RSPO Manual on Best Management Practices (BMPs) for the Management and Rehabilitation of Riparian Reserves

Holly Barclay, Claudia L. Gray, Sarah H. Luke, Anand Nainar, Jake L. Snaddon & Edgar C. Turner

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SUMMARY

Riparian reserves (also called riparian or riverine buffer zones or margins) are strips of natural vegetation located along rivers, streams and lakes, surrounded by areas of non-natural vegetation like plantations.

The presence of natural vegetation next to waterways can provide many benefits within an oil palm plantation or for downstream water users. Riparian reserves help to filter-out pollutants before they enter rivers. They can stabilise river banks, reduce downstream flooding and help maintain natural in-stream conditions for aquatic plants and animals. Riparian reserves can sequester carbon dioxide and provide habitats for a range of plant and animal species. On account of such environmental values, properly managed riparian reserves can generate significant benefits from the conservation of natural vegetation for oil palm companies.

Due to their environmental values, many countries require agricultural managers to leave an area of natural vegetation alongside rivers by law. In addition, the "Protection of water courses and wetlands, including maintaining and restoring appropriate riparian and other buffer zones", is a requirement for RSPO certification (see Principle 4 of the RSPO Principles and Criteria 2013[1]).

This manual provides guidance on how to manage riparian reserves within oil palm plantations in order to comply with RSPO standards for sustainable palm oil production. The manual addresses the following issues:

* Key benefits of riparian reserves (Section 1);
* Where to locate riparian reserves in oil palm plantations (Section 2.1);
* The optimal width of a riparian reserve (Section 2.2);
* Specific guidance for smallholders (Section 2.3);
* Recommended riparian vegetation types (Section 2.4);
* Guidance for establishing riparian reserves in new oil palm plantations (Section 3);
* Guidance for establishing riparian reserves in existing oil palm plantations or in new oil palm plantations on degraded lands, including their planning and implementing restoration programmes for degraded habitats (Section 4);
* Monitoring and adaptive management of riparian reserves (Section 5); and
* Addressing threats to existing riparian habitats and wildlife (Section 5).

The effective and long-term management of riparian reserves can vary between oil palm plantations and across regions. This manual covers general good practices for managing

riparian reserves. However, as not all the relevant topics can be covered exhaustively, oil palm plantation managers should also consider contacting and consulting appropriate experts if the requirements of their riparian reserve sites are not covered within this manual.

1 INTRODUCTION

Key messages

Conservation of natural vegetation within and alongside natural waterways is a compliance requirement for RSPO certified oil palm plantations[1] (Principle 4.4), which is also a legal requirement in many countries.

Natural vegetation should be protected inside riparian reserves (also called river reserves or riparian buffer zones), along all natural waterways – rivers, streams, lakes and springs - within and along the boundary of RSPO certified oil palm plantations.

Key environmental benefits of riparian reserves include water quality protection, bank stabilisation, flood protection, carbon storage and sequestration and biodiversity conservation. Hence, properly managed riparian reserves could generate significant benefits from the conservation of natural vegetation for oil palm companies, besides maintaining good relationships with local communities.

Specific guidance about which waterways would require riparian reserves and how wide such reserves need to be vary from country to country. National guidelines are outlined with appropriate national interpretations[31] at the RSPO website (www.rspo.org).

In the absence of national guidelines, RSPO requires riparian reserves to be established along all natural waterways >1m wide. More detailed guidance on riparian reserve size, location and vegetation type is outlined in Chapter 2 of the manual.

Riparian habitats are also required to be protected as High Conservation Value Areas (HCVAs), typically under HCV4, as areas which provide "basic ecosystem services in critical situations, including protection of water catchments and control of erosion of vulnerable soils and slopes". Riparian reserve habitats should therefore be maintained and/or enhanced as part of the HCV management plans for oil palm plantations (Principle 5.2).

1.1 DEFINITION OF RIPARIAN HABITATS

In this manual the term *riparian* (derived from the Latin for 'river bank') is used to refer to land located next to natural lakes, as well as streams and rivers, although the latter are more commonly found within oil palm concessions.

These areas are also called:

* *riparian reserves;*
* *riparian habitats;*
* *riparian zones;*
* *riparian margins;*
* *riparian buffer zones / riparian buffer strips* (highlighting the role of these habitats in buffering aquatic environments from environmental changes on land);
* *stream buffer zones;*
* *riparian vegetation* (riparian plant communities);
* *river reserve/riverine margin* (referring specifically to riparian reserves next to rivers);
* *river corridors* (where the principal purpose is to facilitate wildlife movement);
* *vegetated buffer strips (VBS)* (strips of vegetation planted specifically to trap pollutants before they flow into waterways); and
* *Riparian preservation areas (RPAs).*

The variety of terms reflects the wide range of benefits stemming from maintaining natural vegetation along waterways. Despite occupying only a small percentage of the land area, riparian reserve habitats support a disproportionately wide range of species and environmental services (see Section 1.2).

For practical purposes, the term 'riparian zone' is usually identified by measuring a predefined distance (e.g. 30m) of habitat from the edge of a waterway.

1.2 KEY ENVIRONMENTAL BENEFITS OF CONSERVING NATURAL RIPARIAN HABITATS WITHIN OIL PALM PLANTATIONS

The main environmental benefits of riparian habitat conservation, include:

1. Water quality protection;
2. Bank stabilisation and flood protection;
3. Carbon storage and sequestration; and
4. Biodiversity conservation.

Some of the aforesaid environmental benefits would occur immediately next to the riparian areas being conserved (particularly of bank stabilisation, carbon storage and biodiversity conservation), while others (particularly of water quality and flood protection) would primarily benefit downstream water users.

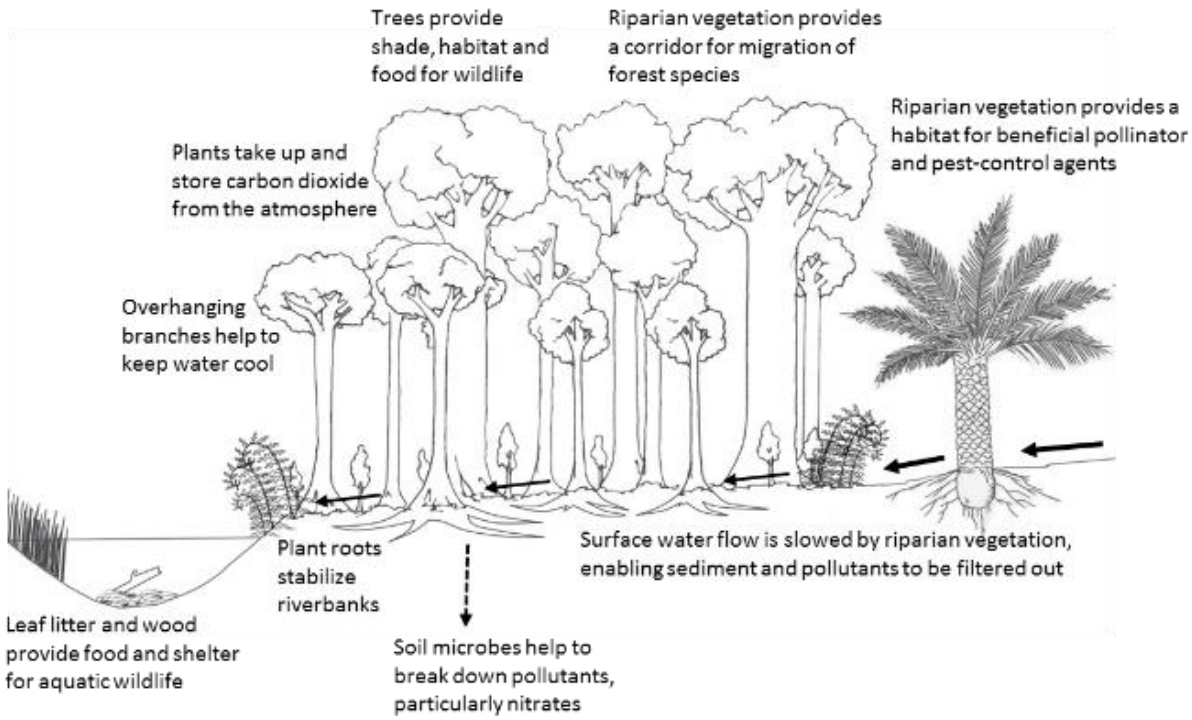

Figure 1.1. Key environmental benefits of maintaining natural riparian vegetation within oil palm plantations. Image: T. Jinggut.

1.2.1 WATER QUALITY PROTECTION

Maintaining natural vegetation along waterways would help protect water quality by:

(1) moving sources of pollution away from the water's edge (e.g. fertiliser and pesticide applications, soil disturbances, etc.); and
(2) Filtering water so that some sediments, fertilisers and pesticides are removed before they flow into natural waterways.

Sedimentation is the run-off of soil particles into waterways. This is a natural process but it is particularly high in places with bare soils, e.g. during forest conversions and oil palm (re)plantings. Even in mature oil palms, unpaved road surfaces would continue to generate high levels of sediment run-off[2]. Sediments increase water turbidity (cloudiness) and reduce water quality. Suspended sediments could also increase the transport of harmful chemicals (which get attached to sediment particles) into waterways, e.g. fertilisers (particularly phosphates), pesticides and heavy metals.

The rough ground surfaces of riparian habitats (tree roots, trunks, leaf litter, etc.) help to trap sediments and slow down water flow so that particles settle out instead of washing into rivers. The small spaces between riparian soil particles enable water to drain into deeper layers where pollutants are also filtered out. In particular, chemicals from pesticides and nitrates from fertilisers are major causes of pollution in rivers draining from agricultural lands. Riparian soils help to breakdown pesticide pollutants and retain nitrates by allowing them to be broken down by soil microbes or taken up by plants[3, 4]. Even relatively narrow riparian vegetation strips (e.g. 20-30m[5, 6]) can reduce the amount of sediments running into rivers. This process works best when water flow is spread evenly along the length of a riparian reserve. If one location along a riparian reserve receives high water flow (e.g. through a drainage channel), the filtering capacity of the riparian reserve could be overwhelmed[7]. Riparian reserves should be used as final defence approaches against water pollution rather than as alternatives to Best Management Practices (BMPs) for minimising the effects of chemical application and soil erosion.

1.2.2 BANK STABILISATION AND FLOOD PROTECTION

Plant roots can stabilise river banks so that they are less likely to collapse into the river. This can reduce downstream sedimentation[8], minimise channel erosion and widening, and help prevent downstream channels from becoming blocked by sediments which reduce the likelihood of flooding. Flooding is a natural process, but occurs more often and affects wider areas after forests have been cleared along water catchments. If some areas of an oil palm plantation tend to flood more frequently or severely, it may be best to 'allow' for such areas to flood during high rainfalls to reduce the likelihood and severity of floods occurring lower down the river. The ensuing costs to the revenue of an oil palm plantation may be minimal as such areas are often low-yielding (and in some areas are even commercially redundant) due to oil palm mortality from flood inundations[9], and crops lost due to their limited access during floods.

Riparian reserves may well turn out to be cheaper and more effective than artificial approaches to flood protection and bank stabilisation like the construction of bank support structures and the straightening of artificial channels. Such engineering-based solutions to flooding tend to displace the same problems onto further downstream water users by increasing the volume and speed of the water moving downstream[10]. Riparian vegetation also provides a broad range of additional benefits for wildlife, water quality and carbon sequestration (see Sections 1.2.3-1.2.5).

Figure 1.2 Oil palm riparian reserves in Sabah, Malaysia. Photos: C.L. Gray.

Figure 1.3 Oil palms planted at the edges of river banks are widespread but illegal in many oil palm producing countries. The oil palms in the lower photo had been planted at the edge of an eroding river bank, leading to the loss of oil palm plantation land and to the direct flow of pollutants into the river. Photos: HUTAN/Marc Ancrenaz (top)/H. Barclay (bottom).

1.2.3 Carbon storage and sequestration

Emissions of CO_2 from agriculture are of global concern because they make significant contributions to climate change. Trees and plants in riparian reserves take up CO_2 during photosynthesis and store the carbon in their tissues as they grow. Forests store more carbon than the same area of oil palms (189 tonnes of carbon per hectare of undisturbed forest compared to 36 tonnes of carbon per hectare of oil palm in SE Asia[11]). When they die, forest trees contribute to the long-term storage of carbon as partially decomposed plant material in the soil. Assuming that no additional forest is cleared to compensate for the allocation of land to create riparian reserves, the uptake and storage of carbon within riparian reserves can reduce the total amount of greenhouse gas (GHG) emissions from oil palm cultivations.

The RSPO "Palm GHG Calculator" measures the amount of GHGs emitted from a mill and its supply base, including oil palm plantations and out growers. Uptake and storage of carbon by vegetation in conservation areas is included in the calculation as a reduction in GHG emissions. Currently, the aforesaid calculator does not include conservation areas that are set aside to fulfill legal requirements, and so only those areas protected beyond the legal minimum can qualify for inclusion in GHG emission reduction schemes. Further information on calculating oil palm GHG emissions is available at http://www.rspo.org/en/rspo_palmghg_calculator. The RSPO Emission Reduction Working Group (ERWG) is presently working to refine and enhance the Palm GHG Calculator and the Carbon Assessment Tool to provide further guidance on assessing carbon storage and sequestration in riparian reserves.

1.2.4 Conservation of biodiversity within oil palm plantation landscapes

Oil palm plantations contain significantly less biological diversity than forests and oil palm waterways contain less biodiversity than waterways in forested areas[12, 13]. This is particularly the case for plant and animal species which can only live under forest conditions as such 'forest dependent' species are of high conservation concern and value.

Riparian reserves can help to reduce some of the impacts of oil palm expansion on biodiversity by:

(1) Maintaining natural processes in rivers and streams so that they contain a wider range of species;

(2) Providing habitats for terrestrial species; and

(3) Acting as 'wildlife corridors' which enable animals and plants to move through the landscape between larger areas of forests.

Maintaining biodiversity within oil palm plantations is important not only for wildlife but also for protecting processes and ecosystem services which benefit humans, e.g. food provision (e.g. plants, fish, animals), biological control of oil palm pests, carbon storage and water quality protection.

AQUATIC WILDLIFE

Riparian vegetation helps to protect aquatic animals and plants by minimising changes in water chemistry and flow rate, shading streams for waters to remain cool and oxygenated, and providing inputs of leaves and wood for fish and invertebrates[14]. In Costa Rica, riparian forest reserves of 15m width, on both river banks, substantially reduced the negative impacts of replacing forests with pasture on stream invertebrates and fish[15].

Many key aspects of water quality, particularly sedimentation, water flow rates and flooding, are strongly influenced by upstream land management[16]. Preserving natural forest cover in upstream portions of a water catchment is therefore particularly important for protecting aquatic wildlife and water quality. Wherever possible, communication and cooperation across oil palm plantations and other land users should be encouraged to protect vegetation along rivers and minimize forest loss at the top of a water catchment[17].

TERRESTRIAL WILDLIFE

Wildlife habitat within the riparian zone

In all tropical regions, there are many species of wildlife which rely on natural habitats and cannot survive in agricultural areas. Oil palm plantations generally support only very few plant species and only about 15% of the mammals, birds, amphibians and insects are found in forested areas[18].

Riparian reserves provide valuable habitats for many species that are dependent on forests, including native trees, and other unique plants and so many animals cannot survive in oil palm plantations. In Brazil, the numbers of bird species in riparian reserves are at least 70% of the total number of bird species found in large areas of forests[19]. The cooler and more humid microclimates of riparian reserve areas are also essential for amphibians, insects or crustaceans that cannot survive in the surrounding oil palm plantations. Many large mammals can be found in riparian reserves, including elephants, mongooses, civets, orangutans, proboscis monkeys and gibbons in South East Asia, as well as tapirs, deer, agoutis, armadillos and tamarins in South America[20]. Surveys of dung beetles in Borneo have also confirmed the importance of maintaining riparian reserve habitats, since such riparian reserves within oil palm plantations can support 60% of the dung beetle species found in large and logged forested areas, when compared to only 25% in oil palm plantations.[21]. For some species, riparian reserves may well provide all the natural resources required for their entire lifecycles, whereas for others the riparian reserves may only provide temporary corridors to facilitate their movement between different areas (see the section on “Wildlife movement corridors” below).

The widths of the riparian reserves determine the amount and often the quality of the habitats available for terrestrial wildlife species. Wider riparian reserves would provide larger areas of habitats for wildlife, particularly for species relying on interior forest conditions – e.g. shaded, humid, cool temperature, relatively open understory, etc. – and cannot survive in narrow (e.g. <10m) riparian reserves. Wider riparian reserves would therefore be able to support more native species of wildlife and larger populations of plants and animals than narrow riparian reserves (see Section 2.2 on “Riparian Reserves Width”). However, riparian reserves can never be replacements for large and intact forested environments, which are essential for wildlife conservation.

Wildlife movement corridors

Many species of wildlife cannot survive in agricultural areas, while other species may prefer to move through natural vegetation, when compared to oil palm plantations. Such species of wildlife can therefore become trapped in dwindling forest fragments if there were no natural vegetation connections for them to move between these areas.

Riparian reserves are particularly suitable for many forest species of wildlife because of their easy access to water, food and shelter. Helping wildlife to move through cultivated landscapes could be very important for the survival of species threatened by oil palm expansions. These include charismatic wildlife species, like large cats, primates, elephants and birds, with large home-range requirements and even some tree species of wildlife which are dispersed by being washed downstream to reach new habitats.

The benefits of using riparian reserves as wildlife corridors include:

- Helping to reduce human-wildlife conflict, including damage to crops and property and injury to people, by giving animals alternative pathways for travelling through oil palm plantations and villages;
- Allowing forest-dependent wildlife species to move through landscapes to reach new areas when they threatened by food shortages, localised disturbances, like fires, diseases and hunting, and climate change; and

- Allowing wildlife populations to interbreed and maintain strong genetic diversity, which would enable greater potential for adaptation to changing environments and reduce problems caused by inbreeding.

Riparian reserve corridors could also have some disadvantages, like allowing the spread of predators, invasive species and diseases between populations of wildlife that would not otherwise be exposed to each other. However, such problems would not outweigh the benefits gained from retaining connectivity between remaining forested areas within oil palm plantations.

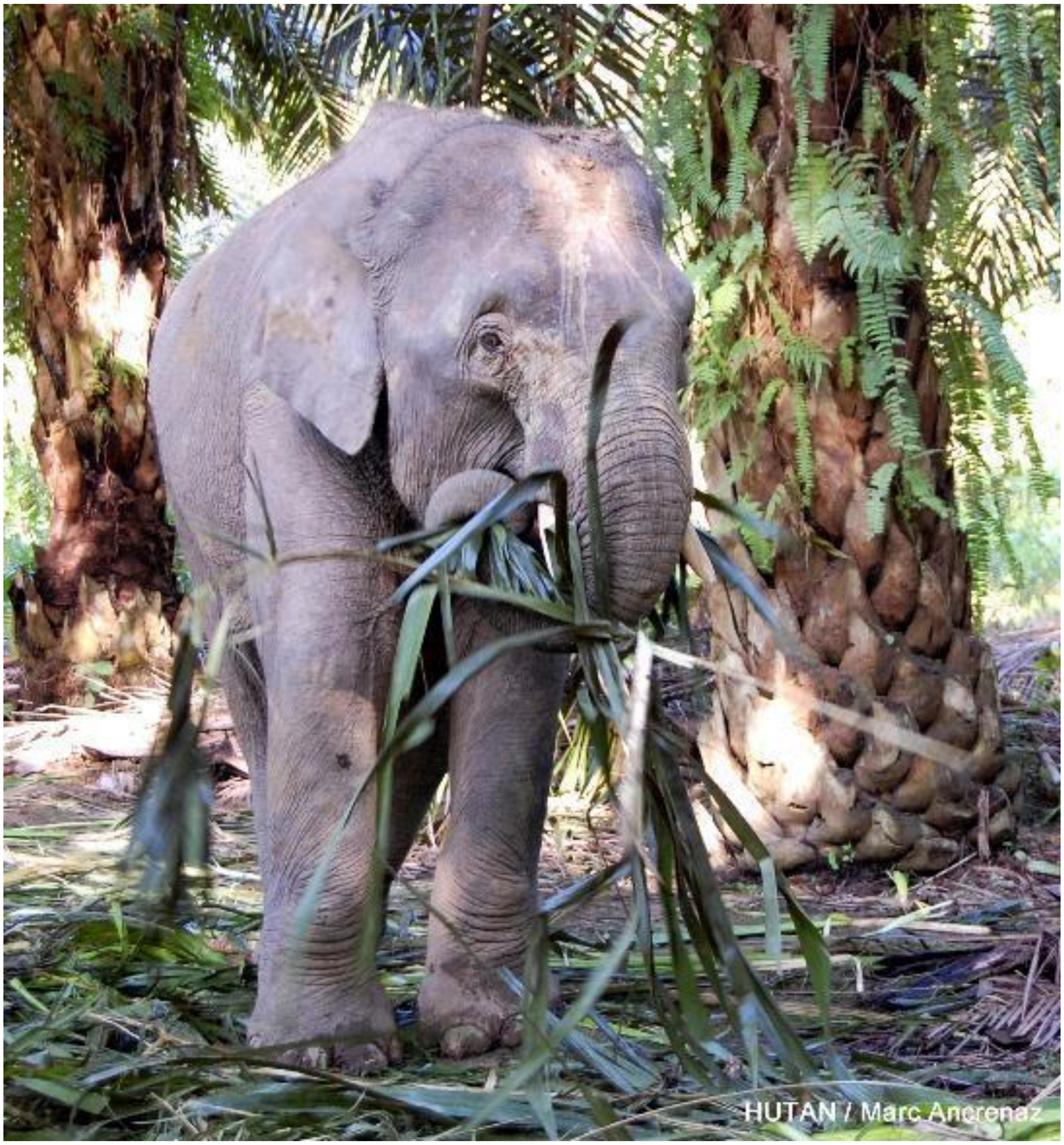

Figure 1.4 the loss of connected riparian habitats along the Kinabatangan River in Sabah, Malaysia, has led to some herds of elephants moving out of the riparian reserve zones and into neighbouring oil palm plantations and villages, resulting in economic losses and danger to local communities. Photo: HUTAN/Marc Ancrenaz.

Biological pest control in neighbouring oil palm plantations

There is evidence, from a variety of agricultural systems, to show that maintaining fragments of natural habitats within landscapes could support wildlife species which can then move into neighbouring oil palm plantations to help control pest outbreaks and/or increase pollination. For example, wild birds are predators of oil palm insect pests, like caterpillars, and more birds are generally found near forested areas in oil palm plantations[22, 23]. Surveys in Malaysia indicate that patches of forests could provide refuge for predators, such as leopard cats, civets and owls, which help to control rat populations in oil palm plantations[24]. The linear shapes of riparian reserves may also act as barriers to pest outbreaks in oil palm plantations by reducing their spread. Forested fragments also provide habitats for both oil palm pests and their predators to co-exist. However, the role of natural forests as sources for both oil palm pests and their predators, which could reduce pest outbreaks, has not as yet been studied extensively in oil palm plantations. Scientific studies carried out in other agricultural systems, like coffee[25], have indicated that agricultural crop systems with high biodiversity near forested areas were generally less susceptible to pest attack and damage.

1.2.5 Legal Responsibilities and Social Benefits

Compliance with legal and industrial standards

- The RSPO Principles and Criteria require oil palm growers to protect "water courses and wetlands, including maintaining and restoring appropriate riparian and other buffer zones (see National Best Practice and National Guidelines)" (Indicator 4.4.2)[1].
- Maintaining natural vegetation along waterways is also a legal requirement in many oil palm producing countries (see Appendix 3).
- Due to their role in water management, riparian reserves could help oil palm plantations to comply with legal water quality standards and maintain positive relationships with downstream water users.
- Riparian reserve habitats also generally qualify as High Conservation Value Areas (HCVAs) due to the range of environmental and social benefits they provide. Appendix 2 provides a detailed review of the RSPO Principles and Criteria relevant to the management of riparian reserves.
- As outlined in Section 1.2.3, riparian reserves could also reduce oil palm plantation GHG emissions, thereby demonstrating compliance with Criterion 5.6, which requires RSPO members to monitor and minimise their GHG emissions[1].
- Monitoring and reducing GHG emissions are also requirements for the voluntary carbon certification standards required for selling palm oil as biofuel within the European Union (EU Renewable Energy Directive 2009/28/EC), including ISCC (International Sustainability

and Carbon Certification), RSB EU RED (Roundtable on Sustainable Biofuels for the European Union Renewable Energy Directive).

Corporate social responsibility and ecotourism

Natural wetland habitats invariably have strong amenity values for both local people and visitors. By supporting diverse plant and animal communities, riparian habitats serve as important sites for ecotourism in many regions of the world. While revenues from ecotourism are unlikely to directly benefit oil palm managers, maintaining healthy wildlife habitats could support good relationships with local communities reliant on incomes from ecotourism. The Kinabatangan River “Corridor of Life” project in Sabah, Malaysia, is a notable example of an ecotourism and riparian reserve restoration site where tourists visiting the area could pay a voluntary conservation fee which contributes towards riparian forest restoration. Further, maintaining forested waterways and hosting tree planting events during forest restoration could also foster links with non-governmental organisations (NGOs) and members of the public concerned about the environmental impacts of oil palm production[26].

2 RIPARIAN RESERVE LAYOUT AND DESIGN

Key messages

Key requirements for compliance with RSPO Principles and Criteria

The most important places for establishing riparian reserves are along natural waterways – rivers, streams, lakes and springs - located within or along the boundaries of oil palm plantations. Specific guidance on which waterways would require riparian reserves and how wide such riparian reserves need to be vary from country to country. National guidelines for riparian reserves are outlined within the appropriate national interpretations at the RSPO website (www.rspo.org).

In the absence of specific national guidelines, RSPO requires certified oil palm plantations to adopt the following management practices for natural waterways:

All permanent watercourses, wetlands and water bodies shall have naturally occurring local vegetation on both (all) banks. Minimum riparian reserve widths should be determined as follows:

River width (m)	Minimum width of riparian reserve (m)
1-5	5
5-10	10
10-20	20
20-40	40
40-50	50
>50	100
All other permanent water bodies	100

Additional considerations

Besides following the national or RSPO minimum size requirements, there would be significant environmental and/or social benefits if wider and/or more extensive riparian reserves were established in key locations. Riparian reserve areas which require additional protection would normally be identified during the HCV assessment process.

For example, riparian reserves would generally need to be much wider to meet terrestrial wildlife requirements (>70m on each river bank or wider for large mammals) than for protecting water quality and aquatic biodiversity (15-30m in most cases). Riparian reserves used as wildlife corridors would therefore need to be much wider than those primarily established for bank stabilisation and water quality protection.

Waterways receiving water from steep slopes would also require wider riparian reserves to filter pollutants and maintain good water quality.

Small streams (<1m wide) and artificial drainage channels do not require riparian reserves under most national and/or RSPO guidelines. However, pollutants entering small waterways could have major impacts on water quality in larger rivers. RSPO strongly recommends that oil palm plantation managers minimise, or ideally eliminate altogether, the application of fertilisers and pesticides within 10m of small and/or artificial watercourses, besides maintaining full riparian reserves along the larger natural waterways. Maintaining good vegetation cover along the banks of small waterways is particularly important during land clearance and planting/replanting of oil palms when large areas of bare soil were often washed into waterways.

Riparian reserves should be regarded as an addition to, and not a replacement for, good soil and water management practices, particularly along waterways in steep areas.

Maintaining natural riparian reserve vegetation on oil palm plantations is the most effective strategy for the long-term protection of riparian reserve habitats. Where the original flora had been lost or degraded, vegetation should be restored to establish a mixture of native and local species.

Smallholders

Smallholders are required to establish riparian reserves based on the national guidelines or, in the absence of specific national guidelines, based on the RSPO size guidelines.

Additional riparian reserve considerations (e.g. wider riparian reserves in key locations) are not typically expected of smallholders, unless there is strong support from the other agencies to help smallholders manage such areas.

The following sections provide guidance on where and how riparian reserve habitats should be managed within oil palm plantations in order to comply with the relevant legal and industrial standards. Oil palm plantation managers may decide to modify such generic guidelines by increasing their riparian reserve widths at key locations (see Section 2.2.2) or by protecting waterways which are smaller than the minimum requirements to meet specific management objectives.

2.1 LOCATION

The most important places to establish riparian reserves are along natural waterways – rivers, streams and lakes - located within or along the boundary of oil palm plantations. Figure 2.1 illustrates the key decisions determining whether or not a particular waterway would require a riparian reserve.

2.1.1 Seasonal wetlands

Wetlands which were only seasonally covered with water – e.g. floodplains adjacent to rivers – are sometimes given specific protection under the national guidelines, as they do also frequently qualify as HCV areas under HCV3 (i.e. rare, threatened or endangered habitat types).

Seasonal wetlands which do not require protection under national or HCV guidelines are likely to produce low oil palm yields and should therefore be carefully surveyed prior to land clearance and planting, which would generally involve reference to topographical and hydrological maps and/or interviews with local communities to identify their flooding patterns. Areas which flood regularly (more than once every 3 years) for more than 2 weeks at a time are not recommended for oil palm cultivation[27]. This could include sites located over a km area from a river if the landscape is very flat. For instance, locations of over 2km from the main Kinabatangan River in Sabah, Malaysia, are unsuitable for oil palm cultivation if the elevation was ≤14m above sea level due to the effects of flooding and/or tidal inundation in coastal areas[9]. For new oil palm plantations, topographic information and hydrological data analysed during the Social and Environmental Impact Assessment (SEIA) phase could be used to produce soil suitability maps (RSPO P&C 7.2). Such analysis could prevent costly land clearance and oil palm plantation development in these flood prone areas. At sites affected by frequent and/or extended flooding which are already planted with oil palm, it might be advantageous to remove the area from cultivation and maintain it as an HCV area.

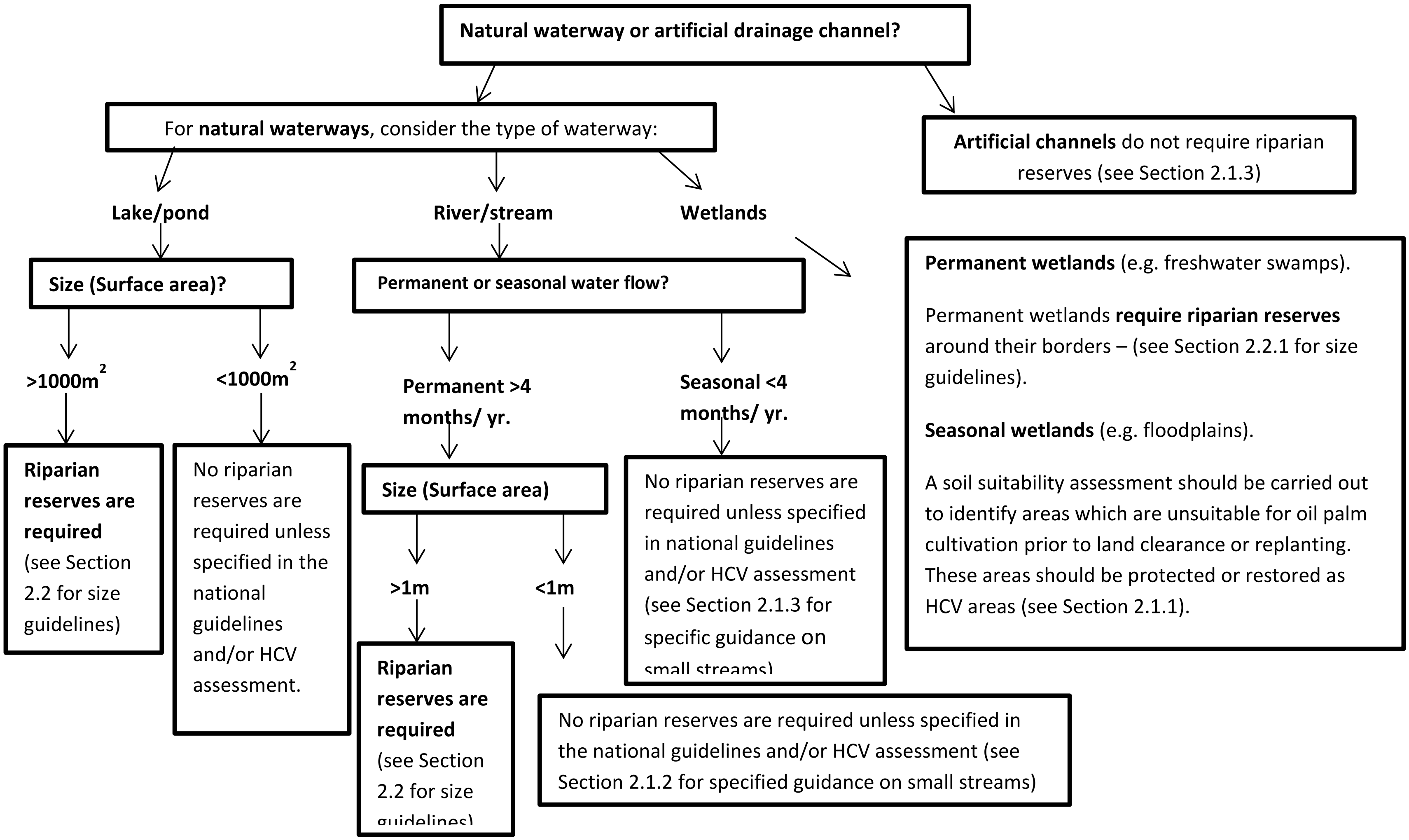

Figure 2.1 Where to establish riparian reserves at waterways within and alongside RSPO certified oil palm plantations.

Figure 2.2 Oil palms planted in areas which flood regularly tend to produce low yields, or may not even survive at all if the flooding is prolonged, and would thus lead to wasted investments and unnecessary loss of natural habitats. The planting of oil palms in such areas could be avoided by carrying out soil suitability assessments prior to land clearing, while flood-prone areas already planted with oil palms should be taken out of cultivation and the natural vegetation restored. Photo: WWF Malaysia.

2.1.2 PEAT SOILS

For detailed guidance on the managing of and replanting on peat soils, oil palm plantation managers should refer to the "RSPO Manual on Best Management Practices (BMPs) for Management and Rehabilitation of Natural Vegetation Associated with Oil Palm Cultivation on Peat"[28]. In general, the guidance for peat soils is similar to that for mineral soils, whereby natural vegetation should be maintained or restored alongside the natural waterways. However, since most peatlands drain through sub-surface flows, it is important to protect all interfaces between the oil palm plantations and peatland areas, and not only where there is surface water flow.

For rivers, this means leaving a strip of natural vegetation along both the river banks. For oil palm plantations bordering intact peat swamp forests, which are a type of wetland habitat, it involves leaving strips of natural vegetation between the planted portions of oil palm plantations and the edges of forests. In Indonesia, the required width of such strips of natural vegetation is 200m[28]. If the national guidelines did not include specific size recommendations for buffer zones between wetland habitats and oil palm cultivated areas, the RSPO minimum buffer zone width for permanent natural waterbodies – i.e. 100m – should be applied[1].

Of key importance for protecting peat swamp forests is the need to maintain the water table within peat swamp forests at natural, but seasonally variable, levels, so that the forest floods during the wet season to form pools that are interspersed by partially dry areas during the dry season. Oil palm plantations bordering peat swamp forests should therefore be managed by maintaining the natural hydrological regime inside the neighbouring peat swamp forest habitats such that no drainage of the forest edges occurs – e.g. by ensuring that the water level in any boundary drain is at or near the surface, and not at the same level as in the rest of the oil palm plantation.

2.1.3 Small streams (<1m wide)

The RSPO guidelines require riparian reserve vegetation to be maintained along all permanent rivers measuring >1m in width (see Section 2.2.1 on "How to determine river width"). However, the corresponding national requirements are often variable and may not always specify a minimum size for riparian reserve vegetation protection at small streams.

Small (<5m) streams, particularly when located on steep slopes, have strong influences on water quality and flooding along the rest of a river network, despite their small sizes. Protecting such small streams would therefore be essential for maintaining water quality, aquatic biodiversity and reducing flooding intensity in larger rivers downstream[29].

Some small streams would already be protected by oil palm planting restrictions on steep slopes (>25°) [1], which would also tend to be unsuitable for oil palm production but yet were of importance for protecting water quality.

RSPO recommends that oil palm plantations with moderate or steep slopes (>9°) bordering small streams should interpret the national regulations as minimum requirements and as far as possible maintain natural forests alongside streams measuring <5m, and even <1m, to help protect downstream water quality.

Small streams occur commonly in some places, and so the protection of all small streams <1m wide with forested riparian reserves may not be always feasible. An intermediate management option for reducing pollution runoff into small streams <1m would be to leave a narrow margin (e.g. 10m width) of understory 'soft vegetation' like shrubs and grasses to be maintained without cutting and spraying along both banks.

Maintaining even narrow strips of riparian reserve vegetation along small waterways would be particularly important during land clearance and planting or replanting when the large areas of bare soil are easily washed into waterways.

2.1.4 Seasonal streams

In general, intermittent (which only flow during the wet season) and ephemeral (which only flow during storms) streams would not require riparian reserves. Permanent streams which contain water for more than 4-5 months per year should be prioritised for riparian reserve protection[30]. Monitoring of suspended sediments and other pollutants at the inlets and outlets of oil palm plantation waterways (see Section 5.1.5) could help to indicate if such management strategies were adequate for protecting water quality. If particular intermittent drainage channels on oil palm plantations were found to contribute towards large amounts of sediments or other pollutants to permanent waterways, then narrow strips of riparian reserve vegetation should be restored along such channels as part of an adaptive management strategy.

2.1.5 Artificial drainage channels

Artificial drainage channels do not require riparian reserve protection. However, the discharge of water from artificial drainage channels into natural waterways would enable pollutants to sidestep the protection of riparian reserves.

For artificial channels draining directly into natural waterways, bank erosion and spraying of chemicals close to the water's edge should be minimised. Leaving narrow strips (e.g. 10m wide) of unsprayed vegetation, like shrubs and grasses, alongside artificial drainage channels, as well as minimising the amount of disturbances (e.g. from dredging) inside the channels, would reduce the amount of pollutants entering natural waterways via artificial channels, particularly during flooding events.

2.1.6 Maintaining connectivity

As far as possible, riparian reserves should be maintained continuously along rivers, which for the sake of water quality and biodiversity would be generally much more important than by creating wide but fragmented riparian reserves[29]. Any gaps along the lengths of riparian reserves would provide sites for pollutants to enter rivers, as well as for breaking the migration routes of wildlife, thereby significantly reducing, or even eliminating, the effectiveness of the management plan.

Management plans which reduced riparian reserve connectivity should therefore be minimised, including by the careful positioning of artificial drainage channels and roads. Further, sites where riparian reserve connectivity had been lost should be duly restored.

Connecting riparian reserve habitats across landscapes, i.e. between different oil palm plantations, would require proper coordination between the various land managers along a waterway, but it would offer much better protection of water quality and wildlife corridors than would non-continuous riparian reserves.

Figure 2.3 Gaps in riparian reserves, including roads and/or small streams and drainage channels without riparian reserves, enable pollutants to enter natural waterways, bypassing the filtration mechanism of riparian reserve vegetation. Gaps along the lengths of riparian reserves should therefore be minimised as far as possible, while small waterways should be managed carefully to minimise the movements of pesticides, fertilisers and sediments into larger waterways (see Section 2.1.1). Photo: C. Beamish/Wilmar.

2.2 RIPARIAN RESERVE WIDTH

2.2.1 MINIMUM RIPARIAN RESERVE WIDTH REQUIREMENTS

National guidelines for riparian reserves are outlined within the appropriate national interpretations[31] and local indicators[32] at the RSPO website (www.rspo.org). Guidelines for some RSPO oil palm producing countries are described in Appendix 3.

In the absence of specific national guidelines the following performance standards should be applied[1]:

All permanent watercourses, wetlands and water bodies should have naturally occurring local vegetation on both banks. Minimum riparian reserve widths should be determined as follows:

River width (m)*	Minimum reserve width (m)
1-5	5
5-10	10
10-20	20
20-40	40
40-50	50
>50	100
All other permanent water bodies and wetlands	100

*How to determine river width

Some riparian reserve width recommendations, including those of the RSPO guidelines, vary with river width. Where national legislation did not provide specific guidance on how to determine river width, the width should be measured from the top of each river bank at the highest water level, i.e. the highest point the water level reaches in an average year before it flooded into the surrounding landscape. The aforesaid water level is sometimes also called the river's 'bankfull width'. If this point cannot be identified, then the river width could be measured from the top of each river bank, which would help to ensure that variations in the water levels between the wet and dry seasons did not alter the riparian reserve width requirements at the site.

The number of river width measurements needed to be taken would depend on the length of the river, and also on how much its width varied within an oil palm plantation. As a general rule, for rivers flowing for <2km within an oil palm plantation, 4-5 evenly spaced width measurements (i.e. every 400-500m) are likely to be sufficient for determining the average width of a river. For rivers flowing for >2km within an oil palm plantation, 10 river width measurements are to be taken along the length of a river, if it was located within the boundaries of an oil palm plantation , separated by distances of approximately 1/10th of the total river length.

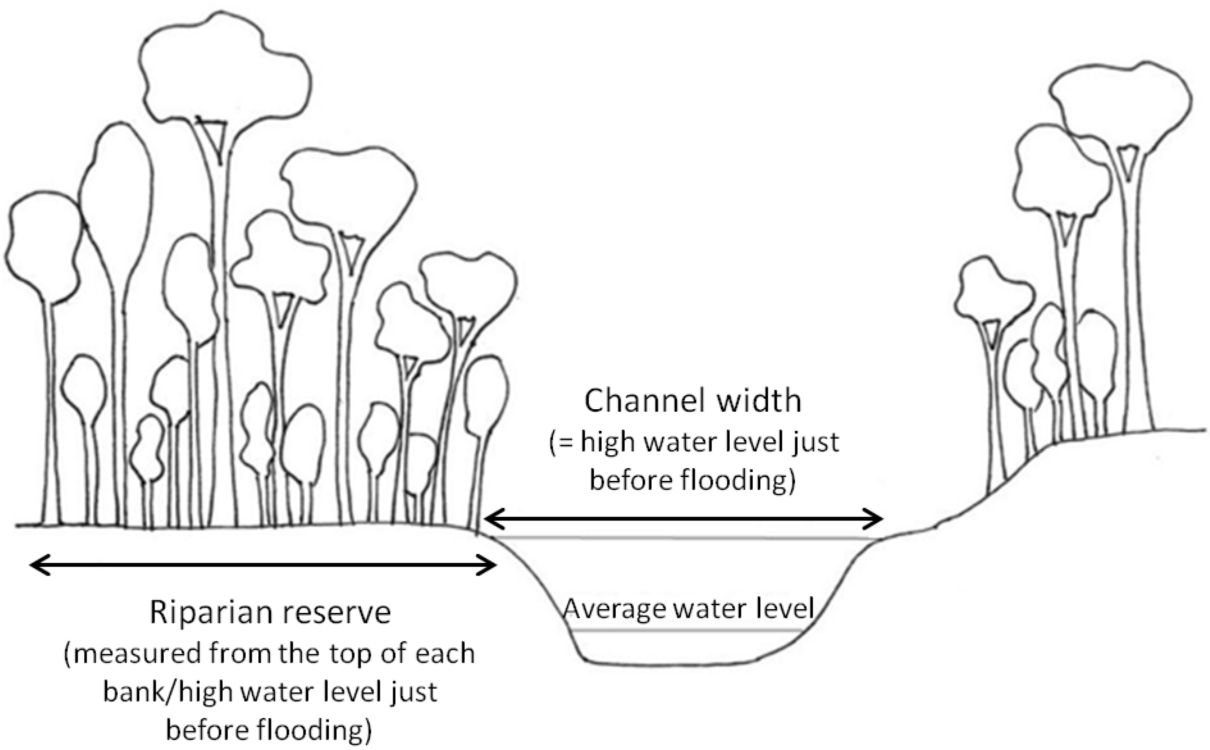

Figure 2.4 the channel width of a river is the maximum width of a river from bank to bank, measured from the top of each bank, where it is visible, or from the estimated high water level based on previous observations, i.e. the highest point the water level reaches in an average year before it flooded into the surrounding landscape. The wetted channel width of a river is the width of the water in a river, which would of course vary from day-to-day and season-to-season.

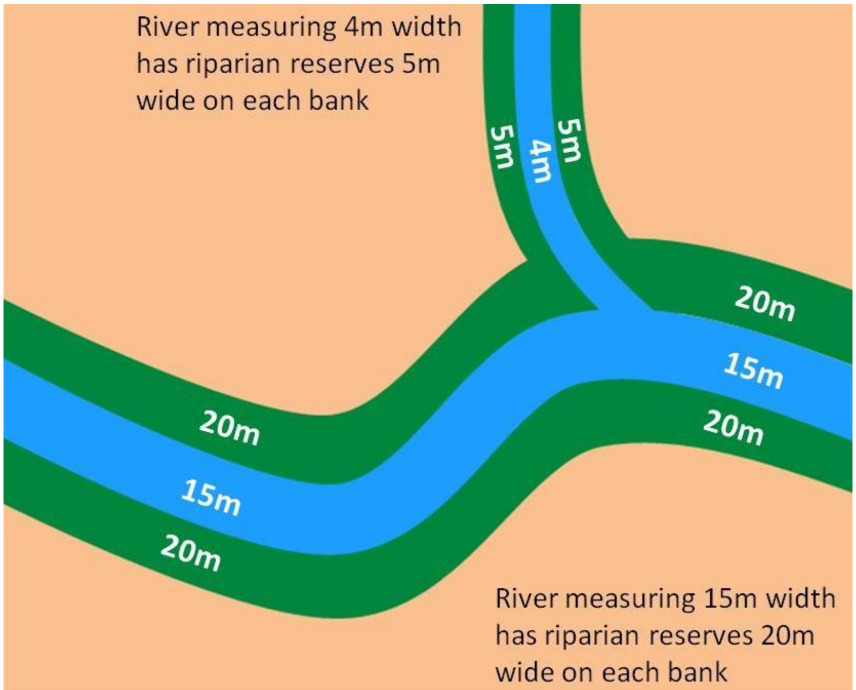

Figure 2.5 Riparian reserve widths refer to the width of natural vegetation to be left behind on each river bank.

2.2.2 Benefits of wider riparian reserves in key locations

Some environmental benefits require the maintenance of wider strips of riparian reserve vegetation than others. Key environmental and social benefits which might require wider riparian reserves in some locations should be highlighted during the SEIA and HCV assessment processes. Figure 2.3 summarises the recommended riparian reserve widths for different environmental benefits, based on existing available information from tropical regions, combined with data from temperate regions for environmental services where little or no tropical data is available.

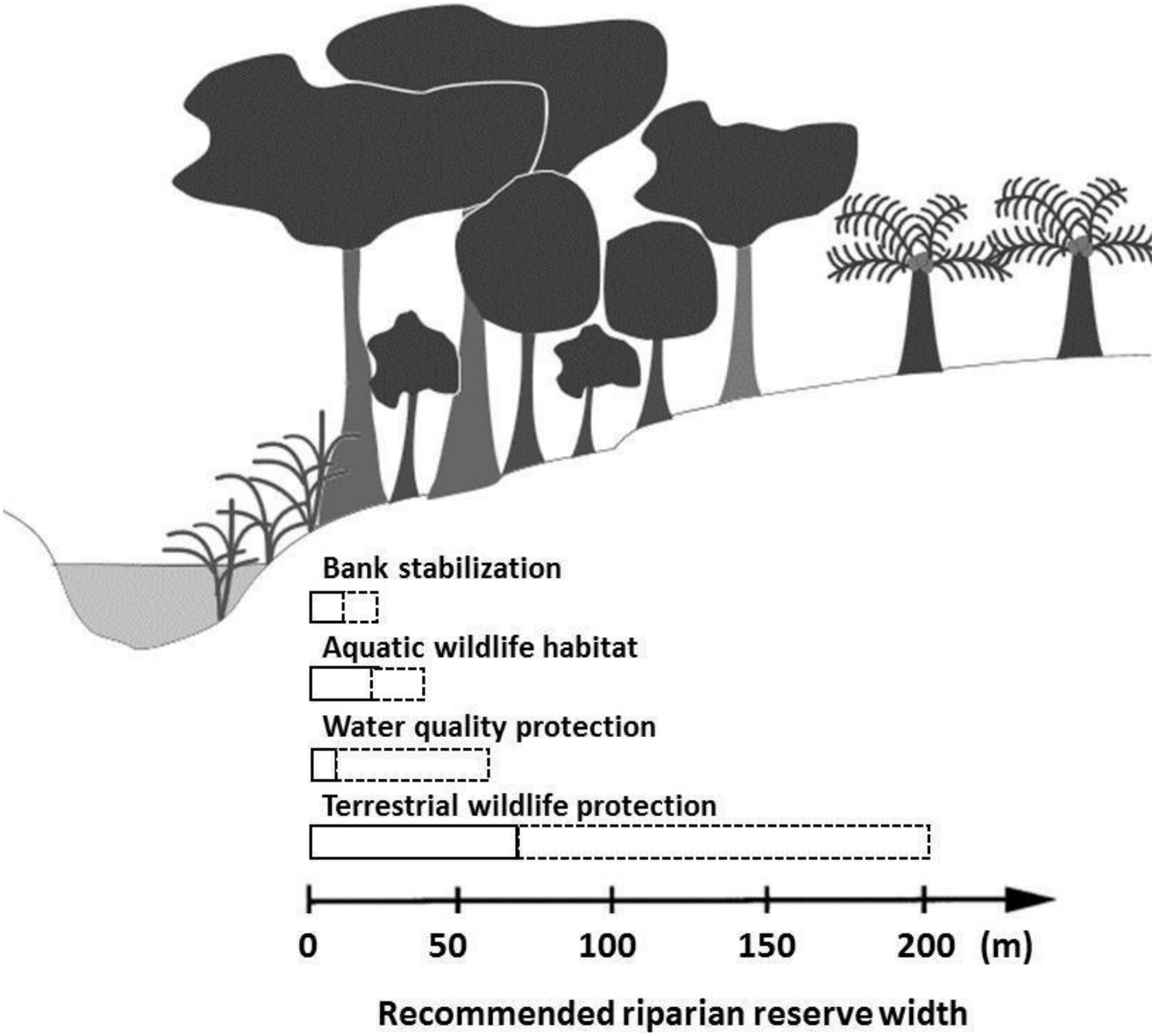

Figure 2.6 Estimated riparian reserve widths for different environmental benefits. The solid lines indicate the minimum recommended riparian reserve widths, while the dashed lines indicate larger riparian reserve recommendations based on variations between the different studies[4, 5, 9, 14, 20, 32–36].

Oil palm plantation sites that would benefit from wider or more extensive riparian reserves than the minimum requirements include:

For areas close to waterways which supply the basic water and food needs of local communities, including of oil palm plantation workers (HCV5), e.g. if an oil palm plantation is located upstream of human populations who rely on a river or lake to supply their water needs for drinking, washing, fishing, etc.:

Recommendation: Riparian reserves should be at least 30m on each river bank along all the small and large waterways in riparian reserves upstream of waterways used for supplying the basic water and food needs of the local communities.

Waterways should be monitored regularly (see Section 5.1.5) to ensure that the water quality remains within relevant national standards.

Other best management practices should also be used to maintain good water quality, particularly during land clearance and planting or replanting of oil palm.

For areas upstream of conservation areas or significant breeding and spawning grounds for fish and aquatic life (HCV1):

Recommendation: As above.

For waterways, including small streams <1m wide, which receive surface water run-offs from steep and moderately steep oil palm cultivated slopes (9-25°):

Recommendation: RSPO prohibits the extensive planting of oil palms on steep slopes (e.g. >25° in general or >18° in Indonesia).

Where oil palms are planted on intermediate slopes (9-25°), RSPO recommends increasing the width of the riparian reserves by 0.5-1m for every 0.5° (1%) increase (above 9°) in the slope gradient alongside a riparian reserve [10].

For areas which are of marginal value for oil palm cultivation, e.g. areas along rivers which flood regularly or have unsuitable soils:

Recommendation: Soil suitability analysis based on topography and hydrology (RSPO P&C 7.2) should be carried out prior to land clearance, or in the case of existing oil palm plantations prior to replanting.

For waterways which connect larger areas of intact forests, which can be used as wildlife corridors by HCV species.

Recommendation: Riparian reserves generally need to be much wider for meeting terrestrial wildlife requirements than for protecting water quality and aquatic biodiversity. Ideally, the riparian reserves should be at least 30m on each bank for small (<5m) streams, 70m on each bank for rivers 3–10m wide, and wider (>200m on each bank) for rivers >10m wide.

For areas where maintaining good wildlife habitats may be of key economic importance for local communities, e.g. alongside, upstream and downstream of ecotourism sites.

Recommendation: As above.

The riparian reserves generally need to be fairly wide to meet the terrestrial wildlife requirements. Identifying suitable riparian reserve widths for a particular species and/or habitat type is likely to involve consultation with local experts.

Biodiversity protection requires wider riparian reserves than those for water quality management.

In general, riparian reserves need to be much wider for meeting terrestrial wildlife requirements than those for protecting water quality and aquatic biodiversity, particularly for conserving large-bodied species like elephants and rhinos. However, the presence of some riparian reserve vegetation would be better than none at all, and any increases in width would further improve the habitat value of a riparian reserve.

To protect wildlife, riparian reserves should ideally be at least 70m on each river bank of 3–10 m width to provide enough habitats and movement corridors for terrestrial species. However, riparian reserves on the larger rivers (>10m across) should be wider, with at least 200m of natural vegetation on each river bank. In contrast, riparian reserve wildlife communities around smaller rivers and streams (<5m across) could be supported with narrower buffer zones (30m of natural vegetation on each bank).

Riparian reserve vegetation, particularly forests, would provide shade (thus reducing water temperature and increasing oxygen levels), leaf litter, and wood and tree roots for shelter and bank stabilisation, all of which would benefit aquatic wildlife species. Such riparian reserves should be at least 15-30m wide (on both banks) to help protect fish and aquatic invertebrates. The conservation of natural riparian reserve vegetation towards the top of a water catchment would be particularly important for maintaining water quality and conserving aquatic biodiversity[16], for which coordinating the management of the riparian reserve vegetation with upstream land users might be required.

Steep slopes and converging water flows require wider riparian reserves to protect water quality. Water draining from steep and high hills would flow quickly and so there would be less time for pollutants to be filtered out by the riparian vegetation.

RSPO prohibits the extensive planting of oil palms on steep slopes (>25° in general or >18° in Indonesia), and so appropriate soil conservation practices must be applied, e.g. the use of cover crops and sediment traps on slopes of intermediate gradients (9-25°). Topographical data for determining slope could be established by using the minimum contour interval spacing available, viz. typically 30m on 1:50,000 scale maps or larger scale maps (e.g. 1:25,000) if available[36].

An additional BMP for protecting water quality when oil palms were planted on intermediate slopes (9-25°) would be to increase the riparian reserve width along waterways in such areas, e.g. by increasing the riparian reserve width by 0.5-1m for every 0.5° (1%) increase in average slope gradient alongside the riparian reserve[10].

Natural contours in the landscape tend to form hollows for water flows to converge during storms, which could overwhelm the filtration capacity of a riparian reserve [5, 37]. Such temporary water channels could carry high water flows during rain storms, but would dry up under normal conditions. Their locations could be determined by observing areas of high water flows during heavy rains and establishing wider riparian reserves, and/or riparian reserves with denser vegetation, particularly in the understory (see Section 2.4) at such key locations.

Besides establishing riparian reserves, BMPs for managing soil erosion and protecting water quality should also be practiced, particularly along waterways in steep land areas. However, it is beyond the scope of this manual to document all and/or detailed guidance on the relevant good soil and water management practices, which could include the following strategies:

- For new oil palm plantations, forest conversion schedules should minimise the time between harvesting, conversion and planting;
- Fast-growing ground cover crops should be planted during oil palm planting, with follow up maintenance as the oil palms mature;

- Oil palm fronds or empty fruit bunches (EFBs) should be placed along the slope contours and across the storm-water flow channels;
- Dense understory plants should be encouraged to grow downhill of areas where bare soils were exposed, e.g. next to roads; and
- Drainage channels should be designed to direct storm-water flows away from natural waterways into oil palm planted areas or temporary storage ponds where the sediments and other pollutants could settle out (see Section 3.4).

"Guidelines for minimising impacts of oil palm plantations and palm oil mills on quality of rivers in Sabah"[38] describe BMPs for minimising soil erosion in more detail. Although the aforesaid guidelines were written primarily for oil palm plantation managers in Sabah, Malaysia, many of the recommendations could also be applied to other regions of the world.

Carbon storage calculations only include widths above minimum legal requirements.

The uptake and storage of CO_2 by vegetation and soils in 'conservation areas' are measured by the RSPO PalmGHG Calculator as a reduction in total GHG emissions in an oil palm plantation. The RSPO PalmGHG Calculator only considers the carbon uptake and storage in conservation areas which were additional to its legal requirements. Riparian reserves wider than, or located along, waterways which did not require a riparian reserve under national laws, could therefore reduce or offset the total net GHG emissions calculated for an oil palm plantation or mill. Hence, RSPO is currently working on a practical methodology for oil palm growers to estimate the mean annual carbon sequestration within conservation areas. For updates on it, refer to the RSPO Emission Reduction Working Group (ERWG) page at the RSPO website www.rspo.org/en/emission_reduction_working_group.

2.3 SPECIFIC GUIDANCE FOR SMALLHOLDERS

Smallholdings (oil palm plantations where the majority of labour is provided by the family itself, where the oil palm plantation provides the principal source of income for the family, and where the planted area of oil palm is <50 Ha) are required to comply with the national legal requirements for riparian reserves in their respective countries, or in the absence of national legislation, with the RSPO minimum riparian reserve criteria.

Smallholders are not expected to maintain and protect riparian reserves beyond the minimum size requirements for their region (see Section 2.2.1), which would, in most cases, be sufficient to provide physical benefits like bank stabilisation and water quality protection, but which may not be large enough to provide significant benefits for terrestrial wildlife.

In the case of existing smallholdings with already established in riparian reserves, oil palm plantation group managers should encourage smallholders to implement manual weeding of oil palm circles close to waterways, with such areas being restored with natural vegetation during replanting. Wherever possible, the assistance of relevant government agencies (e.g. forestry or wildlife departments), or local environmental NGOs with expertise in this particular area, should be sought before restoration to ensure that money was not wasted on unsuccessful riparian reserve restoration programmes.

In a minority of cases, the existing area of land being cultivated by a smallholder might require significant areas (>20% of the total oil palm cultivation area) to be removed from cultivation and replanted with natural vegetation. In such cases, the potential socio-economic impacts of the ensuing loss of income should be weighed and considered by the smallholder project manager and/or the RSPO auditor(s) in consultation with the smallholder(s) in question to allow for a more flexible timescale and tree planting requirement (e.g. with a focus on planting native species to provide alternative sources of income for the smallholder) to ensure the long-term protection of these areas.

2.4 RIPARIAN RESERVE VEGETATION TYPE

The protection and/or restoration of the original riparian reserve vegetation on oil palm plantations would be the most effective strategy for the long-term maintenance of riparian reserve habitats. Where the original riparian reserve flora had been lost or degraded, vegetation should be restored in order to establish a mixture of native and local tree species (see Section

4.0 on "ESTABLISHING RIPARIAN RESERVES IN EXISTING OIL PALM PLANTATIONS OR IN NEW OIL PALM PLANTATIONS ON DEGRADED LANDS").

The key vegetation features to be maintained or restored in forested riparian reserves include:

- **Sufficient density of trees, with high basal areas, to ensure continuous canopy cover.**
  Canopy cover is important for retaining the cooler, shady and humid riparian reserve environments, and hence also for maintaining their characteristic community of plants, animals and fungi.
  In regions where the original riparian reserve vegetation was grasslands, their canopy cover would be very low under natural conditions, and so would not be a useful indicator of good quality riparian reserve habitats.
- **Structural complexity.**
  Retaining a wide range of riparian reserve vegetation forms (e.g. shape and height) since the resulting higher structural complexity would tend to promote higher species diversity.
- **High diversity of plant species.**
  A wide range of tree species and ages (especially of old trees and standing dead wood) would be required for providing a correspondingly wide range of food resources and nesting or roosting habitats for many animals, like birds, arboreal primates and bats. Trees producing edible fruits would in particular benefit a wide range of different animals, besides also encouraging the arrival of frugivorous (fruit-eating) birds and mammals which could disperse seeds from and to other areas, thereby enhancing forest regeneration and diversity.
- **Leaf litter and dead wood.**
  Both on the ground and in rivers, large quantities of leaf litter and dead wood would provide essential habitats and foods for invertebrates, amphibians and fish. Such organic and woody materials should therefore not be cleared or removed from riparian reserve buffer zones or neighbouring rivers. However, exceptions could be made in the case of significant blockages in rivers, especially if they caused localised flooding and/or reduced oil palm plantation productivity.
- **Filtration of sediments.**
  The filtration of sediments by riparian reserves would be most effective when the water was flowing slowly. Hence, an extra layer of soft vegetation, alongside the forests, could increase the removal of sediments from waters flowing through riparian reserves. Grasses and shrubs alone cannot provide many of the other environmental benefits seen in forested riparian reserves, like wildlife habitats and bank stabilisation. However, in areas

where sediment removal was a high priority, an extra layer of soft vegetation could be left to grow alongside the oil palm plantation edge of a riparian reserve. Open areas of grasses or shrubs measuring 20-30m between the oil palms and the natural forests could also minimise the movement of forest animals, like orangutans, into oil palm plantations[39].

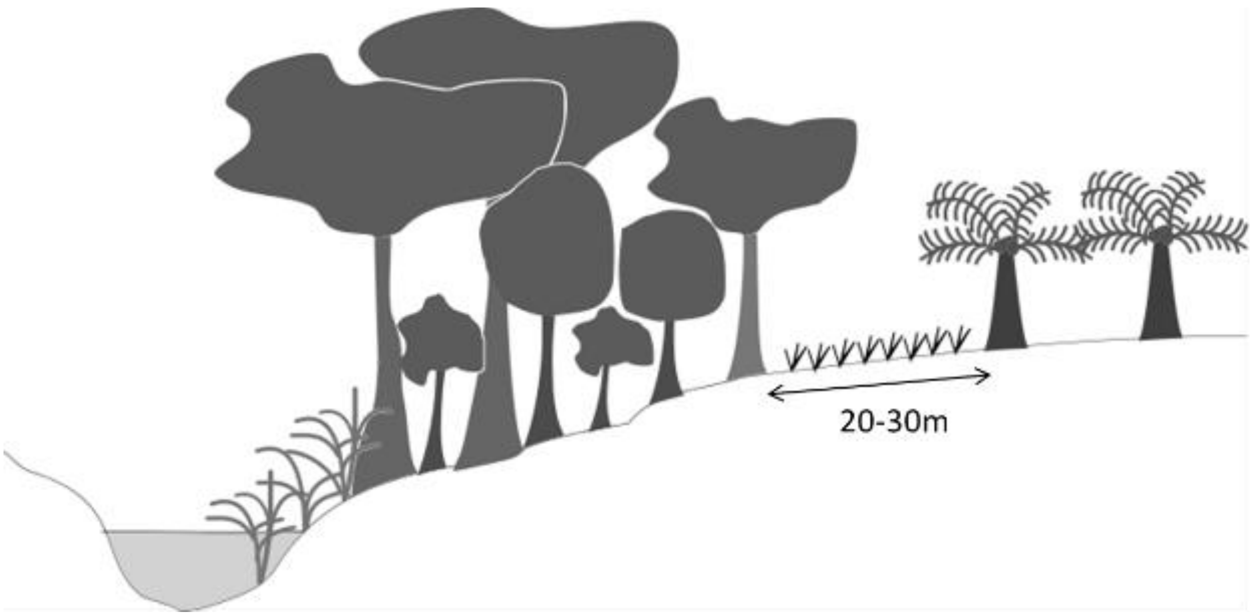

Figure 2.7 Open areas of grasses or shrubs (i.e. dense ground cover) between the oil palms and the edges of a forested riparian reserve could help filter out sediments and spread water flow over wider lengths of a riparian reserve, thereby maximising the water filtration capacity of the riparian reserve vegetation[40]. Open areas of 20-30m between an oil palm plantation and the edge of a forest reserve could also act as a barrier for minimising the movement of forest animals, like orangutans, out of the riparian reserve into the oil palm plantation[39].

Vegetation in narrow riparian reserves

It should be noted that some of the original tree species might not be able to grow and/or reproduce in narrow riparian reserves of <20m width, because the narrow riparian reserves were hotter and drier, with fast understory weed growth, when compared to larger forested areas. For such narrow riparian reserves, maintaining all of the original riparian reserve vegetation might not be possible once the surrounding natural vegetation had been converted to oil palms. If extensive gaps occurred along such narrow riparian reserves, it might be necessary to fill in the gaps by planting tree species which typically grew at forest edges, which are sometimes called 'pioneer' or 'disturbance tolerant' tree species. Alternatively, if the adult trees were still surviving but their seedlings were unable to grow due to the understory weed cover, oil palm plantation staff may need to weed around the seedlings until they grew large enough to shade out the weeds underneath (see Section 4.3.1). Further, Section 4.4.3 describes how to select tree species for the replanting of riparian reserve vegetation in more detail. Care should be taken to select tree species that were native to that country or region, and not to use fast-growing tree species from other regions which could spread into neighbouring oil palm plantations and become difficult to remove. If in doubt, local experts, particularly those from forestry departments, should be consulted for advising oil palm plantation managers on the most suitable tree species to be grown in narrow riparian reserves.

3 Establishing riparian reserves in new oil palm plantations

Key messages

As a general rule for environmental management, it would be always easier, cheaper and more effective to maintain existing habitats or species than to restore habitats or reintroduce species. It is therefore essential to determine which areas should not be cleared during the planning process for new oil palm plantations even well before starting the process of land clearance, so that accidental disturbances, followed by the costly restoration of riparian habitats, could be avoided.

Watercourses within an oil palm plantation concession area that required protection should be identified during the HCV assessment process itself.

For oil palm plantations with riparian reserve areas already containing natural vegetation, the key environmental management priorities would include:

- Marking the boundaries of such riparian reserve areas clearly to prevent accidental encroachment, particularly during initial forest clearance and replanting;
- Carrying out regular monitoring activities (see Chapter 5) in such riparian reserve areas to ensure that threats were detected quickly and management practices adjusted accordingly; and
- Protecting such riparian reserve areas from threats which could cause environmental degradation, including from threats like illegal logging, mining, hunting, fires, land conversion and/or the establishment of human settlements within the riparian reserve areas.

3.1 MAPPING TO DETERMINE RIPARIAN RESERVE LOCATION AND EXTENT

Sections 2.1 and 2.2 describe where riparian reserves are to be located and their recommended widths. . Further, the aforesaid sections also outline considerations for creating wider or more extensive riparian reserves than those required by law in order to meet additional environmental management objectives.

Additional riparian reserve protection for watercourses within oil palm plantation concession areas should be considered during the HCV assessment process, in accordance with RSPO Principle 7: "A comprehensive HCV assessment, including stakeholder consultation, shall be conducted prior to any conversion or new planting"[1]. For further information on HCV assessments see: www.hcvnetwork.org.

Initial assessments of the baseline, or pre-clearance, riparian reserve vegetation and the location of waterways could be made by:

- Aerial or high definition satellite images;
- Pre-existing maps of the oil palm plantation concession areas showing either the locations of the watercourses or indicating where they were likely to occur (topographic maps); and
- Lidar maps, with high resolution aerial imaging, which provide detailed information on topography and vegetation cover.

Notably, the above mentioned remote surveys should also be verified by on the ground observations, particularly in locations where the riparian reserve size may need to be adjusted in response to the river width (see Section 2.2 on "Riparian Reserve Width").

Social surveys with local stakeholders, to be conducted as part of the standard HCV assessment process, should be used to identify waterways supporting the basic needs of local communities, like the supply of food and water. Such waterways, including those in riparian reserve forests alongside and upstream of the areas used by the local communities, should be designated as HCV5 reserves and given strong protection, to be accompanied by water quality monitoring (see Section 5.1.5) for maintaining good water quality.

3.2 MARKING BOUNDARIES TO PREVENT ACCIDENTAL DISTURBANCES TO RIPARIAN RESERVE HABITATS

- Having established areas of an oil palm plantation concession to be protected as riparian reserves, they should be marked clearly (e.g. by using stakes or brightly coloured paints to mark trees) for their recordings in digital GIS-based maps that could be downloaded onto GPS units for their later use to locate riparian reserve boundaries on the ground.
- Riparian reserve boundaries should also be marked with signs to inform oil palm plantation employees and other local people that these conservation areas had been reserved for wildlife and water quality protection.
- The locations and purposes of the riparian reserves should be communicated in person to all oil palm plantation workers and contractors responsible for clearance, ground preparation and planting, particularly to clarify where the riparian reserve boundaries were located and how they had been marked.
- Oil palm plantation staff involved in establishing the riparian reserve locations should be present on the ground during forest clearances to ensure that these areas were not accidentally cleared. Such staff should be equipped with GPS units and should also have the authority to halt clearances in situations where there were uncertainties over their designations[41].

3.3 DESIGNING ROAD NETWORKS

Unpaved roads within logging and oil palm plantation operations contribute significant amounts of sediments and rapid water flows into rivers, particularly during storms. In places where the roads were located within or through a riparian reserve, this effect could undermine any potential water quality protection offered by the riparian reserve[5].

Road networks should therefore be designed to minimise their negative impacts on oil palm plantations [42, 17], including by:

- Careful planning to minimise the extent of necessary road constructions;
- Constructing roads during dry weather;
- Locating roads as far away as possible from streams and rivers, with the roads being always placed above the maximum extent of flood waters and outside riparian reserves, excepting when river crossings are absolutely necessary;

- Particularly on steep slopes, sediment runoff could be captured in sediment traps like artificial ponds or channels located next to, and downhill from, unpaved roads, where the sediments could settle out before the water runs downslope into natural waterways. Depending on the terrain, such sediment capture drains could be constructed at 50-100m intervals to divert water into planted areas for the oil palms[38] ; and
- Wherever roads cross through riparian reserves, the crossings should be maintained at right angles to the riparian reserves and waterways in order to reduce the areas of disturbance.

3.4 LAYOUT OF DRAINAGE CHANNELS

If drainage channels were positioned across riparian reserves and drained into natural waterways during high rainfalls, water cannot be filtered by the riparian reserve vegetation and soils. Hence, drainage channels should be designed to prevent the direct transport of water from oil palm plantations into rivers and lakes, e.g. By placing sedimentation basins or silt ponds at the end of drainage channels, before the water flows into a natural waterway.

Wherever possible, maintaining riparian reserve vegetation along the banks and along the bottoms of drainage channels could help to stabilise sediments, and would allow for some pollutants to be broken down within the drainage channels.

Figure 3.1 Roads and drainage channels should, as far as possible, be located outside riparian reserves to reduce gaps along the riparian reserves, and also to prevent water from oil palm plantations sidestepping the riparian reserve vegetation and flowing directly into natural waterways. Photo: HUTAN/Marc Ancrenaz.

3.5 ESTABLISHING A MONITORING PROGRAMME

Establishing riparian reserves is only the first step towards ensuring these areas being protected in the long-term. Multiple access points along riparian reserves, particularly where people can travel into riparian reserves by boats, render them vulnerable to logging, hunting and other disturbances which would reduce their capacity to improve water quality, support biodiversity and sequester carbon.

Riparian reserves and their waterways should be monitored regularly to ensure that threats are identified and dealt with quickly, with the frequency of monitoring being dependent on local factors like level of human encroachment, size of the oil palm plantation and staff availability. Ideally, riparian reserves should be at least visited once every 6 months for the larger oil palm plantations, and every 2-3 months for the smaller oil palm plantations to check for signs of disturbances within the riparian reserves. For the larger oil palm plantations, such twice yearly monitoring visits could be supplemented by *ad hoc* reports from oil palm plantation field managers to detect and mitigate threats as soon as possible.

More detailed monitoring programmes could be carried out on a less regular basis. For instance, for water quality, collecting water samples every 1-2 months, and for riparian vegetation or biodiversity, surveys once or twice per year. Monitoring programmes could also provide valuable information on the extent to which riparian reserves were fulfilling their intended functions (e.g. for water quality protection which was highly dependent on local factors like soil type, slope, etc.) so that management practices could be adjusted if necessary (see Section 5 on "MONITORING RIPARIAN RESERVES & RESPONADING TO THREATS").

Wherever possible, monitoring programmes should be started even before forest clearance and be continued throughout development of the oil palm plantation. As such, pre-forest clearance information would provide valuable baseline data against which any future changes could be compared.

3.6 CASE STUDY: OLAM – ESTABLISHING NEW OIL PALM PLANTATIONS IN GABON, AFRICA

The concessions allocated for the oil palm plantations of Olam (Oil) Palm in Gabon, Africa, contained a number of natural wetland habitats which required the establishment of riparian reserves. Such wetland habitats included rivers, streams, lakes and areas undergoing seasonal flooding. The Olam Palm Gabon case study provides details on how riparian reserves could be established in new oil palm plantations following the RSPO management and other BMP guidelines. While the steps described here would be relevant to oil palm plantations elsewhere, they may not be always suitable for all oil palm companies, locations and plantations.

Riparian reserve layout and design

At the time the Olam oil palm plantations were set up, there were no specific national legal requirements in Gabon with regard to the width of riparian reserve buffer zones. However, the prevailing Gabonese legislation required the protection of water sources, protection and preservation of fauna and flora, and protection against all forms of pollution.

Olam Palm Gabon developed a management plan for their riparian reserves based on the recommendations of the HCV assessors, local stakeholders and reviewers of the relevant international best practice guidelines. The management objectives set out for the riparian reserves included (1) to enhance connectivity across oil palm plantations for the movement of terrestrial species, and (2) to preserve aquatic wildlife and ecosystem services like the maintenance of good water quality.

The Olam Palm Gabon's Agriculture Policy Manual outlined the minimum requirements for riparian reserve delineation and maintenance as follows:

Waterway	Width (m)	Buffer Zone (m)
Small streams	<5	10
Rivers	5-20	50
Big rivers	>20	100
Permanent lakes	>1000	50

The riparian reserve widths were increased in certain locations when recommended by the independent assessments, e.g. the riparian reserve width was increased to 300m for major rivers where the risks of extensive annual flooding were present, as such areas were unlikely to be suitable for oil palm cultivation.

Natural lakes (>1000m^2 surface area), streams and rivers were protected by riparian reserves measured from the limits of the natural flooding zones, with the annual high-water mark being the starting point for demarcating each riparian reserve. The aforesaid point was also identified by the HCV team and recorded in the GIS database, based both on field surveys and topographic maps of the area.

Small and isolated permanent ponds (<1000m^2 surface area to distinguish them from lakes) were used as water reservoirs for operational purposes. Soft vegetation had been left along the banks of these ponds to prevent soil erosion but they were not surrounded by forested riparian reserves. Sacred ponds or lakes of any size (HCV6), and larger ponds or lakes that may be used by animals and birds, were considered to be of high conservation value, and hence were protected by riparian reserves with signs indicating their location and conservation status.

In the case of highly drained soils, where some important streams were seasonal and reduced to a trickle or dried out completely after a month of low rains, Olam Palm Gabon decided to locate riparian reserves along such seasonal streams due to the high water flows in these drainage channels during the wet season, so that they could potentially transport large quantities of sediments and other pollutants into more permanent downstream waterways.

Mapping to determine riparian reserve location and extent

Riparian reserves requiring protection were determined as part of the HCV and EIA (Environmental Impact Assessment) processes, using field surveys, aerial photographs and LIDAR maps of high resolution aerial imaging for detailed information on topography and vegetation cover. The LIDAR maps provided additional information on the landscapes of the concession areas which could not be seen from satellite images due to the high levels of cloud cover, despite them being expensive and not a requirement.

Topographic maps can be used to indicate the locations of wetlands, particularly in the steeper areas. Olam Palm Gabon identified lands with depressions and slopes of 2° or less as wetlands in the first instance, which was followed up by on the ground surveys in key areas. Due to the complex arrangements of the permanent and seasonal wetlands (HCV3) across its concession areas, Olam Palm Gabon commissioned research to design a landscape 'wetness index', using a digital elevation model, which was constructed using LIDAR data and daily precipitation data to detect and classify permanent wetlands and areas which underwent seasonal flooding that might be unsuitable for planting oil palms. The aforesaid process of categorising wetland habitats based on topography, hydrology and field surveys is further elaborated in the "Common Guidance for the Management and Monitoring of High Conservation Values" available at www.hcvnetwork.org[43].

Across its concession areas, Olam Palm Gabon found that the adequate mapping of watercourses required a combination of both remote sensing and field mapping, with the latter being critical in flat terrains where topographic maps might y not be sensitive enough to identify large enough watercourses which required riparian reserves.

Marking boundaries to prevent the accidental clearance of riparian reserves.

Prior to the start of the land clearances, members of the Olam Palm Gabon HCV and GIS teams worked together to record and demarcate the required riparian reserves, whose locations were communicated to the general manager and contractors so that, wherever necessary, appropriate changes could be made to plans for land clearing.

The riparian reserve edges were marked with red paint on tree trunks with 1.6 metre tall posts ribbon tapes in the savannah areas.

Key challenges and lessons learned

Challenge	**Response**
Ensuring that the HCV teams had enough time to mark clearly the locations of riparian reserves across all areas.	Well trained teams and careful planning could overcome this challenge.
Ensuring that the clearance of riparian reserves for bridge constructions did not result in excessive sedimentation.	Bamboo was planted in some areas around the bridges to stabilise banks in response to the findings of the riparian reserve monitoring programmes.
Preventing riparian reserve areas being mistakenly cleared by subcontractors.	Olam Palm Gabon found it helpful for the HCV team to be present in areas of active land clearing to guide the machine operators when the need arose. Any incidents of non-compliance were recorded and reported to the RSPO manager and general manager. Warnings were issued to contractors and trees replanted with local and fast growing species.
Preventing damage to riparian reserves during the land conversion of adjacent areas.	Subcontractors were trained in the appropriate felling techniques in areas adjacent to the riparian reserves so that falling trees did not damage the riparian reserve during forest clearance.

Challenge	Response
Updating and communicating plans during the introduction of new contractors and changes in the land clearing schedules.	Olam Palm Gabon found it crucial to host regular meetings with its operations staff to ensure a strong line of communications so that everyone was kept up to date on the progress with, and of any changes in, the boundary demarcations.

Establishing a monitoring programme.

Due to the lack of specific guidelines on riparian reserve management in this geographical region, monitoring data was collected at the newly established oil palm plantations for its subsequent use to guide future decisions on the design of riparian reserves.

The Olam Palm Gabon's HCV team was responsible for marking, monitoring and maintaining the riparian reserve areas. The main focus of the early stages of the development of the oil palm plantations was on monitoring to ensure that all the wetlands and rivers were properly identified, and that all the riparian reserves were clearly and correctly marked and respected during land preparations. Water samples were also collected for water quality monitoring, with future monitoring including patrol-based wildlife monitoring across the riparian reserves and HCV areas.

4 Establishing riparian reserves in existing oil palm plantations or in new oil palm plantations on degraded lands

Key messages

In oil palm plantations where riparian reserves no longer contained sufficient natural vegetation, including in plantations where oil palms had been planted within the riparian reserve boundaries, the vegetation would need to be restored. There are two main approaches towards such riparian reserve restoration:

Leaving the area to regrow naturally. This might also involve undertaking activities to increase seedling regrowth, like removing weeds within 1m circles around each seedling. Such approaches would only be successful in areas where there were adequate supplies seeds nearby (e.g. forests), and/or where there were fruit-eating birds and mammals to disperse seeds within the riparian reserve restoration areas.

Planting trees, usually as seedlings of approx. 40-60cm tall. Riparian reserve replanting programmes should use native species occurring naturally in that geographical region. Tree species for riparian reserve replanting should be selected based on their ability to tolerate the site conditions, e.g. canopy cover, soil type, flooding pattern, and on their belonging to a diverse range of at least 10 species. However, exceptions could be made if the riparian reserve replanting sites contained heavily degraded soils, when only the use of a few disturbance-tolerant tree species might suffice. Tree seedlings could be purchased from nearby forestry departments, environmental NGOs, local communities trained in how to rear forest tree seedlings, or oil palm plantations with their own seedling nurseries. The tree seedlings should ideally be planted at distances of 3-5m, or even at higher densities than those at which oil palms are typically planted.

Key to the success of forest and riparian reserve restorations in tropical regions is the need to carry out regular weed removals from around the tree seedlings during the first 18-24 months, or longer, to combat otherwise high tree seedling mortality..

Notably, successful riparian reserve restoration programmes would invariably involve oil palm plantations working alongside key local stakeholders, including members of local communities, forestry and wildlife departments and environmental or social NGOs, during all the phases (i.e. planning, implementation and monitoring) of riparian reserve restoration.

Establishing new riparian reserves within existing oil palm plantations or in new oil palm plantations on degraded lands* will typically involve the following steps:

Identify which waterways require a riparian reserve (Sections 2.1 and 2.2)

↓

Clearly indicate the location of these reserves (on the ground and on relevant estate maps) (Sections 3.1 and 3.2)

↓

Assess the current status of reserve habitats (Section 4.1)

↓

Develop a management plan (Section 4.2)

↓

In reserves which contain (any) natural vegetation and wildlife:

Survey for threats so that these are identified and minimised to prevent further degradation (Section 5)

↓

In degraded reserve areas:

Design and implement a restoration programme (Section 4.3-4.8)

↓

Carry out regular monitoring to detect threats and to assess reserve status (Section 5)

↓

Review monitoring results and adjust practices in response to these results – adaptive management (Section 5.3)

*Degraded lands in this context meant lands where the vegetation cover, usually forests, had been reduced by humans, including of lands logged, burned and/or used for agriculture, livestock grazing and tree plantation, within the last 20 years.

To decide on where riparian reserves should be located, and on how wide they should be, see Sections 2.1 and 2.2, while Sections 3.1 and 3.2 describe how the location of riparian reserves could be mapped and marked out. The guidelines contained in the aforesaid sections are equally relevant to the mapping and demarcation of riparian reserves in existing oil palm plantations.

For waterways in degraded habitats where bank erosion and drainage channels were widening, the riparian reserves being restored should be wider than those of the minimum legal width. This would allow for changes in the positions of the drainage channels during times taken by the newly planted riparian reserve vegetation to become established. The additional drainage channel width requirement could be calculated by measuring the rate of river channel movement per year (e.g. by measuring from a fixed point to the edge of the river channel on a monthly basis) and multiplying this distance by the approximate time it would take for newly planted vegetation to become established, i.e. approximately 5 years from the seedling planting date in most cases.

For example, if the river bank was eroding at a rate of 0.2m every 6 months, and the newly planted tree seedlings took 5 years to form a closed canopy (assuming relatively fast-growing tree species were planted at a distance of 3-5m apart), the riparian reserve width could be determined as follows:

Minimum riparian reserve width	20m
River bank erosion rate 0.4m/year x 5 years	+ 2m
Total riparian reserve width	= 22m

In lowland rivers with particularly large bends in the river channels, there could be sudden and significant movements of river channels during flooding. Such large scale movements in drainage channel positions might be difficult to predict as they were unlikely to be picked up by measuring river bank erosions over the aforesaid short periods of time. The best way to minimise the loss of oil palm plantation lands from rapid river bank erosions along lowland drainage channels would be to designate wide riparian reserves along large rivers, particularly on the outer edges of the river bends.

4.1 ASSESSING RIPARIAN RESERVE HABITATS

The aim of a habitat assessment is to determine how close the existing riparian reserve was to the natural conditions that existed before the onset of human activities. However, in the case of oil palm plantations which had lost most of their natural habitats, it would be difficult to know what 'naturally occurring local vegetation' existed previously.

Reference sites

Ideally, existing riparian reserves should be compared to one or more of nearby riparian reserve 'reference sites' which had not been heavily logged or otherwise modified from their natural states. This would make it possible to identify which riparian reserve sites within an oil palm plantation were still in good condition and needed protection, versus which areas needed to be restored. If restoration was required, such riparian reserve reference sites would serve as targets or goals for the riparian reserve restoration efforts.

The riparian reserve reference sites should be, as far as possible, undisturbed riparian reserve habitats, e.g. within HCVs or other conservation areas. They should also be within the same local areas and with matching environmental conditions for their comparison with the oil palm plantation riparian reserves, e.g. with similar rainfall patterns, soil types and waterways of comparable sizes and slopes to those of the oil palm plantation waterways. Examining more than one oil palm reserve reference site (i.e. checking several locations along a waterway and/or visiting several conservation areas) would provide a more reliable picture of the natural riparian reserve conditions than merely relying on observations from a single reference site.

Key features of the vegetation, soil, wildlife and/or waterways found at particular reference sites could be compared with the same features in the oil palm plantation riparian reserves. Section 5, on "Monitoring riparian reserves & Responding to threats", describes methods to measure some important aspects of oil palm plantation riparian reserve vegetation and biodiversity, which could also be used for examining the riparian reserve reference sites. It is especially important to identify the naturally occurring plants and understand how they were distributed, i.e. which species were common/rare in the riparian reserve areas, which species were found next to, and which species were found further away from water courses. This could also mean consulting specialists (e.g. from forestry, wildlife and university departments, environmental NGOs and HCV assessors) who could identify the plant species at riparian reserve reference sites. However, local community members and/or oil palm plantation workers with sound knowledge of local plants could also help to identify the different plant species, besides providing information on where such plants tended to grow.

Measurements of habitat status must be repeated along the riparian reserves and waterways, with the number of measurements to be taken depending to some extent on the size and variability of the riparian reserve. A useful guide to follow would be to take at least 5-10 repeat observations along a riparian reserve, spaced at least 20 paces (or 20m) apart.

General characteristics of undisturbed forests.

In the absence of local expertise or riparian reserve reference sites which could be compared to oil palm plantation waterways, some straightforward habitat measurements could indicate whether the riparian reserves had 'typical' tropical forest characteristics. Such general habitat descriptions would apply to oil palm plantations where the pre-conversion habitats were tropical forests. However, this would not be always the case, as in some areas where the pre-conversion vegetation were more of open habitat types, like grasslands or freshwater swamps, that lacked extensive tree cover under natural conditions. For such habitat types, the riparian reserve management should aim to maintain, or restore, a diverse range of plant species, despite the previous canopy cover still naturally remaining low due to the lack of tree cover.

Tree canopy cover

In general, riparian reserve sites that were forested prior to their conversion would have had 'closed canopies'. If a riparian reserve still had a closed canopy, the minimum canopy cover at the centre of a riparian reserve would be at least 40% for trees that were >5m tall[44] or >2m tall at riparian reserve reference sites with mangrove forests.

The aforesaid definition would not include canopy cover formed by oil palm, rubber or other monoculture crops. Ideally, >70% canopy cover would be recommended as a target to minimise weed growth that could interfere with forest regeneration[45]. However, this was only an average value to be aimed for along riparian reserves, with gaps where the canopy cover could be more open than that occurring naturally in some other places.

High plant diversity and riparian vegetation structure.

Natural tropical forests are famous for housing a high diversity of plant species. Even when taxonomic experts were not available to assign scientific names to the different plant species, the presence of the different types of plants, primarily of trees, itself would be a positive indicator for intact riparian reserve habitats. Members of the local community, including oil palm plantation workers, who know the local names of the different plant species could help to estimate the variety of plant types present in the area. Natural riparian reserve vegetation should also contain plants varying in size and age, i.e. there should be both large and old trees and also small and young tree seedlings present within the riparian reserve. If the numbers of the different plant species, plant sizes and plant ages were very low, e.g. in riparian reserve areas planted with crops, the riparian reserve vegetation would not represent the natural conditions, thereby needing restoration.

4.2 Developing a Management Plan

Based on the results of the habitat assessments, management plans should be drawn up for:

1. Riparian reserves judged to be in good condition, which needed to be monitored and protected from potential threats (see Section 5); and
2. Riparian reserves no longer containing sufficient naturally occurring vegetation, which needed to be restored (see Sections 4.3-4.8).

Prioritising key restoration sites.

Restoring large areas of habitats, e.g. Multiple oil palm plantations along a river, would take time to be implemented, and it might take years before measurable environmental benefits were recorded. Further, the ultimate compliance goal of restoring natural vegetation and wildlife along all oil palm plantation waterways above certain sizes could well take several years to be achieved. Hence, for large-scale riparian reserve restoration projects and/or for projects with limited funding, e.g. for smallholders, it would be much more beneficial to identify and prioritise the key locations before starting the restoration work.

Priority areas for riparian reserve restoration are likely to be site specific. Discussions with RSPO assessors, environmental NGOs, local experts and local communities could help to determine the locally relevant priority sites for riparian reserve restoration. Such key areas would include the following:

- Areas providing important benefits for local communities, such as food (e.g. fisheries) and water (for drinking and bathing);
- Areas which were actively degrading, and which required more extensive restoration if the degradation continued (e.g. along river banks which were actively eroding);
- Areas adjacent to land use activities generating high levels of water pollution, which could be filtered by the restoration of riparian reserve vegetation (e.g. housing areas, tree nurseries, waterways draining water from steep slopes, replanting areas and patches of bare soils close to waterways);

- Areas extending and connecting existing intact wildlife habitats, such as those along waterways connecting two or more areas of forests (e.g. between forest reserves or existing riparian reserve habitats). Large forest fragments and forest fragments that had only recently become isolated from larger forest areas would contain more biodiversity than small forest fragments that had been isolated for decades. Hence , establishing riparian reserve vegetation reconnecting large and recently isolated forest fragments would usually be of higher conservation priority than those reconnecting smaller and older forest fragments; and
- Areas containing HCV species and areas connecting fragmented populations of HCV species.

The newly planted trees would take at least 3-5 years to develop a relatively closed canopy and start generating environmental benefits like soil protection. Thus, the restoration of degraded riparian reserve areas, particularly in areas dominated by bare soils, should, if at all possible, be started several years prior to activities like replanting which generate high levels of soil erosion.

Key information to be covered in riparian reserve restoration programmes would include the following [46]:

1. Objectives of the riparian reserve restoration programme. In most cases, this would simply state the need to restore riparian reserves complying with national or RSPO guidelines. However, in some cases, there may be additional objectives like the need to provide habitats for locally important wildlife species;
2. A statement of the expected benefits from the riparian reserve restoration programme, along with an agreement as to how such benefits would be shared amongst all stakeholders (e.g. would there be any local community use areas included within the restored riparian reserves?);
3. A description of the riparian reserve area to be restored, in relation to the existing layout of the oil palm plantation;
4. The methods that would be used for restoring the riparian reserve areas, including plans for maintaining and monitoring the areas after their riparian reserve restorations (see Section 5 for further information on "MONITORING RIPARIAN RESERVES & RESPONDING TO THREATS);
5. A task schedule detailing who would be responsible for each task and calculation of the labour required for completing each task; and
6. An estimated budget for the first 10 years of the riparian reserve restoration programme.

Involving local stakeholders in the management of riparian reserves

Successful riparian reserve restorations would frequently involve working with local communities to promote better understanding and support for the programme [47], [48]. Although it may not be necessary or appropriate to do it in all cases, RSPO strongly recommends that oil palm plantation managers always involve the key local stakeholders (primarily members of local communities, forestry and wildlife departments, environmental and social NGOs, etc.) in the planning, implementation and monitoring of riparian reserve restoration programmes. Such involvement of local communities in riparian reserve restorations could include employing people directly (to help in patrolling, growing seedlings for replanting, undertaking tree planting and site maintenance, etc., or to provide harvestable goods and non-timber forest products, like fruits, nuts, fibres, medicinal plants, etc., along the edges of the riparian reserves.

4.3 RESTORING RIPARIAN RESERVE HABITATS

Wherever possible, oil palm plantation managers are encouraged to discuss their riparian reserve restoration plans with local partners, e.g. Forestry and wildlife departments or environmental NGOs, to ensure that the relevant guidelines were applied in a manner appropriate to the local conditions, particularly in their helping with the selection and planting of appropriate tree species.

The key questions to be addressed in determining the best riparian reserve restoration methods to be adopted at a site would include:

(a) Could the area be left to regrow naturally, which strategies would involve activities enhancing natural regrowth, or would it need to be actively replanted?; and

(b) If the area needed to be replanted, what would be the best methods to be adopted?

The aforesaid riparian reserve restoration methods are not mutually exclusive, and hence oil palm plantation managers could opt to use a combination of methods within the same site and/or along the same waterway.

‡In areas of oil palm plantations where extensive areas of the understory had already been removed, it would be rather difficult to detect any signs of natural recovery. However, if the other indicators described in Table 4.1 suggested that natural regeneration could be a successful strategy, but there were only few signs of forest regrowth, it would be more appropriate to wait 6 months without any understory clearance to determine whether or not seeds or seedlings would arrive naturally or if they would need to be replanted.

Table 4.1 Restoration of degraded riparian reserve habitats could involve the enhancing of natural regeneration and/or the active replanting of seeds or seedlings. The suitability of each approach would depend on the initial conditions at the site, and also on the timescale/resources available for the riparian reserve restoration[47, 49, and 50].

Natural vegetation cover	High	Low	*Indicators:* Presence of forest regrowth (i.e. tree seedlings or sprouting tree stumps) within the riparian reserve area; Number of forest trees within the riparian reserve (6-10 seed producing trees per hectare of the riparian reserve is a good indicator that natural regeneration would be successful)[44]; Other areas of natural forests (e.g. HCV areas, forest reserves) within a few km (ideally within 100m) of the riparian reserve restoration site(s).
Seed dispersers	Present	Absent	*Indicators:* Frugivorous (fruit-eating) birds and mammals within the riparian reserve area (see Section 4.3.1 for details); Perches (e.g. trees) and canopy connectivity to encourage birds and mammals into the riparian reserve area; and Natural forests alongside waterways which connect to the riparian reserve restoration site (for seeds to be dispersed by water movement).
Soil disturbance	Low	High	*Indicators:* Time since forest conversion in years (low disturbance) vs. multiple decades (high disturbance); Single planting cycle (low disturbance) vs. multiple planting cycles (high disturbance); Terracing (high disturbances); and Level of ongoing soil erosion (indicated by areas of bare soil within a riparian reserve).
Timescale for vegetation recovery	Slow	Medium-Rapid	
Resources available	Low	Medium-High	Financial resources and/or labour available to carry out restoration.

Recommended riparian restoration strategy:
(Assisted) Natural Regeneration

Recommended riparian restoration strategy:
Replanting

4.3.1 NATURAL REGENERATION AND ASSISTED OR ACCELERATED NATURAL REGENERATION OF RIPARIAN RESERVE VEGETATION

The simplest and cheapest way of restoring riparian reserve vegetation would be protecting sites from further damage and leaving the natural vegetation to regrow from seeds/seedlings already in the soils or from seeds that arrived from nearby areas of forests, through a process called 'natural regeneration'.

Natural regrowth of riparian reserve vegetation could be enhanced by increasing seed dispersal and seedling survival by 'assisted or accelerated natural regeneration' (ANR). Such commonly adopted methods include providing perching sites for seed dispersers, like birds, and removing weeds around naturally occurring seedlings (see Section 4.5.3 on "WEED CLEARANCE").

As outlined in Table 4.1, natural regeneration of riparian reserve vegetation would most likely succeed if some forest regrowth was already occurring before the restoration. However, assessing such regrowth potential would be difficult in areas under oil palm cultivation where the understory had been recently removed.

As a general rule, natural seedlings (i.e. small trees >15cm in height, where all seedlings clumped together within $1m^2$ were counted as a single seedling) at a density of 200-800 seedlings/hectare or more should be able to regrow naturally or with assistance to form forests. A minimum of 700 seedlings/hectare should be expected to generate a closed forest canopy within 3 years[47]. It is recommend that if fewer than 200 naturally growing seedlings were found per ha (i.e. 2 seedlings per $100m^2$), then supplementary trees should be planted[51].

Other characteristics indicating that natural regeneration was likely to be a successful strategy for riparian reserve restoration include the following:

1. Presence of seed sources (i.e. HCVs or other forest reserves) within 1km, ideally within 100m, of the riparian reserve restoration site[52, 53]. Forests located beyond 100m could also provide seeds for the riparian reserve restoration site, but the process would probably be very slow;
2. Presence of reproductively mature trees, large enough to produce fruits and seeds, within the riparian reserve; and
3. Presence of animals for transporting seeds from intact forests into the riparian reserve.

Animals responsible for dispersing tree seeds tend to vary between locations, but they would typically include fruit-eating birds, fruit bats, primates such as monkeys and orangutans, deer, wild pigs and agouti in South America[47]. To disperse seeds into riparian reserve restoration sites, the animals would need to be able to move between forested and non-forested areas. Birds such as bulbuls, pigeons, hornbills, toucans, fruit doves, fruit crows and jays are particularly important for seed dispersals[47].

Limitations of the approach

Natural regeneration and assisted natural regeneration are simple and relatively low investment riparian restoration strategies, but they would only be effective if supplies of native seeds were present in the local area, and also if conditions within the riparian reserve were suitable for the seeds to grow.

Hence, attempts to restore riparian reserve habitats by natural regeneration should be monitored regularly to assess if the tree seedlings were growing properly in the riparian reserves. If the restoration of the riparian reserve did not begin to occur within a pre-determined length of time (e.g. 6 months - 1 year) of attempting natural restoration, the site should be replanted.

Even in areas where natural regeneration successfully established forested riparian reserves, the full range of plant species that were originally present would not regrow without nearby seed sources. As such, natural regeneration should be followed up by the replanting of some of the original tree species which did not arrive naturally. More so, as plants are likely to require active replanting unless there were seed sources very close to the riparian restoration sites, including species with large fruits or seeds, species which fruit infrequently (e.g. Dipterocarps) and species which were rare[54].

4.3.2 Replanting

The replanting of riparian reserves would include the following steps:

(1) Selecting native plant species which were able to grow at the riparian reserve restoration sites, and which were, as far as possible, selected to match the original riparian reserve vegetation that would have occurred naturally at those sites (see Section 4.3.3);
(2) Acquiring plant seedlings or seeds (see Section 4.4);

(3) Site preparation, including the appropriate management of the oil palms already planted within riparian reserves (see Section 4.5);
(4) Planting (see Section 4.6); and
(5) Maintaining newly planted seedlings (see Section 4.7). The costs of maintaining the newly replanted areas would often be significantly higher than the initial costs of planting the trees. However, the aforesaid final stage of the riparian reserve restoration process could be key in determining the very success or failure of the programme itself. Hence, the logistics (e.g. staff time) and costs of maintaining the newly planted seedlings must be committed from the start of the riparian reserve restoration programme for ensuring its long-term success.

4.3.3 Selecting species for replanting

The aim of most riparian reserve restoration programmes would be to establish an area of natural vegetation (and wildlife) along oil palm plantation waterways. The extent to which the natural vegetation was restored would depend on the species selected for the replanting, which would be influenced by the following factors:

(1) What the natural riparian reserve vegetation should be, based on discussions with local experts and local communities, examining nearby riparian reference sites, etc.;
(2) Suitability of the current riparian reserve site conditions for native plant species to grow when planted; and
(3) Which plants were locally available for the replanting, from seedling nurseries or by collecting seeds and seedlings from nearby forest fragments.

Selecting natural riparian reserve species.

Riparian reserve replanting programmes should use native species which grow naturally in that region and in the riparian reserve areas. The planting of non-native species is strongly discouraged as they could out-compete the native plants and could also spread into the neighbouring oil palm cultivation areas, potentially resulting in costly removals at later stages[55].

An exception to the planting of only native plant species might be necessary if the riparian reserve site was so badly degraded that even the hardy native plants were unable to grow (e.g. if there had been complete removal of topsoil at a quarry or mining site). In such cases, it might be necessary to plant non-native 'nurse crops' to restore the soil before its under-planting with a selection of native species of plants.

Local forestry departments, environmental NGOs and other groups involved in habitat restoration and/or tree planting would be able to give the best advice on which species of plants could grow well in a particular area. As this RSPO manual is intended primarily for use by oil palm plantation managers in multiple tropical regions, lists of which tree species 'should' be planted during riparian reserve restoration have not been provided, as that would vary between and even within tropical regions. Nevertheless, as the habitat preferences of the different tree species are better known in some places than in others, some useful sources of information on the selection of species in different tropical regions have been recommended below (see Table 4.2).

Table 4.2 Recommended information sources for helping the selection of species for replanting in riparian reserves.

Information source	Description	Region / Language
Tropical Native Species Reforestation Information Clearinghouse (http://reforestation.elti.org/)[56]	A website summarising information and case studies from multiple tropical reforestation programmes around the world, searchable by forest types (e.g. riparian reserve) and country/region.	Global/ English, Spanish and Portuguese.
Plants of Southeast Asia (http://www.asianplant.net)[57]	An overview of the appearances and habitat requirements of over 1,000 species of SE Asian plants.	SE Asia/ English.
RSPO Manual on Best Management Practices (BMPs) for Management and Rehabilitation of Natural Vegetation Associated with Oil Palm Cultivation on Peat[28]	A guidance manual on the management of oil palm plantations on peat soils or in areas adjacent to peat swamp forests. Chapter 4 covers the rehabilitation of peat swamp forests at degraded sites,	Malaysia and Indonesia/ English.

Information source	Description	Region / Language
	including species suggested for replanting.	
Malaysian Ministry of Natural Resources and the Environment (2009) "Managing biodiversity in the riparian zone"[58]	The manual is available online and it includes a list of species suitable for riparian reserve replanting across Malaysia.	Malaysia/ English.
HUTAN Reforestation Efforts in Kinabatangan, 2010[59]	The report is available online and it describes riparian reserve tree planting at the Kinabatangan River of Life project in Sabah, Malaysia. It includes a list of the 22 species planted and monitored to determine their growth rates, suitable soil conditions and provision of food for orangutans.	Sabah (but also relevant to other states in the Borneo region)/ English.
Guidelines for tree planting in Cambodia[60] http://www.treeseedfa.org/guidelines_site_eng.htm http://www.treeseedfa.org/guidelines_site_kh.htm	A website on guidelines for site selection and tree planting in Cambodia.	Cambodia/ English and Khmer.
Matas ciliares: conservação e recuperação, Rodrigues, R. R. *et al.* (2000)[61]	A book on riparian reserve conservation and restoration in Brazil.	Brazil/ Portuguese
Trees of Brazil (http://www.arvoresbrasil.com.br)	A website that includes a searchable database of riparian reserve species.	Brazil/ Portuguese

Information source	Description	Region / Language
Recomposição Florestal de Matas Ciliares [Riparian reserve restoration in Brazil] 3rd Edition, 2007[62]	The book available free online.	Brazil/ Portuguese
The Forest Rainforest Research Unit at Chiang Mai University, Thailand (FORRU-CMU)[49] (http://www.forru.org/)	A website describing a range of practical forest restoration techniques. It also provides guidance on forest restoration, including that relevant to riparian reserve restoration, with a focus on case studies from Thailand. The forest restoration manuals are available in English, Thai and Indonesian. Additional forest restoration guidance manuals are available in other languages, like Chinese, Lao, Khmer and Vietnamese, by contacting the manual authors via the website.	Global (particularly Thailand)/ English and Thai. Downloadable in English, Thai and Indonesian. Forest restoration manuals request able in Chinese, Lao, Khmer and Vietnamese.
ITTO "Guidelines for the restoration, management and rehabilitation of degraded and secondary tropical forests" (2002)[63]	The book is available online, and Table 9 outlines promising species for use in framework or nurse planting across the tropics.	Global/ English.

In places with little local knowledge or published information on the best tree species to be planted in riparian reserves, it might be necessary to establish a series of test sites where different combinations of tree seedlings were planted under different conditions (e.g. close to the water vs. far from the water and high canopy cover vs. low canopy cover). Monitoring the survival and growth of the different tree species for a year would reveal which species could be planted more extensively across a riparian reserve restoration site to ensure the most efficient use of the available resources.

Assessing whether current riparian reserve conditions are suitable for native plants.

The suitability of a riparian reserve for particular plant species would depend primarily on the following factors:

Canopy cover
Some seedlings grow well at open sites, while other species grow better under the shade. Hence, species for riparian reserve replanting should be selected based on their tolerances for the light levels at the riparian reserve restoration sites. The amount of canopy cover could be modified to suit the seedlings available for the riparian reserve replanting, e.g. by cutting back the overhanging oil palm fronds or by arranging the oil palm fronds around newly planted seedlings to increase shading (see Figure 4.1). However, as reducing canopy cover to increase seedling growth could also increase weed growth, the optimal level of canopy cover might be partial shade.
Flooding extent and duration
If flooding was common and long-lasting, e.g. along lowland rivers, lakes and swamps, then species for riparian reserve replanting must be selected based on their ability to tolerate the typical depth and duration of flooding in that area. If flooding was infrequent and the waters fell quickly, then typical forest species could be replanted, i.e. species not necessarily found to be growing along the river banks [64].
Soil fertility and structure
Only a few tree species would be able to grow on highly compacted soils, e.g. along dirt roads and tractor trails, or where the topsoil had been lost due to erosion or on specialised soil types like peat soils. Low quality soils could be improved by planting 'nurse trees' or by applying soil mulch to the soil surface. Many forest seedlings (e.g. Dipterocarps) also require specialised soil fungi (e.g. mycorrhizae) to grow. It would therefore be helpful to add a small amount of forest topsoil, preferably from underneath a 'mother tree' of the same species, to the soil of the nursery seedlings to expose their roots to beneficial soil microbes[65].

Presence of natural forests and seed-dispersing wildlife within several km of the riparian reserve restoration site
If seed sources, like natural forests and seed dispersing animals, were still present at the riparian reserve restoration sites, then some of the species selected for replanting should be trees or shrubs that grew rapidly and produced flowers, fruits or other resources, like bird nesting sites, to attract seed-dispersing wildlife into the riparian reserve restoration areas. The aim of riparian reserve restoration is to plant trees that attracted animals carrying seeds from outside the riparian reserves to increase the amount of natural regrowth occurring alongside the planted seedlings. Such a strategy is sometimes called 'framework replanting', and two widespread tree groups commonly used for framework replanting are fig trees (*Ficus* spp.) and legumes (Leguminosae). However, any locally available or native trees which produced nectar or fruits attractive to wildlife, particularly birds and bats that could travel from forest fragments located some distance away, should help in enhancing seedling regeneration by attracting seed dispersers into riparian reserve restoration areas. For sites with only a few seed-dispersing animals and/or without nearby forests to supply seeds for the riparian reserve restoration areas, full 'maximum diversity' replanting would be needed to restore as many as possible of the original tree species without relying on natural seed dispersals.

Figure 4.1 in open and unshaded riparian reserve replanting areas, oil palm fronds could be used to shade newly planted tree seedlings, since the palm fronds would gradually decompose to expose the seedlings underneath to increasing levels of sunlight. Photos: H. Barlow.

Restoring degraded soils using 'nurse trees'.

In riparian reserves with large areas of bare soils without any vegetation, or in areas which burned regularly (e.g. *Imperator* grasslands and peat soils), it might not be possible for most tree species to grow, even if they were planted and maintained correctly. In such situations, fast growing species (e.g. legumes and/or disturbance-tolerant trees) could be planted as 'nurse trees' to prepare the areas by restoring soil fertility and providing shady or humid environments, where other more sensitive trees could be subsequently planted.

Suitable 'nurse tree' species include *Macaranga* spp. in Malaysia and Indonesia (which are fast-growing and disturbance-tolerant), local species of *Ficus* spp (which are fast-growing, very disturbance-tolerant and beneficial for wildlife), and members of the Leguminosae family (which are nitrogen-fixers) [47]. Examples of disturbance-tolerant nitrogen-fixers from SE Asia include

Parkia speciosa, *P. roxburghii* and *Koompassia* spp[66]. Care should be taken in the selection of nurse plants to avoid exotic and aggressive species, like Acacia spp., which could spread to other areas of the oil palm plantation, as described in the information available online for particularly aggressive exotic species.

Once the suitable soil conditions had been established by the nurse trees, additional species should be planted to restore a much more natural range of plants, which would not only be beneficial for wildlife, but would also, due to its more diverse range of plants, be much more resilient and require far less maintenance in the long-term.

Figure 4.2 (adapted from a report by ZSL[41]) is designed to simplify decisions on which riparian reserve restoration techniques might be appropriate for use at a particular site, and therefore also for which types of trees should be selected if replanting was required.

How many species to plant.

In general, the planting of a range of species would be better than the planting of only a few species, with ideally at least 10 species, but preferably 20-30 or more species, for proper riparian reserve replanting.

Planting a range of native species would help to buffer against the poor survival rates of some species, while a diverse riparian reserve zone would be more attractive to wildlife and also show faster rates of carbon sequestration. The number of species to be planted would depend on the size of the riparian reserve restoration site and the availability of the different types of seeds and seedlings.

In practice, the selection of species for riparian reserve replanting would depend heavily on which species were available for purchase from local nurseries and/or the feasibility of establishing on-site seedling nurseries.

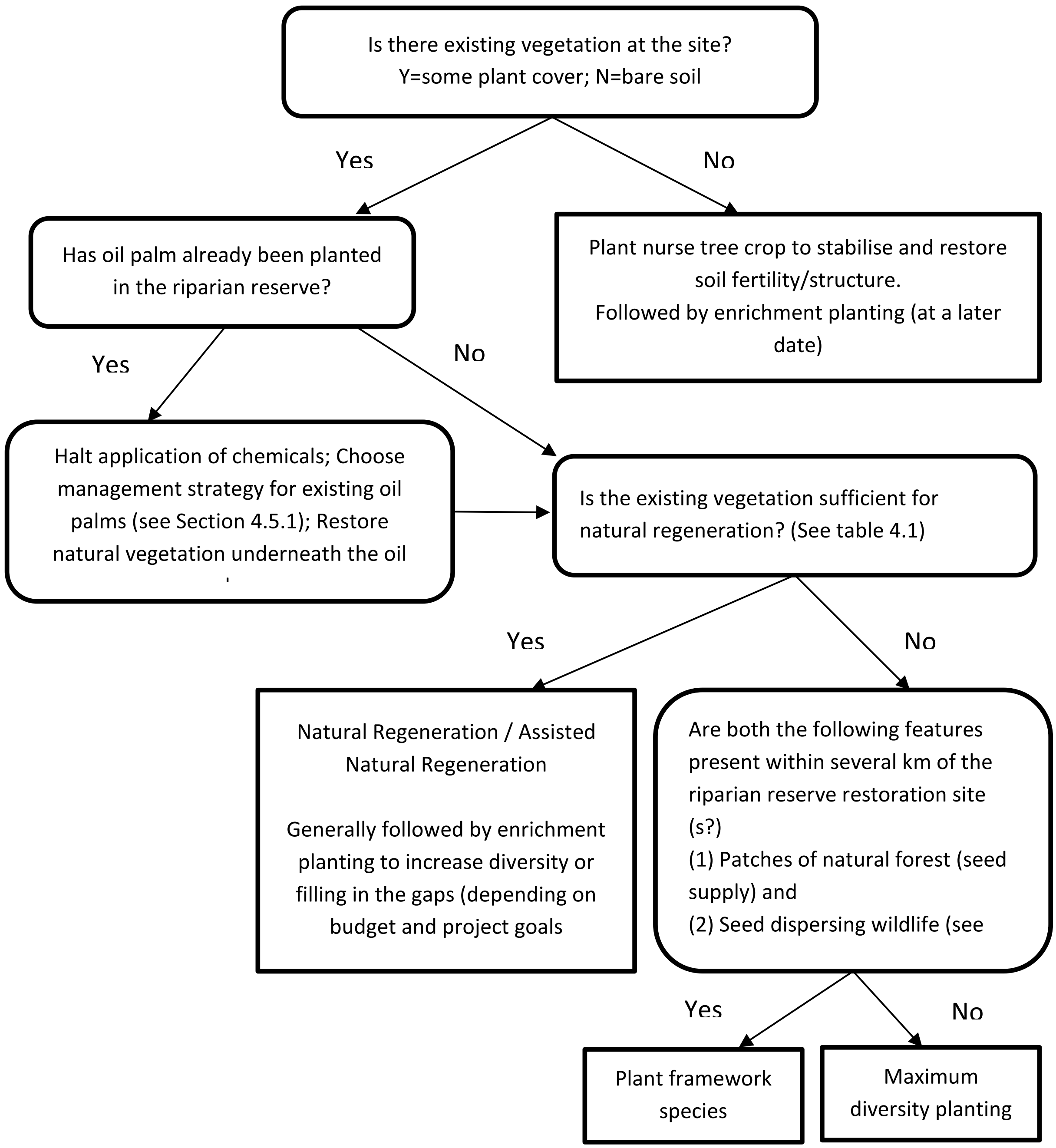

Figure 4.2 – How to choose a restoration strategy for degraded riparian reserve habitats.

4.4 Acquiring seedlings for riparian reserve replanting

4.4.1 Planting densities

The suggested planting distances between seedlings at riparian reserves are 3-5m. Higher planting densities of 1.8m between seedlings might be appropriate for sites where weed growth and/or fire outbreaks were major barriers to seedling regeneration, or where a closed canopy would develop rapidly to shade out most of the understory plants. Hence, shade cover could also serve as the most cost-effective and environment friendly herbicide'[47]. Lower planting densities of 10m x 10m might be appropriate at sites with some existing shade cover and/or some natural regeneration. Higher planting densities would cost more in the short-term (as more seedlings would be required and the costs of labour and transport would be higher), but could reduce costs in the long-term by reducing the length of time before regular weed removal was needed.

Planting trees in lines would be generally better than planting trees in clusters for riparian reserve restoration since the key priority was to establish a connected stretch of natural vegetation along the waterways.

For typical riparian reserve planting densities, the number of seedlings required for replanting each hectare of riparian reserve would be:

- 1.8m x 1.8m planting lines – 3,086 seedlings/hectare;
- 3 x 3m planting lines – 1,111 seedlings/hectare;
- 3 x 5m planting lines – 666 seedlings/hectare; and
- 5 x 5m planting lines – 400 seedlings/hectare.

The tree species should be planted in mixtures, rather than in blocks of one species at a time, in order to recreate the mixture of species found in natural riparian forests.

The involvement of local communities (e.g. school children, community leaders, local politicians and environmental NGOs) in tree planting could help to reduce some of the man power required for the seedling planting, besides providing an excellent avenue for increasing awareness of the location and aims of riparian reserve restoration programmes within the wider community[26].

4.4.2 When to carry out riparian reserve replanting

The planting of tree seedlings in riparian reserves is best carried out during the rainy season. Approximately one month into the rainy season is ideal because there would be sufficient soil water to support the survival of early seedlings. However, the timing might need to be altered alongside waterways prone to flooding and/or for large-scale oil palm planting operations which needed to be continued for much of the year.

Figure 4.3 Local community tree planting by students at the Musim Mas Sorek Estate in Riau, Indonesia. Photo: Musim Mas.

4.4.3 Seedling supplies

The main options for acquiring trees for riparian reserve replanting are:

- Purchasing seedlings from outside oil palm plantations.
  Seedlings could be bought from local tree nurseries maintained by forestry departments, environmental NGOs, other replanting projects or local communities growing their own trees.

- Growing one's own seedlings from seeds.

Seedlings could be grown from seeds collected from nearby forested areas, plants grown by local communities or plants cultivated in nurseries and subsequently planted at the riparian reserve restoration sites.

- Growing one's own seedlings from wild seedlings or 'wildlings'.
  Seedlings could be left to germinate underneath mother trees in nearby forested areas and then collected and cultivated in nurseries before being planted at the riparian reserve restoration sites.

- Growing one's own seedlings from cuttings.
  Seedlings could be generated by taking stem cuttings from suitable parent trees, applying hormone treatments to encourage rooting, and planting the cuttings into soil bags in nurseries before planting the cuttings at riparian reserve restoration sites.

- Planting seeds directly in riparian reserve restoration areas, without rearing them through the seedling stage.

Seedlings should be planted at riparian reserve restoration sites when they were approximately 30-60cm tall, with 20cm being tall enough for seedlings of fast-growing species like *Ficus* spp[47]. As smaller seedlings tend to be more vulnerable to competition from weeds, weedy sites would benefit from the planting of taller seedlings. Saplings >1m tall might survive better in riparian reserve restoration sites prone to heavy and/or prolonged flooding[58] , or in areas with tall grasses like *Imperata*. Taller seedlings would not only be more difficult and expensive to transport, but would also be more likely to die from 'transplantation shock' caused by sudden changes in the conditions between the nurseries and the riparian reserve restoration sites. The aforesaid challenge could however be minimised by trimming the leaves of the seedlings by about 50-75% immediately before planting to reduce water loss through the leaves[58].

Table 4.3 the main pros and cons of the different methods of seedling acquisition as indicated at reforestation.elti.org for riparian reserve restoration programmes in various regions. Additional information on 'How to' grow your own seedlings and collect your own seeds for direct seeding is described in Appendix 4.

Source	Advantages	Disadvantages	Further information
Purchasing seedlings from outside oil palm plantations.	No need for rearing seedlings on-site, which would require some level of expertise and nursery space or resources. Seedlings are immediately available for replanting, without the need for seed collection, germination and rearing before starting riparian reserve restoration... Seedling suppliers could provide practical guidance on planting procedures and species selection for particular areas.	Depending on the availability of suitable species for sale in the local areas, growing one's own seedlings could provide a wider selection of species for replanting. For large-scale riparian reserve restoration, it might be cheaper in the long-term to grow one's own seedlings. Transportation costs incurred, based on the distance between the riparian reserve replanting sites and the nearest seedling nurseries.	Contact local forestry department or environmental NGOs involved in habitat restoration.
Growing one's own seedlings from seeds.	Opportunity for selecting locally adapted tree species by, for example, collecting seeds from nearby riparian reserve sites.	Time consuming, as the time between seed collection and the planting of seedlings would be longer than that for wildling collection or growing from cuttings. The time delay could harm riparian reserve restoration efforts at sites with ongoing degradation.	"Restoring Tropical Forests: a practical guide"[47] , Chapter 6, "Grow your own trees" , describes how to grow tropical trees from seeds in some detail, including *Ficus*

Source	Advantages	Disadvantages	Further information
	Seeds could be grown in large numbers for use in riparian reserve restorations.	Requires space within a nursery. However, an alternative approach would be working with local communities who can grow the seedlings until they are ready for planting. Conditions for seed germination might not be known, particularly for non-commercial species. Inability to provide a continuous supply of seedlings for riparian reserve replanting as: - some trees only produce seeds every few years; and - Many tropical seeds are difficult to be stored for riparian reserve replanting in their non-fruiting years.	spp. (p170), a useful tree for attracting seed-dispersing animals. ZSL[41,] (p45-52), describes several Indonesian projects which have grown seedlings from seeds for replanting in oil palm habitats. See Appendix 4 for general guidance.
Growing one's own seedlings from wild seedlings or 'wildlings'.	Opportunity for selecting locally adapted tree species by, for example, collecting seedlings from nearby riparian reserve sites. Seedlings are ready to be planted much more quickly than growing them from seeds. Seedling supply would be less variable over time than seed abundance.	Dependent on the presence of nearby forest fragments for seedling collection. Requires nursery space, although for a shorter time period than for growing trees from seeds. For largescale riparian reserve replanting schemes, the supply of wild seedlings would not only be insufficient[67], but would also vary between years, although less than seed abundance[47].	"Restoring Tropical Forests: a practical guide"[47], (p174-175), describes wildling collection and recommended conditions for rearing the seedlings through to replanting. See Appendix 4 for general guidance.

Source	Advantages	Disadvantages	Further information
	No need to understand how to germinate the seeds of different species as it would occur naturally. Survival rates could be higher than those of rearing seedlings from seeds, as the non-viable seeds would die before collection.	The impact of wildling collection on natural forest regeneration is not well understood but must be carefully considered. Some control is needed to ensure that sufficient natural seedlings were left behind to maintain natural forest habitats.	
Growing one's own seedlings from cuttings.	Does not rely on natural seed production, and so could supply seedlings for riparian reserve restoration even at times when natural seeds and wildlings were are in short supply. Opportunity for selecting locally adapted tree species by, for example, collecting cuttings from trees in nearby riparian reserve sites. Seedlings would be ready for planting more quickly than growing them from seeds. Might be a suitable for growing rare species whose seeds are difficult to find or germinate[47].	Producing many seedlings by vegetative propagation from a few parent trees would lead to low genetic diversity, since there would be no pollination to increase genetic variability, thereby rendering the riparian reserve restoration areas much more susceptible to pests and diseases. Might require experimentation to determine the best methods of propagating the different species.	Forestry departments are likely to be a useful source of information about vegetative propagation of local species. "Restoring Tropical Forests: a practical guide"[47], (p178-179). "Guidelines to propagate dipterocarp species by stem cuttings", by the Forestry Department of Peninsular Malaysia[68]. See Appendix 4 for general guidance.

Source	Advantages	Disadvantages	Further information
Seeding directly.	No need to rear seedlings on-site, which would require some level of expertise and nursery space or resources. Seeds easily transported to riparian reserve restoration sites, when compared to transporting seedlings in heavy soil bags.	Survival rates are usually much lower than those of planting seedlings: - requires large quantities of seeds; - only some species produce enough seeds for direct planting; and - Seed availability is irregular for some tropical plants. Variable seed survival along a riparian reserve could lead to patchy tree cover. Direct seeding is unlikely to be suitable in areas which flood regularly.	"Ecological restoration", by David Lamb[54]. See Appendix 4 for general guidance.

4.5 RIPARIAN RESERVE SITE PREPARATION

4.5.1 MANAGING AREAS PLANTED WITH OIL PALMS

Once the area to be restored as a riparian reserve had been demarcated clearly, the application of chemicals, like pesticides and fertilisers, should be halted across the riparian reserve, except when required for establishing tree seedlings.

The planting of oil palms inside riparian reserves would not be compliant with the RSPO P&C for certification, but in cases where the aforesaid had happened historically, the existing oil palms must be dealt with accordingly. Hence, Section 4.5.1 covers the main issues involved in dealing with areas already planted with oil palms.

Leaving oil palms in situ during riparian reserve restoration.

Advantages:

- The microclimate (e.g. temperature, humidity and light levels) under mature oil palms would be closer to the microclimate of forests than of cleared areas. As standing oil palms provided shade, shade-tolerant forest tree species could be planted so that the shade provided by the oil palms could also reduce the growth of understory weeds, which would otherwise outcompete the newly planted seedlings.
- Standing oil palms would help to maintain soil structure and hence their clearance could lead to soil erosion, depending on the soil type and slope.
- Standing oil palms would also help to indicate ownership and management of an oil palm plantation, thereby reducing encroachment.
- Unmanaged oil palms could provide habitats for plants and animals which support natural regeneration by, for example, providing bird perching sites and attracting fruit eating birds and mammals which disperse seeds.

Disadvantages:

- It might be difficult to persuade oil palm plantation workers to stop applying business as usual practices in areas with fruiting oil palms, including the continued application of pesticides and fertilisers which should be halted during riparian reserve restoration.
- There is anecdotal evidence to indicate that leaving oil palms in situ, while stopping harvests, might encourage individuals from outside oil palm plantations, who regard the unharvested fruits as economic opportunities, to move into the riparian reserves and establish human settlements.

- Unmanaged oil palms could become sites for pest populations to grow and spread into neighbouring oil palm plantation areas.
- As the oil palms would eventually die and drop their fronds and trunks, they could subsequently cause damage to the trees planted underneath them.

Harvesting oil palms during riparian reserve restoration.

If oil palms were left standing within riparian reserves during restoration, oil palm plantation managers must decide whether or not to continue harvesting the oil palms.

In some oil palm plantations, the halting of the application of fertilisers and pesticides within riparian reserves reduced oil palm yields to the extent that after several months it was no longer economical to continue harvesting the oil palms. However, the aforesaid phenomenon had not been reported to be always the case.

The continued harvesting of oil palms has economic advantages and could also help to limit pest populations and discourage the encroachment of people from outside the oil palm plantations. However, the continued harvesting of oil palms could reduce the survival of young tree seedlings (e.g. due to path cutting, harvesting circles and falling fruit bunches), and thereby slow down the progress of riparian reserve restoration, which could result in additional costs for replacing the dead or damaged seedlings.

Intermediate strategies for dealing with existing oil palms could help to minimise the trade-offs between the different approaches. For instance, the poisoning of oil palms, so that they remained standing but no longer produced fruits, or the pruning of oil palm fronds to leave behind only the central fronds, are good alternatives for allowing more light into the understory without disturbing the soil, which would also promote natural seedling regeneration[26].

The best strategies for managing existing oil palms are likely to vary between different locations and between different oil palm ages. Anecdotally, riparian reserve vegetation could regrow under mature oil palms which were poisoned by trunk injection, or left in situ without harvesting. In areas of young (<5 years) oil palms, where the soils were already disturbed and where there was little benefit to leaving the oil palms in situ, it would usually be better to remove the oil palms (which could be planted elsewhere) prior to riparian reserve restoration.

Whatever be the decision, it would be important to monitor the success of the riparian reserve restoration at the site level, and to adapt the management practices as the programme progressed. If the harvesting of the oil palms was to continue during the riparian reserve restoration programme, there must be a clear end date stated in its management plan.

Once a piece of land had been designated as a riparian reserve, the successful restoration of its intact riparian habitats must remain as the primary management objective for that area in order to comply with the RSPO Principles and Criteria.

4.5.2 Soil amelioration

At riparian reserve sites with heavily degraded or compacted soils (e.g. areas along dirt roads, areas with large areas of ongoing soil erosion, ex-mining areas or areas underneath logging platforms) it might be necessary to restore the topsoil before seedlings could be replanted.

Soil conditions could be improved by planting fast-growing and possibly nitrogen-fixing 'nurse trees' (see Section 4.3.3 on "Selecting species for replanting"). Once the surface layer of the soil was stabilised, a layer of leaf litter had formed on the ground and the nurse trees had started to form a canopy, additional native forest species could be planted. The nurse trees could be eventually removed or thinned back to allow for other species to grow while taking care not to harm the understory plants and the topsoil underneath.

Alternatively, or besides nurse tree planting, mulch could be applied to the soil surface to restore nutrients, beneficial microbes and moisture to the soil before and/or after the seedlings had been planted. Ideally, such mulch could be comprised of locally produced compost, like grass cuttings (see Figures 4.4-4.7) or empty fruit bunches (EFBs), with the composted EFBs thought to be better for purposes of soil mulching when compared to applying EFBs directly after harvesting.

Notably, the mulch should be renewed approximately 2-3 times a year and continued until the canopy shaded over it, when the mulching would be replaced by natural leaf fall.

Mulching should be used with caution in areas and at times of the year when fires could occur, as the mulch would make it easier for the fires to spread into the riparian reserve restoration areas.

For riparian reserve restoration sites with highly compacted soils (e.g. soils underneath old logging platforms or logging roads), some oil palm companies have used good quality topsoil from elsewhere to fill in the oil palm planting holes (see Section 4.7 on "Planting").

Figure 4.4 Compost pile of weed cuttings ready for application to the soil surface and around newly planted seedlings. Photo: H. Barlow.

Figure 4.5 the mulch should be arranged around the tree seedlings in a circle to cover the weeding circle to a depth of about 6” or 15cm, but leaving an inner gap round the stems of about 3” or 7cm in diameter to minimise the risk of fungus attack which could occur if the mulch touched the stems. Photo: H. Barlow.

Figure 4.6 Applying mulch to the soil helps to provide moisture, nutrients and beneficial microbes to the soil. Mulching also helps to reduce weed growth around newly planted seedlings by preventing sunlight from reaching the soil surface to trigger weed germination. Mulching is particularly beneficial for newly planted tree seedlings, but it could also be continued until the canopy shaded over, when the mulching was replaced by natural leaf fall. Mulching might be inappropriate for sites prone to fires, especially during the dry season. Photo: H. Barlow.

Figure 4.7 Corrugated cardboards could be used as mulching material to improve soil quality and suppress weed growth around tree seedlings. Similar procedures could also be applied for other types of mulching, where 5cm gaps were left around seedling stems to ensure that the edges of the cardboards did not touch the seedling stems and lead to infection. Photo: HUTAN.

4.5.3 Weed clearance

Prior to weeding, existing tree seedlings (>15cm tall) should be located and marked clearly, with coloured bamboo canes or a similar indicators, so that they could be easily spotted to avoid accidental trampling or cutting.

Weeds in riparian reserve replanting areas could be cleared by the following methods:

(a) Cutting, using machetes or grass trimmers, taking due care not to damage any naturally occurring seedlings;
(b) Removing weeds completely at their roots, which was not only labour-intensive but could also result in soil erosion;
(c) In areas where weeds regrew rapidly, the initial clearing of weeds should be followed up by the application of broad-scale herbicides, like glyphosate, to the regenerating weed shoots approximately 2 weeks before planting. This method of weed control should be used only in areas where the regrowth of cut-back weeds was rapid and would cause significant mortality of the newly planted seedlings, to the extent that the riparian reserve

restoration success was likely to be compromised without the application of one-off herbicides to 'knock back' weed growth before planting. The standard BMPs for weed control should be followed with such herbicide application, which should be a one-off operation, not to be repeated for the regular maintenance of weeds around seedlings; and

(d) At distances of >0.5m away from the riparian reserve replanting areas, tall grasses could be flattened with planks of wood lowered onto the weeds and then stood on or trampled until their stems broke. Such 'weed pressing' could serve as an alternative to cutting large areas of tall weeds by hand.

Weed cuttings could be left behind at riparian reserve replanting sites to be protected against soil erosion and also to be used as mulch around newly planted seedlings. In open habitats prone to fires, it might be necessary to remove or reduce the volume of weed cuttings left behind in an area to reduce the risks of fires. In fact, fires should not be used to clear weeds at riparian reserve replanting areas.

Figure 4.8: Weed pressing by standing on wooden boards to flatten grasses around seedlings to their enhance survival, which is a type of assisted natural regeneration (ANR). For many grasses, it would lead to stem breakages which suppressed the regrowth of weeds. Photos: K. Shono/FAO.

Figure 4.9 Flattened grasses at a riparian reserve restoration site following weed pressing. Photo: K. Shono/FAO.

4.6 SEEDLING PREPARATION

Appendix 4 describes how to acquire seedlings for riparian reserve replanting programmes. Tree seedlings grown in nursery beds need to go through a process of 'hardening' before they could be planted. This would involve gradual reduction in the level of shade, which was particularly important if seedlings had to be planted in open areas, so that they were exposed to full sunlight or any level of shade at the planting site, for at least 2-4 weeks before planting. Watering should also be reduced by about 50% over a period of 1-2 months weeks before seedlings were planted.

Transporting seedlings to the riparian reserve replanting sites must be done carefully to avoid damages to the tree seedlings, particularly to tree seedlings that needed protection from wind damage during transportation by trucks (e.g. by covering them with shade nets or other light-weight materials). The tree seedlings should also be handled by using plastic containers at their bases such that the seedlings were not handled directly which could cause damage to their stems[28].

4.7 PLANTING

Having marked the locations of the existing natural seedlings, and having cleared the weeds and grasses, seedlings 30-60cm tall should be planted in holes of approximately 45 cm depth.

For sites with highly compacted or otherwise unsuitable soils, seedling survival could be improved by digging larger holes, up to 1m wide and 0.5m deep, and using good quality topsoil or compost from elsewhere to fill in the holes around the tree seedlings. Care should be taken to ensure that the boundary between the different soil types was not distinct (e.g. By mixing together some compacted soil with new topsoil) to encourage the seedling roots to cross into the local soil types. The aforesaid method could also help the seedlings to survive in otherwise unhospitable sites where standard planting procedures were unsuccessful.

Each seedling should be loosely tied to a planting pole to help it grow upright[28]. Ideally, the planting poles should be brightly coloured to avoid accidental damage during site maintenance.

The weeded circle, of approximately 0.5m in radius, around each seedling could then be covered with a layer of mulch composed of cut weeds or corrugated cardboards.

A subset of the seedlings should be tagged to facilitate monitoring, with the tags containing information like scientific name, local name, date of planting and unique reference or ID number so that they could be identified at later dates. Such tags could also be linked to more detailed records on the seedlings and used to track the survival, growth, dates of first flowering and first fruiting of the different species (see Section 5 on “MONITORING RIPARIAN RESERVES & RESPONDING TO THREATS”).

Figure 4.10 newly planted riparian reserve tree seedlings marked with bamboo canes in Sabah, Malaysia. Photo: HUTAN.

Figure 4.11 – A subset of the newly planted tree seedlings should be properly labelled to help monitor their survival and growth over time. Photo: HUTAN.

4.8 SITE MAINTENANCE

Many of the strategies for maintaining and enhancing the survival and growth of newly planted trees could also be applied for assisting the regrowth of riparian reserve natural vegetation. The people involved in maintaining the replanted sites should be instructed to look out for natural seedlings and use the same strategies to help them grow alongside the deliberately planted seedlings.

4.8.1 WEED CLEARANCE

For most tropical riparian reserve replanting sites, it would be essential to allocate sufficient staff time to carry out regular clearance of weeds which would otherwise outcompete the tree seedlings and undermine the time and money invested in the restoration of riparian reserve vegetation. The investment in weed clearance could be equally or even more expensive than the initial costs of tree planting, but without such intervention many riparian reserve restoration programmes would result in failure.

Figure 4.11 Weed clearance could be carried out by hand (e.g. by using a machete) or machine to cover larger areas. Particular care must be taken in areas around newly planted seedlings to ensure that the bamboo canes indicating the location of small tree seedlings were still in place before proceeding with the weed clearance. When tree seedlings were small (i.e. <6 months after planting), it might be appropriate to clear the weeds by hand within the 1m weeding circle around the stems of the seedlings. Photos: HUTAN (left)/H. Barclay (right).

In open areas, for the first 12-18 months, seedlings should be visited and weeded every 4-6 weeks, but sites with fewer weeds would require less maintenance. Weeding could be carried out less often after 18 months until the formation of a closed canopy 3-5 years after replanting in most cases. Some of the steps involved in weed clearance at riparian reserve replanting or restoration sites include the following:

- A circle 1m across of grasses and vines should be cleared around the tree seedlings, ideally by hand. If tools were used for weed clearance, it should be done carefully to minimise the risks of damaging the seedlings, especially the roots. Weed clearance should not be done so intensively that bare earth directly around seedlings becomes exposed.
- The weed cuttings could be used to provide mulch around seedling stems like when the seedlings were originally planted (see Figure 4.5). A circle of corrugated cardboards (see Figure 4.7) could also be used to reduce the regrowth of weeds around the seedlings47. Mulch should not be placed within touching distance of seedling stems to reduce the chances of fungal infection.
- Tall grasses outside the 1m weed clearance circle around the seedlings could be flattened by using weed pressing/stamping until their stems broke, or by cutting with a machete or a strimmer, taking care to look out for any natural regeneration and/or planted seedlings.
- At sites prone to fires, it might be necessary to cut and remove grasses and weeds completely from around the regenerating tree seedlings in order to remove the build-up of dry biomass which would likely burn (C. Webb, personal communication).
- The application of herbicides to reduce weed cover is strongly discouraged, especially close to waterways, but it could be used on a temporary basis, with one or two applications, if other methods of weed clearance were ineffective.

4.8.2 Fertiliser Application

In some riparian reserve restoration programmes, the application of small amounts of Nitrogen, Phosphorus and Potassium (NPK) fertiliser increased the growth rates of small tree seedlings (<1.5m tall). However, care should be taken to avoid the excessive application of fertilisers which would then run into waterways. In open areas with lots of grasses or weeds around the seedlings, the application of fertilisers could also increase weed growth more than it would benefit seedling growth.

One approach for minimising fertiliser run-off and competition from weeds would be to apply the fertiliser at the bottom of the planting holes, rather than onto the ground surface, immediately prior to tree planting, so it is accessible to the plant roots.

Placing mulch around tree seedlings would be a good alternative to applying artificial fertilisers close to waterways.

4.8.3 Wildlife damage

Newly planted seedlings might need to be protected from wildlife damage. Hence, if livestock or other wildlife, like wild pigs and deer, were found within a riparian reserve, the construction of temporary fencing around the riparian reserve restoration sites could help to reduce seedling mortality until trees were tall enough (>1.5m approx.) to survive disturbance from wildlife.

Newly planted seedlings could also be damaged by invertebrates like caterpillars and snails. In general, pest problems could be minimised by planting a mixture of different tree species. Some seedling mortality would be expected in any riparian reserve restoration programme, and so, if possible, the use of chemical pesticides should be avoided unless severe seedling mortality across multiple species was occurring due to invertebrate pest attack.

Figure 4.12 newly planted riparian reserve areas protected by electrical fences to minimise damage from elephants, wild pigs and deer beside the Kinabatangan River in Sabah, Malaysia. The fences were erected only for the first 2-3 years after tree planting, before being removed. Image: HUTAN.

4.8.4 Monitoring

While the maintenance of the newly planted riparian reserve areas was being carried out, a selection of newly planted seedlings should be monitored for their survival and growth over time (see Section 5 on "Monitoring Riparian Reserves & Managing Threats"). Such information would be useful for guiding future riparian reserve restoration work, and could also help to save time and money if the poor survival rates of some species were noted quickly and future planting procedures adjusted accordingly.

4.9 Case Study: Musim Mas - Restoring riparian reserves on an established oil palm plantation in Riau, Indonesia

4.9.1 Project aims

To restore 50m of riparian reserves along river banks previously planted with mature and closed canopy oil palms up to the edge of the rivers. The aims of the riparian reserve restoration project were to primarily to comply with the Indonesian law stipulating that 50m of riparian reserve buffer zones should be protected on both banks of small rivers by protecting 100m of riparian reserve buffer zones along both banks of large rivers (Keputusan Presiden No 32/1990)[41]). An additional management aim was to provide habitats for conserving biodiversity, particularly birds, within the oil palm plantation.

Figure 4.13 newly planted tree seedlings growing in light gaps under mature oil palms at Musim Mas Sorek Estate, Riau, Indonesia. Photos: Musim Mas.

4.9.2 Restoration procedure

The existing mature oil palms were left *in situ* and the restoration carried out underneath the standing oil palms. A combination of restoration approaches were used, including the following:

- Replanting local tree seedlings within 20m of the river's edge, without any application of chemicals or harvesting of oil palms in the restoration area; and
- Allowing the natural regeneration of the understory within 20-50m of the river's edge, without any application of chemicals.

Although the harvesting and manual clearance of the paths and oil palm circles were still allowed in the riparian reserve restoration area, accessing the oil palms was increasingly difficult as the understory grew and hence the oil palms could, in general, no longer be harvested.

4.9.3 Planting

Seedlings of 10 local tree species were purchased for the replanting from the local forestry department in Riau. Planting procedures were observed prior to the restoration by visiting a local forest replanting site managed by an environmental NGO. Two rows of tree seedlings were planted at 10-15m intervals along the riverbank, within 20m of the edges of the banks. School children and other members of the local community were informed about the project and encouraged to join the oil palm plantation workers and other company employees in the planting of the tree seedlings along rivers running through the oil palm plantation. Appropriate signs were constructed at the edges of the riparian reserve restoration site, particularly next to roads, to explain the purpose of the riparian reserve area and also to discourage encroachment (see Figure 4.14).

Figure 4.14 Sign indicating the location of the riparian reserve area at Musim Mas Sorek Estate, Riau, Indonesia.

4.9.4 Maintenance

A small quantity of NPK fertiliser was applied to the tree seedlings after their planting, with no more additional fertilisers applied. . A particular problem was the reduced survival rates of the tree seedlings due to the shade from the vines growing over the tree seedlings. The aforesaid problem was likely to be compounded by the distance of 10m between the tree seedlings, which meant that the understory continued to receive large amounts of sunlight. Even 5 years after planting of the tree seedlings, the vines had to be cleared manually every 4-6 months, with more frequent clearances required during the first year after tree seedlings were planted.

4.9.5 Monitoring

The rates of tree seedling survival and growth were monitored on a monthly basis after their replanting. While the newly planted tree seedlings were checked, emerging threats to the riparian reserve, like signs of human encroachment and hunting, were also recorded and reported so that they could be acted on rapidly.

A key management priority for Musim Mas was the enhancement of biodiversity within its oil palm plantation. Biodiversity surveys were carried out in conjunction with the standard monitoring of the riparian reserves and other HCV areas to understand how their recovery would benefit wildlife. A monitoring protocol for birds in the Musim Mas oil palm plantation was developed in collaboration with visiting scientists, while sightings of butterflies were also recorded during the riparian reserve visits.

4.9.6 Lessons learned

The initial riparian reserve restoration procedure trialled at Sorek Estate involved the cutting down of oil palms along the river, planting of cover crops to reduce soil erosion and planting the new tree seedlings. However, the procedure resulted in large amounts of soil erosion while the cover crop was being established, which was followed by significant seedling mortality due to shading by the cover crops that grew over the neighbouring oil palm trees. The cover crop overgrowth around the replanted tree seedlings and surrounding oil palms continued to remain a problem at sites where mature oil palms were cleared and weeds deliberately planted to reduce soil erosion. More so, as the weeds required continued clearing around the tree seedlings (see Figure 4.15).

The current riparian reserve restoration procedure involves leaving the mature oil palms in situ during replanting to reduce soil erosion, maintain humid conditions and provide shading for the newly planted tree seedlings (see Figure 4.13). Musim Mas found that halting the application of pesticides and fertilisers led to gradual reduction in the production of oil palm fruits, so that, over time, it proved to be uneconomical to continue harvesting the oil palms in the riparian reserve restoration areas. Leaving the oil palms unharvested helped to maintain the humid conditions and stabilise the soils while the newly planted tree seedlings became established.

Figure 4.15 Removal of mature oil palms prior to replanting led to soil erosion, which was tackled by planting cover crops, like *Mucuna bracteata*, which grew extensively across the riparian reserve restoration areas to outcompete the planted tree seedlings.

Figure 4.16 Native tree seedlings planted in two rows of approximately 10m and 20m from the water's edge alongside the Sorek Estate River in Indonesia. The now visible tree seedlings were planted in 2008 and the photograph was taken in 2013.

Five years after establishing the riparian reserve, the tree seedlings were naturally regenerating underneath the mature oil palms in areas not actively replanted 20m-50m from the edge of the river (see Figure 4.17). The Sorek Estate contains an HCV forest reserve, which could supply tree seeds to the riparian reserve restoration areas. Oil palm plantations located far away from natural forests were less likely to succeed using such riparian reserve restoration methods. The diverse community of birds present would also have contributed to seed dispersal and natural regeneration at the Sorek Estate oil palm plantation.

Figure 4.17 Natural regeneration underneath mature oil palms at Sorek Estate in Indonesia. The oil palms were not poisoned, but halting the application of fertilisers and other chemicals led to drooping fronds and minimal yields, besides difficulty in accessing the oil palms, so that their harvesting had to be completely stopped, as shown in the photograph taken in 2013, five years after starting the riparian reserve restoration. A tall tree seedling could be seen growing in the light gap, at the centre of the photograph, generated by the drooping oil palm fronds.

5 MONITORING RIPARIAN RESERVES & RESPONDING TO THREATS

Key messages

Regardless of whether they contained intact natural vegetation or if they were undergoing restoration, riparian reserves should be monitored regularly in order to:

- Record any threats to the riparian reserves, which were then to be addressed;
- Assess whether the riparian reserves were being managed as described in their management plans; and
- Assess whether the current management practices were effective for maintaining or restoring the riparian reserves and their associated waterways.

In many tropical regions, the best ways to manage riparian reserves for achieving specific management goals may not be always adequately known. Hence, it would be essential to review the monitoring data on a regular basis, at least once per year, and to use such information to adjust the management practices where necessary to protect the oil palm waterways and their riparian reserves through adaptive management.

5.1 MONITORING RIPARIAN RESERVES

Monitoring requires investments for staff to visit riparian reserve areas frequently to take measurements on a regular basis, as there are several benefits for carrying out such regular monitoring of riparian reserves, including the following:

- Monitoring provides evidence for auditors to check if oil palm plantations were complying with the RSPO Principles and Criteria;
- Frequent monitoring would ensure that threats were detected early to be dealt with timely before significant damages occurred, which could reduce the overall costs of managing the riparian reserves by minimising the need for costly restoration works in future; and

- Restoration outcomes would vary between regions with different environmental and social contexts, and hence it would be important to track the progress of the riparian reserve restorations to ensure that the time, money and land area invested were used effectively.

The aims of riparian reserve monitoring programmes would include the following:

(1) Were the riparian reserves being managed as described in their management plans or 'operational monitoring'?

This would usually involve visiting the riparian reserves on a regular basis to check if:

- The boundaries of the riparian reserves were clearly demarcated and remained intact so that they continued to comply with the national or RSPO size requirements. This would be a particularly important monitoring activity to be carried out during the development of and replanting at oil palm plantations to ensure that the riparian reserve areas were not accidentally encroached.; and
- There were any prohibited activities occurring within the riparian reserves.

(2) Were the current management practices effective for maintaining or restoring the riparian reserves or do they needed to be modified to achieve better results though 'effectiveness monitoring'?

Deciding on what to monitor.

Oil palm plantation managers are not expected to collect information on each and every aspect of a riparian reserve, and so this RSPO manual describes some selected indicators and techniques that could be used for the monitoring of riparian reserves.

Where existing monitoring procedures were already in place for HCV or wildlife monitoring, they could also be used for monitoring riparian reserves. For example, some oil palm companies are already using the Spatial Monitoring and Reporting Tool (SMART) system developed by the Zoological Society of London (ZSL) for monitoring HCV areas, and the same procedures and software systems could also be used for monitoring riparian reserves.

Effectiveness monitoring should provide useful information for guiding management decisions, and so the choice of what and how to monitor would depend on the following factors:

1. Location-specific management objectives. For example, water quality protection upstream of human settlements would require water quality monitoring, while the conservation of a particular HCV species would require population monitoring for that particular species; and
2. Internal capacity would also determine the most appropriate types of monitoring to be carried out. For example, population monitoring of HCV species would likely require training and guidance from outside experts, whereas routine patrols to detect encroachment and illegal activities within riparian reserves could be designed and carried out by the oil palm plantation staff[69]. Smallholders would not be expected to carry out complex monitoring of riparian reserves, but they could still carry out basic visual checks along riparian reserve boundaries and within riparian reserves to detect illegal activities.

For most oil palm plantations, the simplest riparian reserve indicator for monitoring would be vegetation structure. Even basic measurements of vegetation structure, like canopy cover, basal area, presence of natural regrowth or seedlings and ground cover, could help to determine whether the habitats inside a riparian reserve remained in good condition or whether the vegetation was recovering in newly restored riparian reserves. In some riparian reserves, it would be appropriate to monitor additional indicators, like water quality, carbon storage and biodiversity, which would be particularly important for riparian reserves which contained, or were used as movement corridors by, HCV species.

Ideally, at least some of the indicators chosen for monitoring should provide quantitative information which would make it easier to compare results over time and between different riparian reserve sites[67].

Monitoring should be carried out regularly, with its frequency dependent on what is being measured. Effectiveness monitoring should be carried out at least once per year, ideally by the same member(s) of staff to ensure consistency, with the results being reviewed as soon as they were available so that the threats could be identified and addressed timely.

Additional information on monitoring HCV and riparian reserve areas is available at the HCV Network website (www.hcvnetwork.org/resources), and its guidelines for the "Management and Monitoring of High Conservation Value for Sustainable Palm Oil Production in Indonesia" (see its Chapter 4 on "Monitoring")[69] could also be applied to oil palm plantations in other geographical regions.

5.1.1 Monitoring riparian reserve boundaries

The most straightforward method of monitoring riparian reserves would be to inspect them visually on a regular basis using GPS units to check for the locations of riparian reserve boundaries. This should include the mapping of any places where the riparian reserves were fragmented or degraded and recording the reasons for such disruptions, so that they could be addressed effectively.

The riparian reserve boundary areas could be marked using posts or brightly coloured paints to provide a baseline margin for future surveys so that any encroachments into the areas were immediately noticed and dealt with efficiently.

5.1.2 Monitoring threats

The following activities are generally prohibited within riparian reserves, as they would undermine the effectiveness of the areas for water quality and habitat protection:

Application of chemicals and fertilisers, except when necessary for habitat restoration, housing and other construction activities, including road building;

- Agriculture;
- Hunting and fishing,
- Starting fires;
- Waste disposal, both domestic and commercial; and
- Mining.

Some exceptions may be made in consultation with local communities where the area was important for small-scale fishing, fruit harvesting and other activities which did not have a negative effect on wildlife and vegetation within the riparian reserve.

Detailed methods for identifying threats to conservation areas have been developed by the Zoological Society of London (ZSL) - see “HCV monitoring protocol for oil palm landscapes”[70] - which included regular weekly or monthly staff patrols to survey oil palm plantations, focussing on the HCV and riparian reserve areas.

Threats noted by the staff patrol teams and their locations were recorded with GPS units, while the use of photographs provided rapid and reliable records of the prevailing situation, which the survey teams reported back to the managers of oil palm plantations for appropriate remedial action.

ZSL has also developed a computer software system for recording and analysing the data collected during the staff patrols, which provided additional guidance on changing management practices in response to the monitoring data collected (see www.smartconservationtools.org).

Suggestions for dealing with prohibited activities detected inside riparian reserves have been outlined in Section 5.2.

5.1.3 MONITORING VEGETATION IN NEWLY RESTORED RIPARIAN RESERVES < 5 YEARS FOLLOWING RESTORATION

Basic assessment.

Visual inspections could be carried out in areas recently restored alongside site maintenance (e.g. by weed clearance) to quickly assess whether weeds, wildlife damage or human activities were causing harm to newly planted seedlings so that preventative actions could be taken before extensive damage occurred.

Monitoring riparian reserve restoration sites.

More detailed riparian reserve restoration site monitoring would, in general, involve two main components, viz. Record keeping and assessment of changes in site conditions over time. Site conditions could be determined by measuring the growth and survival of a subset of newly planted or naturally regenerating seedlings, besides taking note of any obvious disturbances which might be limiting progress of the riparian reserve restoration. The aforesaid information could be used to track riparian reserve restoration progress and adjust its management practices in response to low seedling survival or growth rates.

(1) Record keeping.

Information on how a riparian reserve restoration project was carried out should be recorded to a level of detail that people unfamiliar with the project could replicate the successes and avoid the failures of similar projects in future.

The following information would be particularly useful to record[45]:

- Project objectives and location(s) by GPS coordinates, including a map of the riparian reserve restoration area(s).
- Pre-restoration site description, including its elevation, soil type and existing vegetation cover.
- Restoration strategy, including natural regeneration, assisted natural regeneration and tree planting. If different strategies were used in different locations, they should be indicated on a map or diagram.
- Site preparation, including description of how existing vegetation of oil palms, weeds etc. were managed.
- Seedling source for replanting.
- Species planted, including the number of seedlings belonging to each species, planting dates and planting distance/layout.
- Description of maintenance activities, including mulching, methods used to control weeds, fencing of wildlife and pest control.
- Project costs.
- Key problems encountered during the riparian reserve replanting, including important dates and management responses.

(2) Changes in riparian reserve restoration site conditions.

A subsample of newly planted or naturally regenerating tree seedlings (approximately 30-40 of each species) should be monitored individually to record some or all of the following information:

- Scientific name if known and local name.
- Seedling location by GPS coordinates.
- Date of planting.
- Source of planting material.
- Tree survival, with a >80% survival rate being considered to be a good survival rate.
- Tree health, which could be scored to provide early warning of poor site performance, with 0 = trees appearing dead, 1 = poor condition with few and discoloured leaves and/or severe pest damage), 2 = some signs of damage but with some healthy leaves still present, and 3 = trees appearing to be in good health[47.]
- Tree size (young trees), with the diameter of the small stems measured using a pair of callipers and tree height and crown width measured using a tape.
- Tree size (trees >5m tall). As the trees grew larger, it would become more common to measure the girth at breast height of 1.3m above the ground rather than the tree height.

This could then be converted to diameter at breast height and stem diameter using the formula:

$$DBH = \frac{GBH}{3.14}$$

- Canopy cover (trees >2m tall), which could be used instead of crown width as trees became taller.
- Weed cover percentage (%) within a 1m circle around each seedling.
- Noting threats to the riparian reserve restoration site where known, including weed overgrowth, wildlife damage, livestock damage, invertebrate pests and fires.
- Date of first flowering.
- Date of first fruiting.

Seedling survival and size should be measured for the first time approximately 1-2 weeks after planting to provide baseline for future growth measurements and to assess the level of immediate mortality following tree planting. The resulting information could be used immediately to assess the suitability of each tree species and of the current planting procedures so that they could be adjusted accordingly, if necessary, before further tree planting.[47].

After the first assessment at 1-2 weeks, most replanting sites should be monitored for approximately 3 times per year during the first 18 months or more frequently, with 'basic assessments' used in the intervening months to detect high levels of weed growth, pest damage, human encroachment etc.

Survival and growth at 18 months are usually strong indicators of whether seedlings were likely to survive in the long-term. For sites where seedling survival had been <70%, additional planting might be needed to fill any gaps. After 18 months, the riparian reserve restoration areas could be monitored on an annual basis[47]. Once a closed canopy of >70% had formed across the riparian reserve, in approximately 5-10 years, the procedures described in Section 5.1.4 on "MONITORING VEGETATION IN ESTABLISHED RIPARIAN RESERVES" could be used instead.

5.1.4 MONITORING VEGETATION IN ESTABLISHED RIPARIAN RESERVES, WITH TREES >5-10 YEARS OLD

Basic assessment.

Visual inspection would be the simplest method for the rapid assessment of major changes in riparian reserve habitats.

Taking photographs from specified points along a riparian reserve would be one way of ensuring that visual inspections would be standardised between different observers and to also document visual long-term records of any changes.

Monitoring vegetation structure.

The following features could be used for monitoring vegetation structure within riparian reserves. The number and location of sampling points would depend on the length and width of the riparian reserve, with at least 3-5 vegetation monitoring sites at the centre of each continuous riparian reserve, leaving at least 20m between each monitoring site or further apart for the longer riparian reserves.

Vegetation monitoring should be carried out once per year, preferably backed up by patrols on a more frequent basis, to detect encroachment and deter intruders.

Some straightforward vegetation measurements within riparian reserves that could provide valuable information on how close the current habitat structure resembled natural forest conditions would include the following:

(a) Canopy cover of >70% is considered to be a good level of canopy cover for most tropical forests. A spherical densitometer could be used to take four readings of the % canopy cover standing at a single location, being rotated 90º between each reading. The average of the four reading values would be the % canopy cover at that location. Canopy cover could also be monitored by comparing a series of photographs of the canopy taken over time by looking upwards from the same location.

(b) Ground cover could be assessed by looking down at a 1m x 1m survey area and estimating the proportion of the ground surface % made up of leaf litter and dead wood as positive indicators, and the proportion % of bare soil, grasses or weeds as negative indicators. Any other types of ground cover, like bare rocks, should also be recorded. The total ground cover of the survey area would then add up to 100%.

(c) Tree size and tree density, with the presence of large and small trees, including tree seedlings <1m tall in the understory, serving as an indicator of good quality riparian reserve forest.

    The size of the area to be surveyed for determining tree size would depend on the type of vegetation being assessed, with a smaller survey area being needed for surveying small trees when compared to large trees. An example of a vegetation survey for assessing tree size and density within squares of measuring different sizes of trees has been described by ZSL[71]:

Survey area size	What to record
20m x 20m	Number of trees >20cm diameter at breast height (DBH)
10 x 10m	Number of trees 10-20cm DBH
5 x 5m	Number of trees >1m tall and <10cm DBH as number of saplings
1m x 1m	Number of trees <1m tall, as number of seedlings, an important indicator for forest regeneration

Interpreting vegetation survey results.

An intact riparian forest should have a high percentage of canopy cover (averaging >70%), with its ground cover made up mostly of leaf litter and dead wood. Weeds and grasses would be expected to occur at the edges of a riparian reserve, but they should not generally extend into the centre of a wide riparian reserve (>20m), except for isolated patches where a tree had fallen down to create a gap in the canopy. The presence of large (i.e. >20cm DBH) and small (i.e. 10-20cm DBH) adult trees, as well as young trees (saplings and seedlings), in a riparian reserve would also be an indicator of good quality riparian forest.

In general, riparian reserves measuring 5-15m in width would not be expected to acquire fully natural forest conditions due to their narrow shape, but their status (which would generally be of poorer quality than those of riparian reserves measuring 20m or more) could still be tracked over time.

The monitoring data could be used to:

- Track changes in vegetation structure over time. Sites where seedling densities were low or declining (which would vary between years so several years of data were needed to track long-term changes) might be unable to regenerate naturally following disturbances and hence may require more active management practices, like the planting of seedlings, to fill in the gaps along a riparian reserve.
- Good quality riparian reserve habitats, based on the above mentioned measurements, could also indicate that a site was likely to be suitable for wildlife. However, oil palm

plantation managers whose aims were to conserve specific HCV species within their riparian reserves should ideally carry out more specific surveys to determine whether a riparian reserve was suitable for that particular species.

- Additional aspects of vegetation structure, like tree size (basal area and height) and presence and size of large woody debris, could also be linked to carbon storage and sequestration. Hence, it might be appropriate to use carbon assessment protocols (see Section 5.1.7) to monitor riparian reserve vegetation, which could then be used to assess vegetation structure and carbon storage at the same time.

5.1.5 Water monitoring

Water quality.

Water quality monitoring in rivers and streams is complicated because the measurements would be affected by activities upstream of oil palm plantations, over which the managers had no control. However, a basic picture of the extent to which oil palm plantation activities were reducing water quality could still be measured by monitoring waterways which flowed into and out of oil palm plantations by calculating the differences in the measurements of the water quality parameters being monitored at their points of entry and exit.

If new riparian reserves were being established within an oil palm plantation, measuring water quality before, during and after the riparian reserves were established would provide valuable information on their effectiveness.

Key parameters to be measured regularly within oil palm plantation waterways could be determined by consulting their respective national water quality guidelines. It would be important to sample water quality on a regular basis, e.g. once every 1-2 months, so that measurements were representative of the range of rainfall conditions within an oil palm plantation, e.g. during low water flows, when water temperatures would be high and oxygen levels low, and at high water flows, e.g. within 1-2 hours following heavy rainfall, when suspended sediments and other pollutants were likely to be high.

Useful parameters for monitoring water quality include total suspended solids (TSS) and turbidity, which indicate water cloudiness or sedimentation, nitrates and phosphates related to fertiliser runoff, conductivity, and pH and water temperature.

Biological indicators, like the presence and abundance of particular fish or invertebrate species in waterways, could provide valuable additional information to chemical water tests because the animals and plants living in the water were being continuously exposed to pollutants, thereby providing reliable indication of changes in water quality over time. Monitoring aquatic animal populations would be particularly important if a waterway was used by local communities for fishing to meet their basic needs (HCV5), or if it contained rare, threatened or endangered species of significant value at the global, regional or national level (HCV1).

Where water quality values within an oil palm plantation waterway exceeded their national standards at its outlet but not at its inlet, then the prevailing management practices would need to be adjusted to prevent such deterioration of water quality from reoccurring, including by:

Step 1.

Identifying and eliminating any potential 'point sources' of water pollution, such as from palm oil mills, villages, construction sites, oil palm nurseries and pesticide storage facilities.

Generally, such sources of pollution should be located as far away as possible from natural waterways. While palm oil mills need to be located close to natural waterways, their wastes must be treated before being released into the environment, using treatment ponds located away from the edges and above the maximum flood limits of natural waterways, and with sufficient capacities so that the wastes would not overflow into the waterways during high rainfall.

Step 2.

Addressing other causes of low water quality resulting from diffuse or 'non-point sources' of pollution, like sediments, fertilisers and pesticides, drained from multiple locations across the surrounding landscape**.** While riparian reserves could reduce diffuse water pollution by filtering oil palm plantation runoff, in order to be effective they need to be wide enough (see Section 2.2), with the water needing to flow through the riparian reserve and not through gaps along the riparian reserve.

If riparian reserves had been established within an oil palm plantation but the water quality still remained below the required national standards, it could be because the polluted water was flowing around, rather than through, the riparian reserve. Likely reasons for the aforesaid observation could include:

- There may be sites along a riparian reserve where large amounts of oil palm plantation runoff were flowing through gaps in the riparian reserve;

- Water flow during heavy rainfall might overwhelm the filtration capacity of the riparian reserve in areas where large volumes of water flowed through one particular place along the riparian reserve due to the landscape topography; and
- Water might be flowing through small streams or drainage channels which were too narrow to require a riparian reserve, and so was transporting pollutants into larger waterways.

Once such water pollution 'hotspots' had been identified, it might be appropriate to (a) increase the width of the riparian reserve at these locations, (b) extend protection to small waterways transporting large volumes of pollutants, and/or (c) redirect surface water flows away from natural waterways into, for example, sediment pits.

For further information on strategies for monitoring and managing oil palm related water quality, see "Guidelines for minimising impacts of oil palm plantations and palm oil mills on quality of rivers in Sabah"[38].

Aquatic habitat structure.

An additional aim of riparian reserves could be the stabilising of river banks, for which some indicators for monitoring water channels could include:

- River channel width.
- Bank stability. A simple method for determining bank stability would be to establish a series of fixed points, with marked trees or poles fixed firmly into the ground, along a river, using a compass to measure a fixed angle from each point and measuring the distance of the bank edge from that fixed point over time.
  Qualitative observations, including taking photographs of the same area of a river bank, could also be made at these points to monitor the frequency and extent of bank erosion along the river channel.

- The presence of leaf litter, plants and woody debris, like branches and logs, in rivers would be beneficial for many aquatic animals, such as fish and invertebrates. A visual assessment of the aforesaid observation, as % cover over a defined area, could be made from the banks of a river, unless the water was very deep and/or very cloudy.

5.1.6 Biodiversity

Measurements of vegetation structure (see Section 5.1.3) are generally cheaper and easier than measuring biodiversity, particularly for non-experts. However, records of species and biodiversity could be important for determining the conservation value of riparian reserves.

Patrols for detecting threats and carrying out site maintenance could record wildlife encounters on an *ad hoc* basis. Records of their GPS locations, species names where known and the number of individuals spotted could be important in informing and guiding future biodiversity monitoring work.

Notably, the larger and more obvious forest species of mammals and birds would be less likely to persist in significant numbers in fragmented forests unless the riparian reserves were very wide (>200-400m), when there would be enough habitat. Such mammals and birds would also be very sensitive to even low levels of hunting pressures. The loss of such species should therefore not be always regarded as a failure in efforts to conserve biodiversity within oil palm plantation landscapes. The occasional records of some of these species could be useful to establish whether the riparian reserve areas were being used as corridors by wildlife crossing and moving between larger areas (See Figure 5.1).

Figure 5.1 Pig-tailed macaques crossing a river in Sabah, Malaysia. Photo: HUTAN/Marc Ancrenaz.

Useful indicator groups for monitoring biodiversity in tropical regions include birds and butterflies, which are sensitive to changes in habitat quality and which are reasonably easily identified using field guides. Since frugivorous (fruit-eating) birds played a key role in forest regeneration by dispersing seeds, while butterflies were important pollinators, their presence or absence could be linked to the long-term persistence of riparian reserve vegetation. Other useful groups for monitoring biodiversity in riparian reserve habitats would be animals, like amphibians and dragonflies, which used both aquatic and terrestrial habitats, and so that their presence or absence could be used to monitor both environments simultaneously.

In areas where the conservation of a particular species and/or its movement along corridors was a key management priority, it would be appropriate to involve environmental NGOs for providing guidance on species of local conservation importance and in training how to monitor such species.

Several methods for monitoring biodiversity within oil palm plantations have been presented in Appendix 5, and also in reports produced by the Zoological Society of London (ZSL) [71] and Wild Asia[26].

5.1.7 Carbon storage and sequestration

RSPO is currently developing guidelines on assessing and monitoring carbon storage in oil palm plantation conservation areas. The monitoring guidelines have yet to be finalised (see http://www.rspo.org/en/rspo_palmghg_calculator for more up-to-date information), but they are likely to include measurements of vegetation within oil palm plantation reserves, including riparian reserves. Many of the measurements used for monitoring vegetation structure, like tree size (diameter at breast height and height) and presence and size of woody debris, like tree trunks and branches (either standing or lying on the forest floor), within a fixed riparian reserve area (e.g. 50 x 20m), could also be used to assess carbon storage and sequestration.

5.2 Managing threats to riparian reserves

Human encroachment.

Riparian reserves are sometimes viewed as 'spare land' for people outside oil palm plantations to move into and utilise. Unfortunately, such encroachments could severely undermine efforts at oil palm plantations to protect and restore riparian habitats. Specific threats to riparian reserves from the encroachment of people include illegal logging, mining, hunting, fires, land conversion and/or establishment of human settlements within riparian reserves.

The prohibition of human activities would be a key management component at many HCV areas, particularly at riparian reserves, due to the easy access into these areas along waterways and oil palm plantation roads. However, there are currently no effective strategies to really prevent human encroachments under all circumstances. Nevertheless, some management strategies that could help to alleviate the problem of human encroachment into riparian reserves include the following:

Communicating the location and function of riparian reserves with clear signage and verbal communication with local communities:

- Members of local communities were unlikely to be aware of the laws and environmental justifications for protecting areas of natural vegetation alongside waterways.
- Clearly defined boundaries, accompanied by conspicuous sign boards, could be used for explaining that certain areas had been set aside for conservation purposes, highlighting the significance of protecting these areas on the wider environment, besides communicating activities which were prohibited in these areas. Such sign boards should ideally be in the local languages, accompanied by visual explanations.
- Information on the sign boards could be supported by outreach activities for local communities, possibly with support from environmental NGOs or local environmental groups. Such outreach activities could include workshops for local school children and inviting local communities and local media to participate in riparian reserve restoration activities, like tree planting. Involving local people in growing seedlings for replanting, and in patrols for monitoring and maintenance, within riparian reserves could help raise awareness and provide economic incentives for people to conserve these areas.

Monitoring regularly to detect early signs of human encroachments:

- It would be easier to minimise the extent and impact of human encroachments if they were detected early, while random patrols could deter human encroachments in the first place. Ideally, riparian reserves should be visited every few weeks and timetabled to avoid visiting the same locations on predictable days/times, with occasional weekend patrols being valuable additions to the standard patrolling timetables.
- Operating patrolling schemes could be expensive, and so other useful activities could also be undertaken alongside the patrols, including removing weeds growing around newly planted tree seedlings, carrying out other maintenance tasks, monitoring riparian reserve habitats, recording wildlife sightings and removing hunting snares.
- Involving local people in patrols would provide direct employment benefits and could also help to raise awareness of the importance of the riparian reserves[41, 47].
- Patrols would be more effective if they involved people with authority to tackle and take action on anyone found to be undertaking activities which were prohibited. This could include forming joint patrols with representatives from local forestry or wildlife conservation departments.

Identifying drivers of human encroachment:

- By engaging local communities directly, it might be possible to identify the causes and reasons for human encroachments, which could then help to identify appropriate ways and means to reduce such problems. For example, if local communities were clearing areas to grow crops, could it be because of the lack of land available for them to produce food elsewhere? If so, it might then be possible to identify alternative sites outside riparian reserves for use by the local communities.

- Another challenge often encountered was the lack of understanding among local communities that forested lands were not 'surplus to requirements', but that they played an important role in the protection of local waterways. In such cases, the better and clearer communication of the significance of riparian reserve habitats could help to resolve the ensuing human encroachment disturbances.

Recording instances of prohibited activities occurring within riparian reserves and showing clearly the steps undertaken to minimise the human encroachments**:**

- Oil palm plantation managers should maintain records describing instances of illegal activities occurring within riparian reserves, including descriptions of dates and actions taken, so that RSPO auditors could subsequently confirm that appropriate steps had been taken to reduce the threats posed to the riparian reserves, and whether or not the actions employed had successfully reduced the threats.

Fire prevention.

Fires are a common cause of damage to degraded riparian reserves, particularly during the early stages of riparian reserve restoration in open and weedy sites during periods of low rainfall. Since fires were usually started by people[47], many of the steps employed for preventing human encroachments could also be applied for fire prevention. "Restoring Tropical Forests: a practical guide"[47] discusses some specific strategies for the prevention of fires in riparian reserve restoration sites.

Protecting wildlife within riparian reserves.

For the successful regeneration and long-term viability of riparian reserve vegetation, it would be important to minimise the hunting of wildlife responsible for seed dispersal. Primates, fruit bats and fruit-eating birds could play important roles in seed dispersal, but, in general, it would be advisable to protect all species of wildlife since animals responsible for the dispersal of tropical seeds not often well known or documented.

Managers of riparian reserves are required to protect all HCV species within their oil palm plantations, including species which move through riparian reserves for their dispersal between larger forest fragments. The narrow widths of riparian reserves make HCV species particularly vulnerable to poaching in these areas.

One way of limiting hunting pressures inside riparian reserves would be to reduce human encroachment, particularly by potential poachers, into these areas. Patrols and local community outreach activities should be coordinated with other local agencies capable of providing guidance and support in addressing such issues, including local law enforcement and wildlife protection agencies and environmental or social NGOs, who could help coordinate efforts in raising awareness and promoting alternatives to hunting wildlife.

Soil and bank erosion.

This would be a natural process in some locations, but it could be exacerbated by changes in hydrology from upstream deforestation and reduction in riparian reserve forest cover within oil palm plantations. Good quality riparian reserve vegetation along river banks should help in minimising rates of bank erosion, although it might not fully prevent bank erosion from occurring.

5.3 USING MONITORING DATA FOR ADAPTIVE MANAGEMENT

The main reasons for monitoring riparian reserves are to determine whether:

(1) The riparian reserves were being managed as described in their management plans; and
(2) The current management practices were effective for maintaining or restoring riparian reserves, or if they needed to be modified for achieving better results through adaptive management.

It would therefore be essential to use the data collected from monitoring exercises to assess and to, wherever necessary, improve the management protocols being adopted for riparian reserves and their associated waterways.

A system for reporting and responding to the monitoring data should be in place even before the monitoring had begun, including a named individual within the oil palm company responsible for ensuring that the monitoring results were properly analysed and acted upon when necessary. Besides the monitoring data, direct observations during field activities and operations could also provide useful information for reviewing oil palm plantation management practices. Hence, it is recommended that oil palm plantation managers responsible for analysing and interpreting the monitoring data should, at least occasionally, accompany the field staff during data collection. The monitoring data should be reviewed at least once a year to assess progress in meeting management objectives.

Interpreting monitoring data.

In the case of photographs, it would be useful to compare earlier site pictures with more recent ones.

The ZSL Spatial Monitoring and Reporting Tool (SMART) could be used to analyse and interpret the data on threats, including by mapping the locations of the different threats collected during riparian reserve patrols. Manuals on how to use the standardised SMART protocols for data analysis and their training materials are freely available online at www.smartconservation.org.

One method for tracking changes in quantitative data would be plotting a graph of the chosen indicator over time, and to examine whether its general trend observed was positive, negative or neutral, as indicated below:

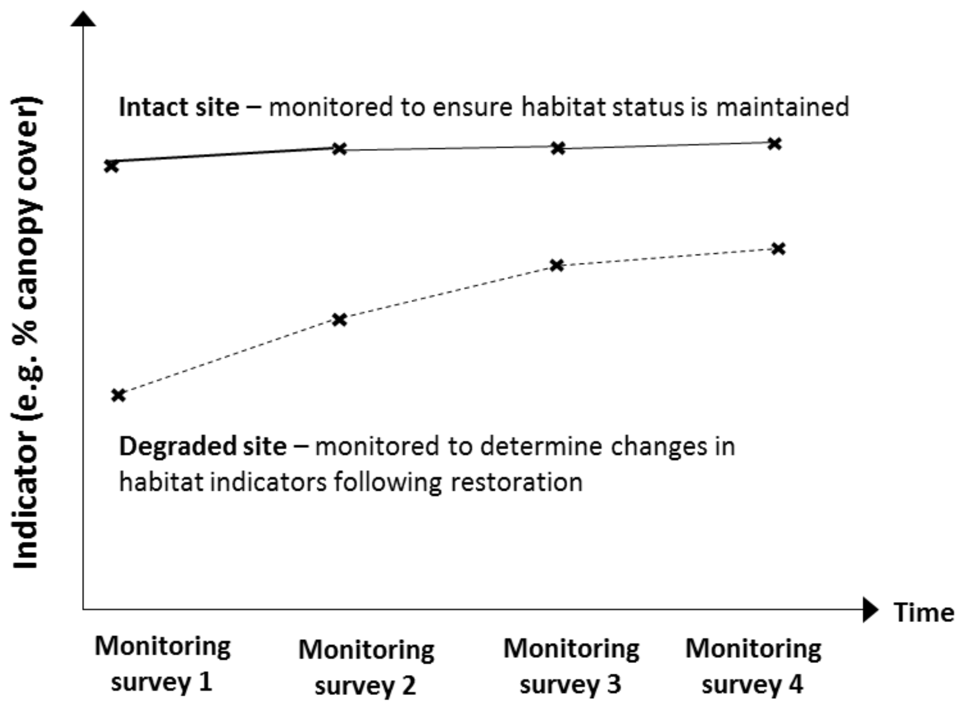

Figure 5.2 Changes in quantitative monitoring indicators could be tracked over time by entering data into a spreadsheet and drawing a graph to visualise the trends.

Using monitoring data to improve management practices.

If existing management practices were failing to protect or restore a riparian reserve and its associated waterways, the management plans should be reviewed and amended.

In cases where reasons for the poor management of riparian reserves were not readily obvious, it would y be necessary to consult local experts to identify the causes for any declines in the status of the riparian reserves, besides suggesting alternative management practices.

The most effective ways to manage and restore riparian reserves in tropical regions is an area of continuing scientific research, and so adaptive management practices based on regular reviews of monitoring data and consultations with field staff and local experts would be essential for the successful management of riparian reserves.

In addition to the sharing of management practices and outcomes merely within an oil palm company, it would be much more useful to also share information with the other local stakeholders. For example, different companies, government agencies and/or NGOs might be attempting to restore natural riparian reserve vegetation and habitats along the same waterway, and so the coordination of their efforts and the sharing of their results would lead to lower costs and higher success rates for all concerned, rather than for any one organisation working alone and sharing outcomes only internally.

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7 APPENDICES

Appendix 1 - List of abbreviations used in the RSPO manual.

ANR - Assisted or Accelerated Natural Regeneration

BMPs - Best Management Practices

CO_2 - Carbon dioxide

DBH - Diameter at breast height (measurement of tree trunk width at 1.3m above the ground)

DID - Department of Irrigation and Drainage (Malaysia) (http://www.water.gov.my)

EFB - Empty Fruit Bunch

EIA- Environmental Impact Assessment

EU RED - European Union Renewable Energy Directive (2009/28/EC) - Sustainability requirements for biofuels sold within the European Union.

GBH - Girth at breast height (measurement of tree trunk circumference at 1.3m above the ground)

GHG - Greenhouse gas

GIS - Geographic Information System

HCV - High Conservation Value (www.hcvnetwork.org)

HCVA - High Conservation Value Area

ISCC – International Sustainability and Carbon Certification (www.iscc-system.org/en) - Certification scheme for sustainability and greenhouse gas emissions, e.g. to demonstrate compliance with European Union Renewable Energy Directive requirements)

NGO - Non-governmental organisation

RSPO - Roundtable on Sustainable Palm Oil (www.rspo.org)

SEIA - Social and Environmental Impact Assessment

SMART - Spatial Monitoring and Reporting Tool (www.smartconservationtools.org)

ZSL - Zoological Society of London (www.sustainablepalmoil.org)

Appendix 2 - RSPO Principles & Criteria relevant to riparian reserve habitat management.

Besides following the relevant national laws, oil palm plantation managers are also required to protect natural riparian reserve habitats under the RSPO Principles & Criteria[1]. The primary criteria for riparian reserve management include the following:

Principle 4: Use of appropriate best practices by growers and millers.

Criterion 4.4 – Practices maintain the quality and availability of surface and ground water.

Indicator 4.4.2: Protection of water courses and wetlands, including maintaining and restoring appropriate riparian and other buffer zones (refer to national best practice and national guidelines) shall be demonstrated.

Indicator 4.4.1: An implemented water management plan shall be in place [and will]:

- Ensure that the use and management of water by the operation does not result in adverse impacts on other users within the water catchment area, including by local communities and customary water users;
- Aim to ensure that local communities, workers and their families have access to adequate and clean water for drinking, cooking, bathing and cleaning purposes; and
- Avoid contamination of surface and ground water through run-off of soil, nutrients or chemicals.

Criterion 4.2 - Practices minimise and control erosion and degradation of soils.

Indicator 4.3.2: A management strategy shall be in place for plantings on slopes above a certain limit (this needs to be soil and climate specific).

Indicator 4.3.5: Drainability assessments shall be required prior to replanting on peat to determine the long-term viability of the necessary drainage for oil palm growing.

Guidance for 4.3.5: Where drainability assessments have identified areas unsuitable for oil palm replanting, plans should be in place for appropriate rehabilitation or alternative use of such areas. If the assessment indicates high risk of serious flooding and/or salt water intrusion within two crop cycles, growers and planters should consider ceasing replanting and implementing rehabilitation.

Principle 2: Compliance with all applicable laws and regulations**.**

Criterion 2.1 - There is compliance with all applicable local, national and ratified international laws and regulations.

Indicator 2.1.1: Evidence of compliance with relevant legal requirements shall be available.

Indicator 2.1.2: A documented system, which includes written information on legal requirements, shall be maintained.

Principle 5: Environmental responsibility and conservation of natural resources and biodiversity.

Criterion 5.1 - Aspects of plantation and mill management, including replanting, that have environmental impacts are identified, and plans to mitigate the negative impacts and promote the positive ones are made, implemented and monitored, to demonstrate continual improvement.

Indicator 5.1.1: An environmental impact assessment (EIA) shall be documented.

Guidance for 5.1.1: The EIA should cover the following activities, where they are undertaken:

- Building new roads, processing mills or other infrastructure;
- Putting in drainage or irrigation systems;
- Replanting and/or expansion of planting areas;
- Clearing of remaining natural vegetation.

Principle 7: Responsible development of new plantings.

Criterion 7.1 – A comprehensive and participatory independent social and environmental impact assessment is undertaken prior to establishing new plantings or operations, or expanding existing ones, and the results incorporated into planning, management and operations.

The assessments should include:

- Assessment of potential effects on adjacent natural ecosystems of planned developments, including whether development or expansion will increase pressure on nearby natural ecosystems;

- Identification of watercourses and wetlands and assessment of potential effects on hydrology and land subsidence of planned developments. Measures should be planned and implemented to maintain the quantity, quality and access to water and land resources.

Criterion 7.2 – Soil surveys and topographic information are used for site planning in the establishment of new plantings, and the results are incorporated into plans and operations.

Measures should be planned to minimise erosion through appropriate use of heavy machinery, terracing on slopes, appropriate road construction, rapid establishment of cover, protection of riverbanks, etc. Areas located within the plantation perimeters that are considered unsuitable for long-term oil palm cultivation will be delineated in plans and included in operations for conservation or rehabilitation as appropriate (see Criterion 7.4). Riparian reserve habitats would also qualify as High Conservation Value Areas (HCVAs) (for further information, see: www.hcvnetwork.org).

All riparian reserve habitats qualify for protection under HCV4, i.e. areas which provide "basic ecosystem services in critical situations, including the protection of water catchments and control of erosion of vulnerable soils and slopes".

Some riparian reserve areas may also qualify for protection under additional HCV criteria like:

- HCV1 - Concentrations of biological diversity, including endemic species, and rare, threatened or endangered species, that are significant at global, regional or national levels (this includes riparian areas which function as wildlife corridors for HCV species to move through the landscape).
- HCV 3 - Rare, threatened, or endangered ecosystems, habitats or refugia.
- HCV5 **-** Sites and resources fundamental for satisfying the basic necessities of local communities or indigenous peoples (for livelihoods, health, nutrition, water, etc.), identified through engagement with these communities or indigenous peoples, e.g. if a plantation is located upstream of human populations who rely on a river or lake to supply water and food.

Hence, the protection of riparian reserve habitats should be included in the process of HCV assessment and management.

Principle 5: Environmental responsibility and conservation of natural resources and biodiversity.

Criterion 5.2 - The status of rare and threatened or endangered species and other High Conservation Value habitats, if any, which exist in the plantation or that could be affected by plantation or mill management, shall be identified and operations managed to best ensure that they are maintained and/or enhanced.

Indicator 5.2.1 Information shall be collated in a High Conservation Value (HCV) assessment that includes both the planted area itself and relevant wider landscape-level considerations (such as wildlife corridors).

Indicator 5.2.2: Where rare, threatened or endangered (RTE) species, or HCVs, are present or are affected by plantation or mill operations, appropriate measures that are expected to maintain and/or enhance them shall be implemented through a management plan.

Such measures would include:

- Ensuring that legal requirements relating to the protection of the species or habitats were met;
- Avoiding damage to and deterioration of HCV habitats by ensuring that HCV areas were connected, corridors conserved and buffer zones around HCV areas created; and
- Wherever HCV benefits could be realised outside of the management unit, collaboration and cooperation between other growers, governments and organisations should be considered.

Where communities are asked to relinquish rights so that HCVs can be maintained or enhanced by the companies or State agencies, then great care needs to be taken to ensure that communities retain access to adequate land and resources to secure their basic needs; all such relinquishment of rights must be subjected to their free, prior, and informed consent (see Criteria 2.2 and 2.3).

Principle 7: Responsible development of new plantings.

Criterion 7.3 – New plantings since November 2005 have not replaced any primary forests or areas required for enhancing or maintaining one or more High Conservation Values.

7.3.1 There shall be evidence that no new plantings have replaced primary forest, or any area required to maintain or enhance one or more High Conservation Values (HCVs), since November 2005. New plantings shall be planned and managed to best ensure the HCVs identified are maintained and/or enhanced (see Criterion 5.2).

7.3.2 A comprehensive HCV assessment, including stakeholder consultation, shall be conducted prior to any conversion or new planting. This shall include a land use change analysis to determine changes to the vegetation since November 2005. This analysis shall be used, with proxies, to indicate changes to HCV status.

7.3.3 Dates of land preparation and commencement shall be recorded.

7.3.4 An action plan shall be developed that describes operational actions consequent to the findings of the HCV assessment, and that references the grower's relevant operational procedures (see Criterion 5.2).

7.3.5 Areas required by affected communities to meet their basic needs, taking into account potential positive and negative changes in livelihood resulting from proposed operations, shall be identified in consultation with the communities and incorporated into HCV assessments and management plans (see Criterion 5.2).

Appendix 3 – National guidelines for riparian reserves in selected oil palm producer countries.

The following size guidelines for riparian reserves are based on national interpretations and government or NGO reports available as of 2014.

For up-to-date information on national laws for riparian reserves, readers are recommended to consult the latest updates of the national interpretations for various countries available at the RSPO website (www.rspo.org/certification/national-interpretations).

Democratic Republic of Congo

Based on the HCV National Interpretation of the Democratic Republic of Congo available at www.hcvnetwork.org [in French]: Directives pour les zones sensible autour des cours d'eau (Ministère de l'Environnement, Conservation de la Nature ET Tourisme, Guides Opérationnels 2010)

Cours d'eau (mesuré aux hautes eaux)	**Largeur de la zone sensible**
Largeur <10m	50m sur chaque rive
Ravines	10m de chaque côté
Ruisseaux ou marigots	20m de chaque côté
Marécages	10m à partir de la limite
Tête de source	150m autour

Ghana

Implementation of the National Buffer Zone Policy of Ghana, with recommendations on buffer zones, include[72]:

(1) Municipal reservoir shoreline protective buffer zone: 60 to 90 meters (e.g. Weija Dam, Lake Bosomtwe);
(2) Major perennial rivers and streams: 10 to 60 meters (e.g. Volta, Tano, Offin);
(3) Minor perennial streams: 10 to 15 meters;

(4) Important intermittent streams: 10 to 20 meters;
(5) Streams within forest reserves: 10 to 50 meters; and
(6) Wetlands which require buffer zones of 30 meters around their perimeters as defined from their high water elevations.

Note: The slopes do affect the sizes of the buffer zones. For slopes of 15-20 %, add 3 meters; for slopes of 20-25 %, add 10 meters; and for slopes of 25-30 %, add 20 meters.

Indonesia

Relevant legislation on riparian reserves in Indonesia include the Minister of Agriculture Decrees No: 837/Kpts/Um/11/1980 and No: 683/Kpts/Um/8/1961, and the Presidential Decree No: 48/1983[69].

Guidelines for developments in Indonesia involving rivers and other water resources recognise the importance of protecting the following riparian reserve buffer zones:

1. 500 meters from the edges of water reservoirs like dams and lakes.[28]
2. 200 meters from the edges of water springs and alongside rivers in swampy areas.[28]
3. 100 meters from the left and right banks of rivers that are >30m wide.[69]
4. 50 meters from the left and right banks of rivers that are <30m wide.[69]
5. A coastal green belt with a width of 130m times the average tidal range in meters[28].

Note: Since decentralisation, the interpretation and implementation of the aforesaid legislation are the prerogative of regional or local governments[28], and so local laws may vary from the national size guidelines.

Further information on defining riparian reserve ecosystems in Indonesia to be protected under HCV4 is available in the “HCV Toolkit for Indonesia - Guidelines for the identification of high conservation values in Indonesia”[69]

Papua New Guinea (PNG)

In PNG, riparian reserve buffer zones should be maintained and/or rehabilitated as per the PNG logging code of practice[73] at the time planting or replanting[74]:

Watercourse definitions[73] in PNG include the following:

Permanent water courses	Have water flowing for part or all of the year for most years. The beds have no vegetation growing on them, and may consist of water-washed sand, silt, stone, gravel or exposed bed rock materials. Class 1 Stream bed width = >5m Class 2 Stream bed width = <5m and >1m
Non-permanent water courses or drainage channels	Are usually stable, non-incised depressions which carry surface water during times of high rainfall? The beds are comprised of soil and are usually covered with leaf litter and vegetation.
Swamps	Have surface water present for 6 months of the year.
Stream buffer zone starting point adjacent to the stream	Delineation of the buffer zone would start where the vegetation was 10m high or higher*.

*NB. The said guidance does not account for habitats where the natural riparian vegetation was <10m high over extensive areas, e.g. in grassland riparian reserve habitats, when oil palm plantation managers could default to the standard RSPO guidance on starting the delineation of riparian reserves or stream buffer zone from the top of each river bank or high water mark.

Minimum buffer zone widths[73]:

Category	Minimum width	Comments
Lakes, lagoons, coastal shoreline and swamps	100 metres	From the water body, high tide mark or edge of the mangroves
Class 1 permanent streams	50 metres	Each side of the watercourse
Class 2 permanent streams	10 metres	Each side of the water course

Permanent or non-permanent streams of any width used by the local community	50 metres	Each side of the water course. Buffer zones for culturally significant water sources require careful consideration, which could include the exclusion of logging to protect the catchment area of the water source. If there is doubt, it should be evaluated on a site specific basis.
Non-permanent water courses and streams less than 1 metre not used by the local community	No buffer zone	

Peninsular Malaysia & Sarawak State

Garis panduan Pembangunan Melibatkan Sungai dan Rizab Sungai (Guidelines for Development Involving Rivers and River Reserves):

Kelebaran laluan air antara tebing (Width of water channel between banks)	Keperluan kelebaran rizab dari kedua belah tebing (River reserve width requirements between both banks)
>40 m	50 m
20 – 40 m	40 m
10 – 20 m	20 m
5 – 10 m	10 m
<5 m	5 m

Source: Drainage and Irrigation Department (DID) of Malaysia, 2001) (www.water.gov.my). "Managing biodiversity in the riparian zone", Malaysian Ministry of Natural Resources and Environment, 2009[58].

Sabah State

Rivers in Sabah are protected by the Department of Irrigation and Drainage (DID) of Malaysia under Section 40 of the Sabah Water Resources Enactment (1998)[38] , which states that "all permanent water courses more than 3 metres wide should maintain a river reserve of at least twenty metres from the top of each riverbank."[36] Subsequent guidelines of the Sabah Environment Protection Department (EPD) recommend stricter requirements during the planting stages of oil palm plantation development, including 5m riparian reserves for rivers less than 3m wide[38]. Further, the Sabah EPD "takes into consideration EIA findings of proposed areas whereby environmentally sensitive, wildlife and steep areas" may require "provisions of 50 – 100 m of river reserves".

Solomon Islands

Buffer zone sizes in the Solomon Islands are to comply with the SI Logging Code of Practice[75], "National Interpretation of RSPO Principles and Criteria for Sustainable Palm Oil Production, Independent State of Solomon Islands":

Type of excluded area	Minimum buffer zone	Comments
Oceans, lakes and lagoons	100m excepting for a log pond which may be 50m	The buffer zone starts from high water mark
Streams that flow for more than 6 months of the year	Class 1 Streams with beds more than 10m wide) – 50m on each side Class 2 Streams with beds less than 10m wide – 25m on each side	Use the flowchart[75] to determine the class of stream or gully. Buffer starts from edge of vegetation.
Gullies that flow for less than 6 months of the year	10m on each side	Use the flowchart[75] to determine the class of the stream or gully, with the buffer zone starting from the edge of the vegetation.

Appendix 4 – Growing one's own seedlings.

For larger buffer zone restoration projects, or in places where seedlings could be readily purchased, it may be necessary and/or cheaper in the long-term to establish seedling nurseries either by:

(1) Growing local tree seedlings within existing oil palm nurseries;
(2) Working with local communities who can grow local tree seedlings by themselves in exchange for payments; and
(3) Establishing separate seedling nurseries within oil palm plantations. Ideally, such seedling nurseries should be located near the buffer zone restoration sites to reduce the costs of transporting seedlings from the nurseries to the planting areas.

Genetic diversity

It is important to collect local tree seedlings and seeds from a variety of different parent trees, both from a range of different tree species and also from several trees belonging to each tree species, in order to generate tree seedlings with high levels of genetic diversity. Such genetic diversity would help to maximise tree seedling survival, besides ensuring that the resulting trees would be able to tolerate changing environmental conditions like the onset of pests and diseases. Further, it is essential that tree seedlings grown from cuttings were taken from more than one parent tree. In fact, some authors[47] have recommended collecting seeds from at least 25-50 parent trees, including a few (e.g. 10%) from outside the local area for large-scale restorations rather than for oil palm plantation -level restorations). In any case, local tree seeds and seedlings should always be collected from as many trees as possible and, wherever possible, also from several locations rather than merely relying on a single tree of each tree species.

Practical guidance on seed collection.

Germinating seeds from forest trees would be easier for some tree species than for other tree species, and so some trial and error may be needed to find suitable conditions for the different seeds to germinate and grow properly.

Two useful resources on growing tropical seedlings from seeds are:

"Restoring Tropical Forests: a practical guide", S.D. Elliot, D. Blakesley & K. Hardwick[47], which is available online at www.forru.org; and

"A Practical Handbook for Conserving High Conservation Value Species & Habitats within Oil Palm Landscapes", Zoological Society of London[41], which is available online at www.sustainablepalmoil.org.

Some general advice on growing seedlings from seeds include:

(1) Wherever possible, seeds should be collected from local examples of the target habitats, like along waterways in intact forests with similar soil types, slopes and flooding regimes to those of the buffer zone restoration sites.
(2) Seeds should be collected from ripe fruits, either by cutting them from branches (which is usually the best method although it may not be possible for tall trees), or from the forest floor, with due care to avoid fruits and seeds that are rotten or have signs of fungal infections, teeth marks of animals or small holes made by seed-boring insects[47].
(3) Parent trees should ideally be marked by recording their GPS locations to prevent too many collections being taken from the same trees. Wherever possible, the tree species should be identified, possibly by collecting and/or photographing samples of the fruits and leaves for experts to identify the tree species.
(4) Seeds of most rainforest trees should be sown as soon as possible after their collections, and hence the planting materials and nursery spaces should be prepared prior to seed collection.
(5) For most tree species, seeds should be removed from the fruits and cleaned before being sown in suitable planting mediums. Some experts[47] have recommended a mixture of 50% forest topsoil, preferably along with other soils, and 50% coarse sand for germinating forest seeds. River sediments, collected from the bottom of rivers when water levels were low, have been used for successfully germinating a number of forest seeds at the MESCOT Forest Restoration Initiative in Sabah, Malaysia.

Figure A4.1 recently germinated tree seedlings at the MESCOT Forest Restoration Initiative in Sabah, Malaysia. The photograph on the right illustrates one method for maintaining the humid conditions which many rainforest seeds need to germinate.

Figure A4.2 Tree seedlings are ready to be transferred to individual pots when they have developed at least two leaves and when their stems are relatively sturdy. The MESCOT Forest Restoration Initiative in Sabah, Malaysia, uses river sediments to grow their seedlings. Other experts[41] have recommended the use of 50% forest soil, if accessible, without causing damage to the forest floor, and 50% organic matter, like oil palm mulch, rice husk or coconut husk, which help to ensure that water, oxygen and nutrients reach the roots.

Figure A4.3 Sterculia seeds ready for collection in PNG. Photos: W. Unsworth/NBPOL

Figure A4.4 Sterculia seeds germinating at the seedling nursery in PNG. Photos: W. Unsworth/NBPOL.

Practical guidance on collecting wild seedlings.

Another option for replanting would be to dig up tree seedlings from local forests and to grow them until they are tall enough to be replanted at buffer zone restoration sites.

Direct transfers of tree seedlings from forests to buffer zone restoration sites are generally not recommended due to the high rates of seedling mortality resulting from sudden changes in the prevailing conditions. Hence, wild tree seedlings are usually grown in nurseries, or by local communities, for several months after their collection before they are replanted elsewhere. One project[76] in Kalimantan, Indonesia, managed to successfully transfer *Hopea nervosa* seedlings directly from the forest to a buffer zone restoration site about 2km away, with the success being attributed to planting done during the rainy season, when soil and air humidity were consistently high, and planting under vegetation cover which significantly reduced light intensity. It could thus be possible to transfer some tree species as wildlings for their direct replanting at well-shaded buffer zone sites.

The following guidelines, from "Restoring Tropical Forests: a practical guide"[47], describes the procedures for collecting and maintaining wild seedlings in more detail:

- Wild tree seedlings should be collected when they are small (<20cm tall) or when they have sprouted 2-4 leaves. Tree seedlings collected within a 5m radius of the parent trees are otherwise likely to die due to competition for resources with the parent trees, and so their removal should not affect natural forest regeneration.
- Wildlings should be collected when the soil was wet and soft, using a spoon or trowel, taking particular care to minimise root damage by leaving a ball of soil around the roots for protection.
- Key to the survival of tree wildlings is their condition during transport, and so they should be tightly packed and kept moist during transport[77] (e.g. in damp cloth bags or buckets with small amounts of water) before being transferred to planting pots at the nursery.
- Until they regrow their roots, wildlings are particularly sensitive to the lack of water, which is particularly the case for the larger wildlings >20cm tall. Newly collected wild seedlings should therefore be watered frequently in small doses to prevent flooding. In some projects, it was necessary to keep the newly collected wildlings in a greenhouse or polytunnel at 95% relative humidity for the first 3 weeks after their collection[67].

Alternatively, parts of the leaves could be removed from the larger seedlings by cutting across the leaves to reduce transpiration.

- Potted wildlings should be kept under shade, as similar as possible to the conditions from where they were collected, with, for instance, 20% of normal sunlight for 4-6 weeks if the wildlings were originally growing under full forest canopy. The level of shade cover could then be gradually reduced until the level of shading at the nursery was the same as that of the replanting site.

Practical guidance on propagating seedlings from cuttings.

Methods for the vegetative propagation of tree seedlings are described in further detail in “Restoring Tropical Forests: a practical guide”[47], which include the following steps:

- Taking cuttings of medium-sized juvenile shoots from either re-sprouting tree trunks or re-sprouting shoots of previously pruned young trees <10cm stem diameter[77]. Not all tree species would regrow after their pruning, and so the method should be tested before being used extensively.
- Placing the cuttings in plastic bags with some water and transporting them to a nursery.
- Removing and discarding both ends of each cutting at its lower woody part and growing tip. Cutting the remaining stem into sections of approximately 10–20 cm long, with each section containing at least one leaf, and taking care so that the tip and the base are recognisable. The base of each cutting should be cut at a slanted angle.
- Trimming the larger leaves by about 30–50%.
- Dipping the base of each stem cutting in a hormone rooting powder, with the best treatment often varying between species so that it should be trialled earlier on a small number of cuttings.
- Planting the cuttings 5-10cm deep into a free-draining rooting medium (e.g. comprising 50% sand and 50% rice husk or coconut husk to allow the excess water to be drained while retaining some moisture and air spaces) in the same orientation as those of the base-tips from where the cuttings were originally taken. The cuttings should then be maintained at high humidity while they grow roots, (e.g. approximately 3-12 weeks for Malaysian dipterocarp cuttings[68]). Groups of cuttings could be kept in large and clear plastic bags with 1L of water at the bottom to maintain high humidity[47].
- After the cuttings had grown a network of roots, transplanting them into soil bags and rearing them in the nursery alongside other seedlings until they were ready for planting elsewhere.

Practical guidance on growing seedlings in a nursery.

- Seedlings which have been reared in a nursery or collected from the wild should be potted into progressively larger plastic bags filled with potting mix, without bending the tap or main root.
- A suitable potting mix comprises 50% forest topsoil and 50% organic matter, like oil palm mulch, coconut husk or dried cattle dung, to hold moisture and supply nutrients[41]. Some tree species may not require a specific soil type, with tree seedlings having been successfully grown in both standard soils collected from village gardens and also in river sediments collected from the bottom of the river at low flows, during riparian reserve restoration along the Kinabatangan River in Sabah, Malaysia.
- Seedlings should be weeded and watered regularly, but without the plastic sleeves becoming water logged. When very young, seedlings need to be watered every day, possibly even twice a day, which should be reduced several months prior to their replanting.
- Seedlings are typically grown under nettings which provide shade, for instance approximately 50% of shade for the young seedlings.
- The sprouting seedlings need to be moved around within a nursery by lifting each container individually every few weeks to prevent the larger roots from growing into the ground which would then be broken when the seedlings were transported for planting.

Figure A4.5 Bombax spp seedlings growing at a seedling nursery in PNG. Photo: W. Unsworth/NBPOL.

Figure A4.6 a seedling nursery with shade netting to protect the seedlings from full sunlight as they grew. The seedlings, to be replanted into open habitats, would need to undergo a process of 'hardening' by gradually reducing the level of shade cover and frequency of watering over a period of 4-6 weeks, before being replanted to prepare them for survival under the field conditions at the replanting site.

Figure A4.6 Nauclea seedlings in open sunlight ready for replanting. Photo: W. Unsworth/NBPOL.

Practical guidance on hardening seedlings before replanting.

Tree seedlings grown in nurseries need to undergo a process of 'hardening', by incrementally introducing a much more natural environmental regime, before they were replanted into a riparian reserve. It typically involves gradually reducing the level of shade, which is particularly important for seedlings to be replanted in open areas, and slowly reducing watering by about 50% over a period of 1-2 months weeks, before their replanting.

If the tree seedlings were purchased from local nurseries, including from local community nurseries, they could be initially left in a testing area under the sun for about 4 days, with watering, to ascertain if they were hardy enough to be used restoration, since trees not hardened sufficiently were likely to die at the testing stage.

Practical guidance on direct seeding.

Typically, forest restoration involves the planting of tree seedlings, but it could be easier and cheaper to avoid the costs of growing seedlings in nurseries and transporting them to the riparian reserve restoration site by planting the seeds directly at the riparian reserve restoration site itself.

Seeds collected from native trees in nearby reference sites could be subsequently sowed at a time of the year best suited for seed germination, which would usually be during the wet season if the weather patterns were seasonal.

The main factors involved in reducing the success rates of direct seeding include desiccation, predation, mainly by ants and rodents, and competition from weeds. Predation and desiccation could be minimised by planting the seeds below the soil surface, for instance inside small holes part-filled with topsoil and covered with a shallow layer of topsoil and/or mulch like weed cuttings. The choice of tree species for direct seeding is important, with typically large (>0.1 g dry mass) seeds with medium moisture content (35–70%) and tough outer coating being most suitable for direct seeding for tree species like members of the Leguminosae (Fabaceae) family[47].

Since the outcomes of direct seeding were likely to be highly variable, often leading to patchy vegetation cover[54], direct seeding could be more useful as a method for increasing crop diversity once some tree cover had been established rather than as the main riparian reserve restoration strategy.

Appendix 5 - Possible indicator groups for monitoring biodiversity in riparian reserve habitats.

Indicator group	Suggested monitoring methods	Recommended further reading
Birds	Birds are best surveyed at dawn or dusk, during good weather conditions without rains. The birds should be surveyed several times per year, e.g. twice during the rainy season and twice during the dry season. Birds could be surveyed using point counts or walking transects through or around the riparian reserve areas at dawn or dusk. Point counts involve one standing at pre-determined points for a standardised period of time (e.g. for 15 minutes) and recording the identity of the birds seen or heard. Transects involve one walking along a line (e.g. 100 m) within or adjacent to the riparian reserve area at a constantly slow pace and recording the identity of all the species of birds seen or heard.	"Biodiversity in Plantation Landscapes: A Practical Resource Guide for Managers and Practitioners in Oil Palm Plantations", Wild Asia[26], pp 62-64, describes the monitoring of common birds using transect counts. "A Practical Toolkit for Identifying and Monitoring Biodiversity in Oil Palm Landscapes", ZSL71, pp 40-51 describes several methods for surveying birds.
Mammals	Marking out equal area grids (e.g. 30 m by 30 m) or transects (e.g. 100 m) and carrying out surveys for signs of animals in or along these areas. Animal foot prints could often be seen in the mud or sand at the edges of rivers, and photographs of such prints, which included a ruler for scale	"A Practical Toolkit for Identifying and Monitoring Biodiversity in Oil Palm Landscapes", ZSL71, pp14-39 describes several methods for surveying mammals, particularly of HCV species. "Biodiversity in Plantation Landscapes: A Practical Resource Guide for Managers and

Indicator group	Suggested monitoring methods	Recommended further reading
	purposes, could be taken to aid in identification. Signs of animals feeding, fur and mammalian scats could also be photographed and recorded at the grids or transects. Camera traps are more costly, but they could provide very good data on the animals using the riparian reserve buffer zones.	Practitioners in Oil Palm Plantations", Wild Asia[26], pp 65-66, describes nocturnal mammal and bird surveys including by camera trapping.
Amphibians	Amphibians could be surveyed using transects and grid or quadrat searches, whereby a standardised area (e.g. 5m by 100m) was searched by hand and all the amphibians encountered recorded. An alternative method would be to search across a larger area over a pre-determined fixed length of time. Such searches could be carried out within streams and/or on land in riparian reserve areas. In water channels, a net could be held downstream to catch the dislodged amphibians. Additionally, drift fences and pitfall trap arrays could be set up in riparian reserve areas, consisting of a line of solid fencing, along which several buckets were dug into the ground. Foraging amphibians crossing the areas would meet and travel along the fences until they fell into one of the buckets. All buckets should be filled with moist sponges and leaf litter, with the individuals being recorded and released every morning.	"A Practical Toolkit for Identifying and Monitoring Biodiversity in Oil Palm Landscapes", ZSL71, pp 52-58, describes several methods for surveying amphibians using transects, quadrats, and timed surveys.

Indicator group	Suggested monitoring methods	Recommended further reading
Butterflies and dragonflies	Both butterflies and adult dragonflies could be surveyed by measuring out a transect (e.g. 100m), walking at a steady pace and noting the species and number of any butterflies or dragonflies seen in an imaginary 5m x 5m box placed in front of the recorder. Species which could be identified in the field could be photographed, which might be made easier if they were first captured by hand-nets. Butterfly traps could be set up within or adjacent to riparian reserves for monitoring butterfly communities in these areas. Such traps consist of a cylinder of net which was closed at the top, with a plate tided approximately 10 cm below the bottom of the net. Decomposing fruits (e.g. old bananas) are placed on the plate to attract butterflies and moths. Upon landing on the fruits, the insects would fly up into the net and tend to stay there. The traps should be re-visited after 24hrs, and all the species captured identified, photographed if necessary and released.	BEFTA (2013), Butterfly and dragonfly transect protocol, which is available at: http://oilpalmbiodiversity.com/resources/

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Roundtable on Sustainable Palm Oil
Unit A- 37-1, Level 37, Tower A, Menara UOA Bangsar
No. 5, Jln Bangsar Utama 1, 59000 Kuala Lumpur, Malaysia
T : +603 2302 1500 F : +603 2302 1542 E : rspo@rspo.org

Other RSPO Offices
Jakarta, Indonesia
London, United Kingdom
Beijing, China