Or

Invasiveness (3) X Impacts (2) X Potential distribution (1) = 6

The first three values should be assumed as C (see categories

described below), for 4-6 it will be B, and for 9 or higher is of high risk (A):

A-(High) Of high dispersal and serious impacts to the ecosystem.
B- (Medium) Problems as above but limited to specific areas of the country or the region, e.g. a plant coming from a region of temperate climate unable to grow well in hot climate conditions but able to establish and reproduce in hilly areas where the temperatures are soft and much lower than in plain areas.
C-(Low) The presence of the plant does not pose any particular problem.

3. Technically-feasible coordinated control

The risk of the plant and its actual spread in the field will give the proper advice for the coordinated control action to be implemented. When the plant is scarcely spread eradication is the ideal option, but if it is spread to different sites, some of them with problems of accessibility, the best approach is to contain its further spread. To this end, the **Current distribution criterion** is useful, as it describes the total known extent of spread of the weed. Mapping of a weed's present distribution in the management area is needed to accurately address this criterion. The smaller the size and number of infestations of a weed species the easier it is to achieve a coordinated control. Three key factors are:

- Total area infested. This is the area bounded by all known plants, summed for all known infestations. It includes all land uses in which the weed occurs within the region of interest. It also includes areas where it may be deliberately grown in gardens or on farms, with mass plantings for commercial or amenity use adding considerably to total area infested. Infested area may be described in terms of actual area (e.g., hectares), proportion of the region occupied (%) or proportion of the land use occupied (%).

- Number of infestations. This is the number of distinct infestation sites that need to be independently searched and treated. Infestations may be separated by distance, barriers (e.g., a river), property/jurisdictional boundaries or different land types. Work effort increases with the number of infestations (e.g., frequent packing up of equipment, greater liaison effort with landholders). When the new plant is detected the likely area at risk should be determined for immediate monitoring. This observation may also compel the monitoring of other new areas depending on the spread of the plant. Usually new plants are not detected once they enter into the new territories and for this reason monitoring is a compulsory action.

- Accessibility of infestations. This relates to travelling times to and movement within infestations, for searching and control activities. Two sub factors are the maximum distance between infestations and the ease of movement within infestations (e.g., limits due to slope, rockiness, dense vegetation and/or presence of water).

In all cases, no matter whether eradication or containment is to be implemented, efforts should be made to prevent the reproduction of the plant and the build up of seeds or other propagules in soil. The feasibility of the coordinated control will also depend on the treatment(s) to be used. In this stage the control action is chosen based on what is advised to be done. Table 1 gives an example of possible control actions according to weed risk/spread of the plant. Final decisions should be discussed and agreed upon by the steering committee in close consultation with all stakeholders.

Table 1. Examples of weed risks and likely control actions to be implemented

Weed risk/ Required control action	Scarce presence of the plant, found in a few sites	Plant found in several sites but with low abundance	Plant widely spread in specific climate conditions
C- Low	eradication	eradication	eradication/ containment
B- Moderate	eradication	eradication/ control	control
A-High	containment	control*	control

*Control means here the implementation of traditional strategies for the suppression of native or naturalised weeds.

4. Economical feasibility of coordinated control

For evaluating the economical feasibility of the chosen control action it is necessary to calculate the annual control cost per unit area, and number of years required to achieve the desired programs aim to achieve eradication or containment of a weed within the management area, through locating and treating infestations, and restricting movement of propagules. In simple economic terms, the total cost of a successful coordinated control program will be a function of total level of control. However, quantitative data for such calculations are often lacking. For ranking feasibility of coordinated control the three key criteria are (i) current distribution (ii) control costs, and, (iii) duration of control effort.

For each feasibility criterion, the species is assessed in terms of their response to specific control measures. In addition to the Current distribution, already explained above, it is also convenient to evaluate the **Control Costs criterion** which considers expenses associated with

searching for the weed, treating infestations, and achieving landholder involvement. Three key factors are:

- Detectability. Weeds that are difficult to detect will require a greater search effort. Two sub-factors are ease of locating new infestations and ease of locating individuals within a known infestation prior to reproduction. Both are dependent on how conspicuous the weed is amongst other vegetation, the weed's height and its life cycle timing. If new infestations can't be readily detected, or individuals can't be found before reproduction, then feasibility of coordinated control will be lower.

- Treatment of infestations. Treatment of weed infestations using various control techniques (e.g., herbicides, physical removal) is the fundamental cost in coordinated control programs. Some weeds will require multiple treatments before being killed. Both operating and labour costs need to be considered, the latter being relatively high in situations where off-target damage must be limited (e.g. natural ecosystems).

- Farmers' involvement. Coordinated weed control relies on cooperation and involvement by affected farmers or landowners. To achieve this requires expenses for extension/ education, enforcement, project management and administration. The ease of motivating and coordinating farmers in an ongoing program will vary between land uses and regions, particularly in relation to the financial support they should receive to undertake weed control measures.
  In developing countries usually the leaseholder of the land has no means for any action except to produce food for his family, therefore it is compulsory to request the landowners to cooperate in this action.

And the **Duration criterion -** an index of how long a coordinated control program takes to achieve its desired goal. The longer this time period, the more expensive and less feasible it becomes. The weed's

response is considered under targeted control measures (to make this distinct from the WRA Invasiveness criterion). There are four key factors:

- Efficacy of targeted control. This considers whether the targeted treatments cost in Treatment of infestations kill all treated plants in an infestation. Efficacy may be less than 100% due to tolerance to or recovery from treatment, or incomplete application of a treatment.

- Reproduction under targeted control. There may still be reproduction (sexual or vegetative) within a weed infestation despite a coordinated control program being in place.

- Propagule longevity. This is the major determinant of the time to achieve eradication and relates to both sexual and vegetative propagules.

- Ongoing dispersal. Feasibility of limiting dispersal is low where a weed is primarily spread by natural means and/or where it continues to be deliberately grown as an agricultural, forestry, horticultural or garden plant. If public attitude strongly favours the continued cultivation of a species, due to its commercial, cultural and/or aesthetic values, then control programs will be hindered.

Once summed all expenses for the control and with the evaluation of duration and current distribution it will be possible to determine whether the action is economically feasible. The cost of monitoring should always be added to the cost of the required action. Data from regular monitoring will also serve to improve the ongoing control action.

For economically-poor countries donor support may be necessary for implementation of the planned action.

For eradication purposes, biological control is not an option, while for places with difficult access biocontrol is also the ideal alternative for containment and control.

In most developing countries eradication and containment should be well supported by the governments since authorities at the level of county-province or village usually do not have necessary funds for this purpose. If the risk of the plant is high for the whole country, the government has no other choice than to request technical and financial assistance from the donor community. This request is better accepted by the donors when the whole process of WRM is completed and the action plan is well described.

5. Implement weed management actions

This stage is the transition from strategic planning to operational planning, leading to active, ongoing coordinated control programs. Such programs may include quarantine, surveillance, enforced control, research and extension, depending on resources available and the weed risk management context.

Appendix 1: Example post-border weed risk analysis and feasibility of coordinated control systems

Note that these systems precede the development of FAO WRM Procedure.

Champion, P.D. and Clayton, J.S. 2000. Border control for potential aquatic weeds. Stage 1. Weed risk model. Science for Conservation. No. 141, 44pp. (New Zealand Department of Conservation: Wellington)

Cunningham, D.C., Woldendorp, G., Barry, S.C. and Burgess, M.B. 2004. A framework for prioritising sleeper weeds for eradication. Weed Technology 18, 1189-1193.

Hiebert, R.D. 1997. Prioritizing invasive plants and planning for management. Assessment and Management of Plant Invasions. (Eds J.O Luken and J.W. Thieret) (Springer-Verlag: New York) 195-212.

Panetta F.D. and Timmins S.M. 2004. Evaluating the feasibility of eradication for terrestrial weed incursions. Plant Protection Quarterly 19(1), 5-11.

Robertson, M.P., Villet, M.H., Fairbanks, D.H.K, Henderson, L., Higgins, S.I., Hoffmann, J.H., Le Maitre, D.C., Palmer, A.R., Riggs, I., Shackleton, C.M. and Zimmerman, H.G. 2003. A proposed prioritisation system for the management of invasive alien plants in South Africa. South African Journal of Science 43, 1-7.

Thorpe, J.R. and Lynch, R. 2000. The determination of Weeds of National Significance. (National Weeds Strategy Executive Committee, Launceston).

Timmins, S.M. and Owen, S. J. 2001. Scary species, superlative sites: Assessing weed risk in New Zealand's protected natural areas. Weed Risk Assessment (Eds. R.H. Groves, F.D. Panetta and J. G. Virtue). Ch. 18, pp. 217-227. (CSIRO Publishing: Collingwood, Australia).

Virtue, J.G., Groves, R.H., and Panetta, F.D. 2001. Towards a system to determine the national significance of weeds in Australia. In 'Weed Risk Assessment', pp. 124-150. (Eds. R.H. Groves, F.D. Panetta and J.G. Virtue). (CSIRO Publishing: Collingwood, Australia.)

Virtue, J.G. 2005. SA Weed Risk Management Guide. (Department of Water Land and Biodiversity Conservation, Adelaide, South Australia). www.dwlbc.sa.gov.au

Walton, C. (in preparation). Risk assessment of pests in Queensland. (Department of Natural Resources, Mines and Energy, Brisbane).

Weiss, J. and McLaren, D. 2002. Victoria's pest plant prioritisation process. Thirteenth Australian Weeds Conference: Papers and Proceedings (Eds. H. Spafford Jacob, J. Dodd, and J.H. Moore). pp. 509-512 (Plant Protection Society of Western Australia).

Williams, P.A. and Newfield, M. 2005. Testing the weed risk assessment system for new conservation weeds in New Zealand. DOC Research and Development Series 225 (New Zealand Department of Conservation, Wellington). www.doc.govt.nz

For further information please contact:

By mail: Dr. Gualbert Gbèhounou
Plant Production and Protection Division
Food and Agriculture Organization of the United Nations (FAO)
Via Delle Terme di Caracalla, C713
00100 Rome, Italy
By e-mail: Gualbert.Gbehounou@fao.org
Fax. +39 06-57053057

Or visit our Website at:
www.fao.org/fileadmin/templates/agphome/documents/Biodiversity-pollination/Weeds/Docs/Sp._Final_modified_proc._weed_risk_assessment1.pdf