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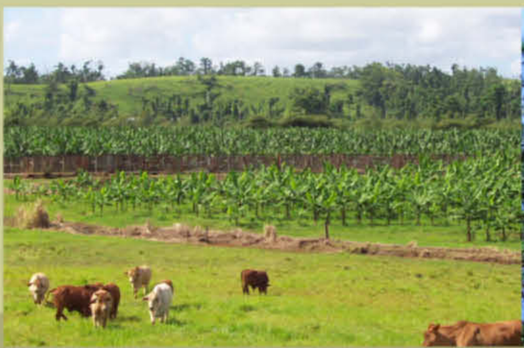
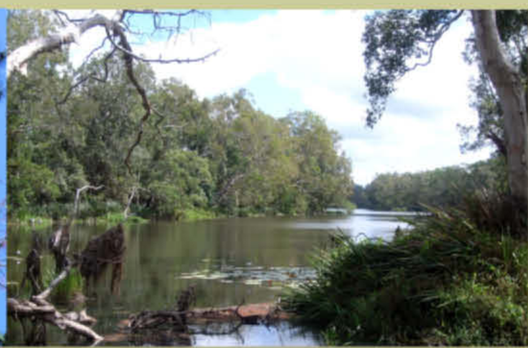
Mapping Land Use

Land Use Change Mapping from 1999 to 2004 for the Murray River Catchment





Australian Government
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from 1999 to 2004
for the Murray River Catchment

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Disclaimer

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Introduction

The Department of Natural Resources and Water (NRW) through the Queensland Land Use Mapping Program (QLUMP; www.nrw.qld.gov.au/science/lump) has produced a consistent and seamless statewide land use dataset for the year 1999. This dataset and the mapping methodology are described by Witte *et al.* (2006). The 1999 land use dataset for Queensland provides the basis for monitoring and mapping of land use change.

Information on land use change is important for reporting on trends within catchments or regions. Spatial land use change data is critical for monitoring processes within the landscape and the effectiveness of natural resource management objectives relating to these. This includes salinity and water quality, rates of soil erosion, acidification, nutrient decline and carbon losses. Changing patterns in land use also have strong links to economic and social activities within a catchment or region.

Land use change mapping from 1999 to 2004 has been completed for the Fitzroy, Johnstone, Burdekin, Tully and Murray River catchments. This report briefly documents the methodology used for mapping land use change in the Murray River catchment and the various products generated:

- the 1999 land use dataset which includes a number of improvements and corrections to the previous 1999 dataset
- the 2004 land use dataset
- the land use change dataset from 1999 to 2004
- summary statistics derived from the above spatial datasets
- the results of the accuracy assessment.

QLUMP is part of the Australian Collaborative Land Use Mapping Programme (ACLUMP) which is coordinated by the Bureau of Rural Sciences in Canberra with partner agencies in all states and territories. For further information on ACLUMP see www.brs.gov.au/landuse.

Catchment overview

The Murray River Catchment is approximately 110,763 hectares in area and is located in far north Queensland. The catchment area extends from the Kirrama Ranges in the north-west across the Murray River flood plain to the coast and down the coast to include the locality of Kennedy and the town of Cardwell. It stretches further south along a narrow coastal strip between mountain ranges and Hinchinbrook Island for about 30km and ends in the extensive mangroves and channels of the Hinchinbrook Passage. The catchment underwent significant clearing in the early half of this century with approximately 30% of the catchment being used for human settlement and agricultural practices at the present time. The remainder of the catchment, approximately 70%, is made up of natural environments such as tropical rainforest, mangroves, wetlands and water bodies. Approximately 50% of the catchment is listed under the Wet Tropics of Queensland World Heritage Area.

During the initial land use mapping for the year 1999 a wide diversity of agricultural practices were noted including sugarcane, bananas, plantation forestry and grazing, predominantly beef cattle and cattle fattening.

Objectives

The primary objectives of this project were to:

- further develop and improve the methodology to map land use change which is applicable to a broad range of catchments
- apply this methodology to the Murray River catchment and produce a detailed land use dataset for 2004
- produce an improved land use dataset for 1999 which includes more detailed attribution of crops and horticulture land uses
- produce a land use change layer between the years of 1999 and 2004
- assess and describe the accuracy of the land use data.

This data can then be utilised for a range of natural resource management applications.

Methodology

A method for detecting and mapping land use change has been developed and applied in the Pioneer River catchment. The method makes use of best available spatial information, satellite imagery, aerial photography, expert knowledge and field survey. It involves successive stages of data collation, interpretation, verification, validation and production of final outputs.

The mapping scale is 1:50,000 with a minimum mapping unit of 1ha and a minimum mapping width of 50m for linear features.

The Murray catchment was clipped from the statewide 1999 land use data (for details see Witte *et al.*, 2006) and formed the basis for the 2004 land use dataset. The 1999 and 2004 datasets were then improved and updated, primarily by interpretation of, Landsat TM, Landsat ETM+ imagery and Spot 5 imagery, scanned aerial photography and inclusion of expert local knowledge. This was performed in ERDAS Imagine by overlaying the land use datasets on Landsat imagery (1999, 2000, 2001, 2002, 2004) and digitising or modifying areas previously omitted or incorrectly mapped (1999 mapping) as well as areas of actual and potential land use change (2004).

A number of ancillary datasets were utilised to identify potential land use changes, including:

- woody vegetation change mapping by the Statewide Landcover and Trees Study (SLATS)
- the Queensland Valuations and Sales System (QVAS) data
- the digital cadastral database (DCDB)
- National Park, State Forest and Timber Reserves data.

Digitised areas of uniform land use type were assigned to classes according to Australian Land Use and Management Classification Version 6 (ALUM Version 6; see Appendix 1 in this report and Bureau of Rural Sciences (BRS) 2006 for more detail). Local authorities, regional NRW and other state government officers, regional natural resource management groups, CSIRO and landholders supplied information and confirmed land uses not identified from the satellite images and other data. Field checking occurred in areas where the land use was still uncertain.

During the process of mapping land use change, cropping and horticultural areas in both the 1999 and 2004 land use datasets were attributed to the tertiary level of ALUM Version 6 wherever possible. Previously in the 1999 data, cropping and horticultural areas were attributed to the secondary level with the exception of *sugar*, *irrigated sugar* and *irrigated cotton*.

A differencing algorithm was developed in the python scripting language to produce a dataset representing the land use change (eg. from *grazing natural vegetation* to *cropping*) between 1999 and 2004.

An independent validation was undertaken for the improved 1999 and 2004 land use map and the land use change layer using a stratified random sample to assess thematic (attribute) accuracy based on the ALUM classification. Note that only a subset of classes was sampled for this exercise. Some classes that are defined by tenure and are assumed correct (e.g. *national parks*) were generally not assessed. Classes which are small in total area (<10,000ha) and do not occur frequently (<10 polygons) were also not sampled, but the polygons were checked using imagery, aerial photography and in some cases field survey. The number of points assessed for the remaining classes was determined based on the area that each class occupies within the catchment.

Land use was assessed at each point through interpretation of Landsat imagery, aerial photographs and referral to ancillary datasets. Where the land use could not be determined confidently through this process or expert knowledge, the point was assessed in the field or the landholder was contacted directly. Any points which could not be confidently classified were not used in the accuracy assessment.

Further information on data specifications and land use mapping procedures are provided by BRS (2006).

Products

1999 and 2004 land use data

Figure 1 shows the 1999 and Figure 2 the 2004 land use data for the Murray catchment using the secondary level of the ALUM classification (see Appendix 1 for the classification).

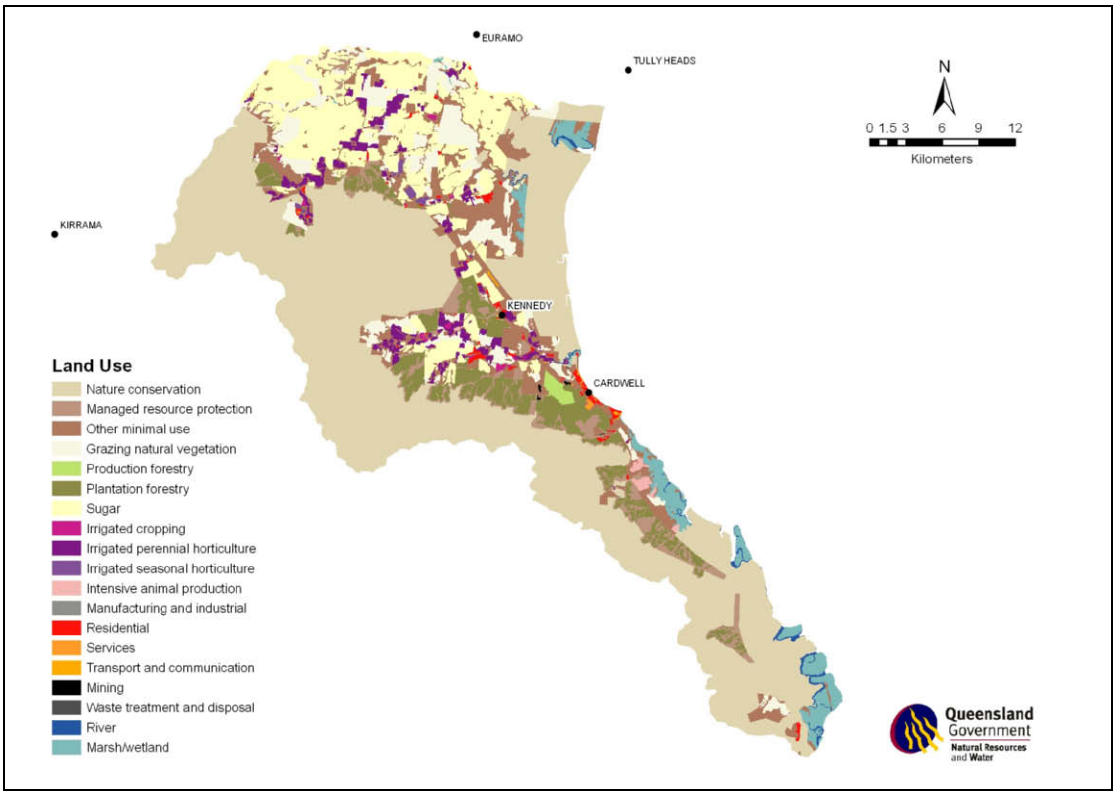

Figure 1: 1999 land use map for the Murray River catchment

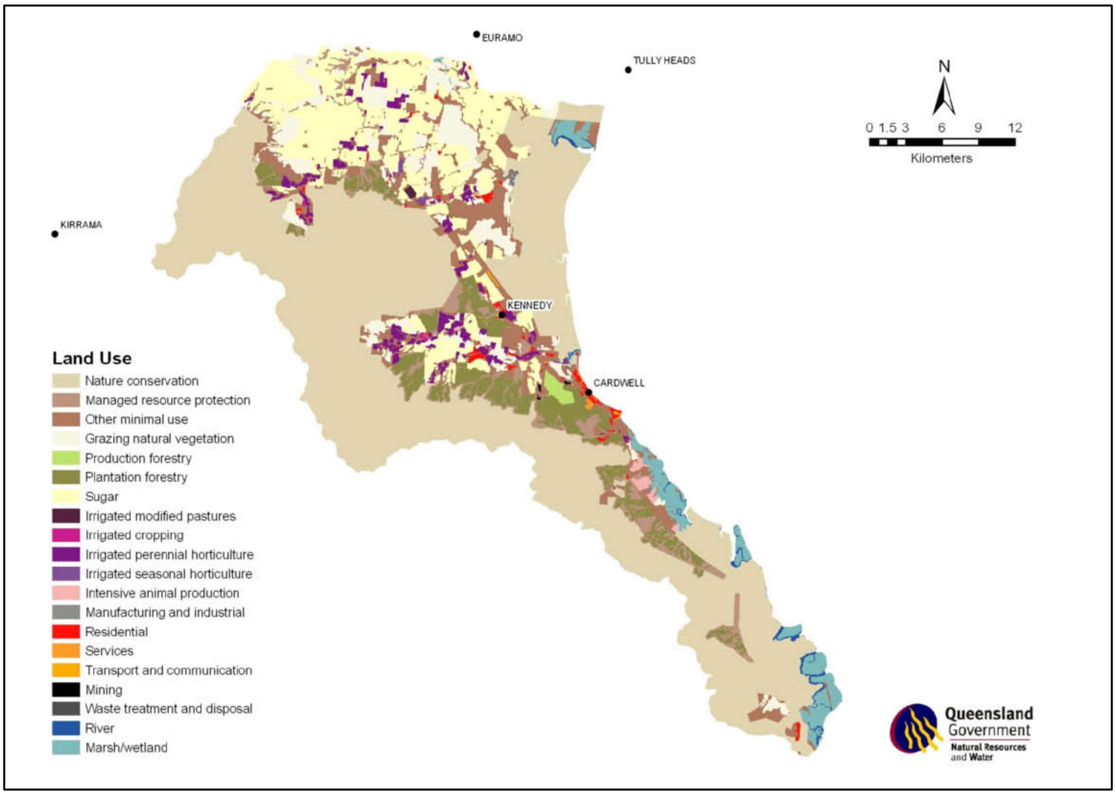

Figure 2: 2004 land use map for the Murray River catchment

Some tertiary classes, such as *irrigated sugar* (part of *irrigated cropping*), *dairies* (part of *intensive animal production*), *rural residential* (part of *residential*) and various classes under *nature conservation* have been mapped, but were not shown separately in Figures 1 and 2.

Table 1 and Table 2 provide the summary statistics for the 1999 and 2004 land use datasets respectively.

Land Use Code	Land Use Classes	Area ha	Area %
1	Conservation and natural environments	74,268	67.05
1.1	Nature conservation	59,287	53.53
1.2	Managed resource protection	4,086	3.69
1.3	Other minimal use	10,895	9.84
2	Production from relatively natural environments	7,550	6.82
2.1	Grazing natural vegetation	7,184	6.49
2.2	Production forestry	366	0.33
3	Production from dryland agriculture and plantations	20,849	18.82
3.1	Plantation forestry	6,256	5.65
3.3	Cropping	14,593	13.18
3.3.5	Sugar*	14,593	13.18
4	Production from irrigated agriculture and plantations	3,074	2.77
4.3	Irrigated cropping	191	0.17
4.4	Irrigated perennial horticulture	2,667	2.41
4.5	Irrigated seasonal horticulture	215	0.19
5	Intensive uses	1,142	1.03
5.2	Intensive animal production	286	0.26
5.3	Manufacturing and industrial	23	0.02
5.4	Residential	658	0.59
5.5	Services	97	0.09
5.7	Transport and communication	44	0.04
5.8	Mining	32	0.03
5.9	Waste treatment and disposal	4	0.00
6	Water	3,880	3.50
6.3	River	537	0.49
6.5	Marsh/wetland	3,343	3.02
	Grand Total	110,763	100.00

* The tertiary class *sugar* is generally a subset of the secondary class *cropping.* In this case, all *cropping* was mapped as *sugar.*

Table 1: Summary statistics of land uses in 1999 in the Murray River catchment

Land Use Code	Land Use Classes	Area ha	Area %
1	Conservation and natural environments	74,188	67
1.1	Nature conservation	60,022	54.19
1.2	Managed resource protection	4,049	3.66
1.3	Other minimal use	10,117	9.13
2	Production from relatively natural environments	7,372	7
2.1	Grazing natural vegetation	7,006	6.32
2.2	Production forestry	366	0.33
3	Production from dryland agriculture and plantations	21,979	20
3.1	Plantation forestry	6,256	5.65
3.3	Cropping	15,723	14.20
3.3.5	Sugar*	15,723	14.20
4	Production from irrigated agriculture and plantations	2,490	2
4.2	Irrigated modified pastures	66	0.06
4.3	Irrigated cropping	72	0.07
4.4	Irrigated perennial horticulture	2,241	2.02
4.5	Irrigated seasonal horticulture	112	0.10
5	Intensive uses	1,209	1
5.2	Intensive animal production	318	0.29
5.3	Manufacturing and industrial	28	0.03
5.4	Residential	686	0.62
5.5	Services	98	0.09
5.7	Transport and communication	44	0.04
5.8	Mining	32	0.03
5.9	Waste treatment and disposal	4	0.00
6	Water	3,525	3
6.3	River	523	0.47
6.5	Marsh/wetland	3,002	2.71
	Grand Total	110,763	100.00

* The tertiary class *sugar* is generally a subset of the secondary class *cropping.* In this case, all *cropping* was mapped as *sugar.*

Table 2: Summary statistics of land uses in 2004 in the Murray River catchment

Data limitations

The ALUM class *grazing modified pasture* has not specifically been mapped separately from *grazing natural vegetation* due to the difficulty in identifying and separating these classes using imagery, aerial photography and field observation.

Land uses that include linear features (e.g. roads and railways) are generally not mappable at the minimum mapping scale of 1:50,000 and minimum mapping width of 50m. Area estimates of these linear features therefore represent only a small proportion of the actual area of these land use classes. This is of relevance to the following land use classes:

- *transport and communication*
- *utilities*

The 1999 and 2004 land use datasets are both a snapshot in time showing what was considered the main land use, or primary management objective of the land manager, for each of those years. However, some effort was given to distinguish between an actual land use change and a rotation. For example, an area of cropping that did not appear to be under crop in the year of interest was often still mapped as cropping, as this was not considered an actual land use change, but rather a rotation, with the primary management objective likely to be cropping.

A number of data sources are used to identify *irrigated cropping* and *irrigated horticulture*. This includes irrigation infrastructure mapping, the location of water entitlements (irrigation licences), local knowledge, field survey and image interpretation. It's possible that areas mapped as *irrigated cropping,* for example, are only irrigated on a supplementary basis and were not actually irrigated in either 1999 or 2004.

The ephemeral nature of many water features can lead to confusion as they may be present in imagery on one date and either absent or of differing extent in imagery on subsequent or previous dates. As a result, there are likely to be errors and omissions and some disagreement in the mapping of features such as farm dams, reservoirs, lakes, wetlands and other water-related features.

Please refer to the metadata for details on the mapping of specific classes

1999 to 2004 land use change data

Figure 3 shows the 1999 to 2004 land use change data for the Murray catchment using the secondary and, where possible, tertiary level of the ALUM classification (see Appendix 1 for the classification).

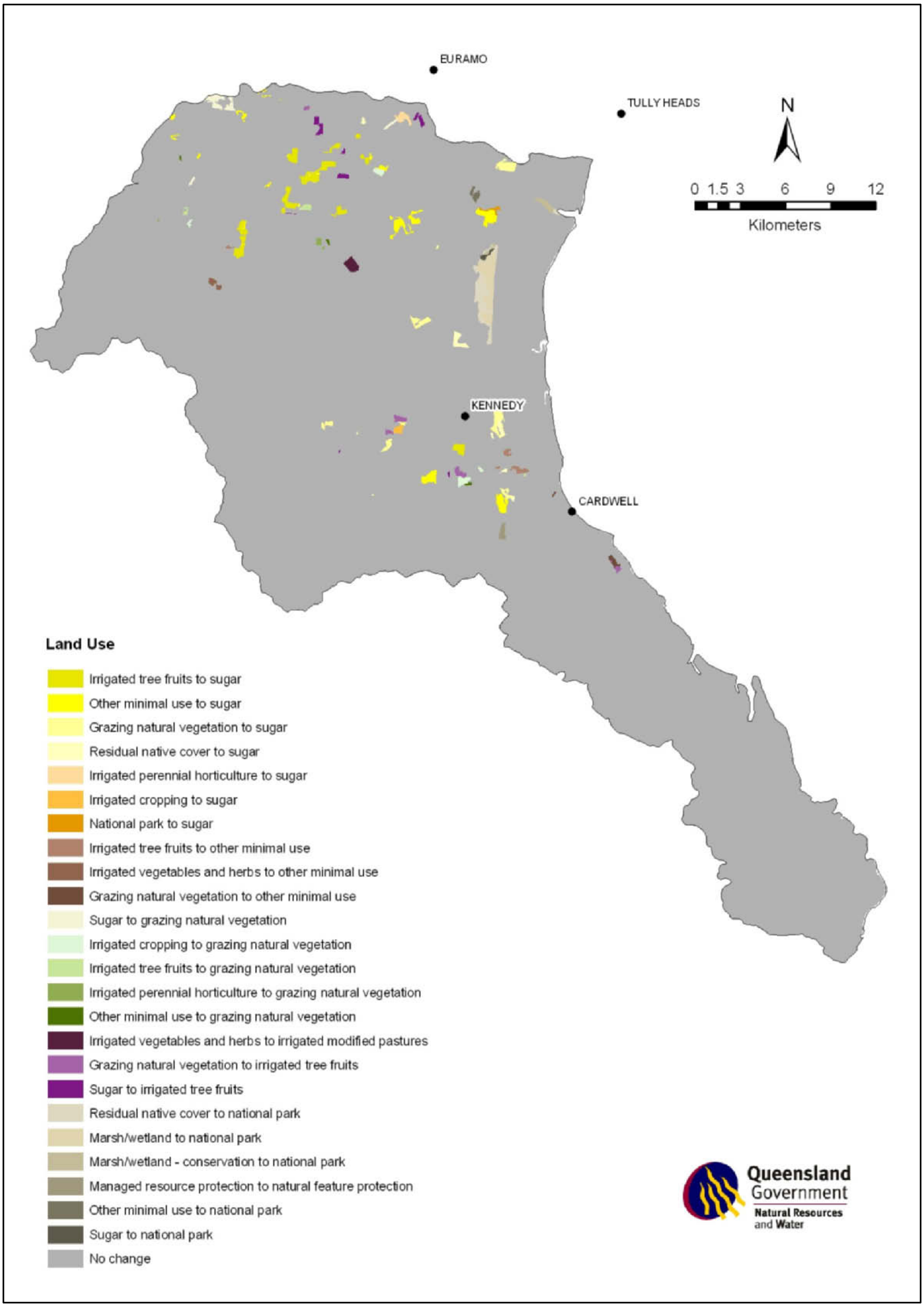

Figure 3: 1999 - 2004 land use change map for the Murray River catchment

The total area of mapped land use change from 1999 to 2004 in the Murray River catchment is 2,938 hectares. This is equivalent to 2.65% of the catchment. However, over 60% of the catchment had the tenure of National Park, State Forest or Forest Reserve in 1999 with relatively little change occurring in these areas. Approximately 28% of the catchment was freehold in 1999 with 6% of this experiencing a land use change during the 5 year period. Over 70% of the total land use change occurred on freehold land.

Land Use Code 1999	Land Use Class 1999	Land Use Code 2004	Land Use Class 2004	Area of Change (ha)	Area of Catchment (%)
4.4.1	Irrigated tree fruits	3.3.5	Sugar	474	0.43
1.3.0	Other Minimal Use	3.3.5	Sugar	417	0.38
1.3.3	Residual native cover	1.1.3	National Park	302	0.27
2.1.0	Grazing natural vegetation	3.3.5	Sugar	301	0.27
6.5.0	Marsh / Wetland	1.1.3	National Park	279	0.25
3.3.5	Sugar	2.1.0	Grazing natural vegetation	131	0.12
3.3.5	Sugar	4.4.1	Irrigated tree fruits	106	0.10
1.3.3	Residual native cover	3.3.5	Sugar	103	0.09
2.1.0	Grazing natural vegetation	4.4.1	Irrigated tree fruits	98	0.09
4.3.0	Irrigated Cropping	2.1.0	Grazing natural vegetation	79	0.07
4.5.4	Irrigated vegetables & herbs	4.2.0	Irrigated Modified Pastures	66	0.06
4.4.1	Irrigated tree fruits	1.3.0	Other Minimal Use	64	0.06
6.5.1	Marsh / wetland - conservation	1.1.3	National Park	61	0.06
4.4.0	Irrigated Perennial Horticulture	3.3.5	Sugar	47	0.04
4.4.1	Irrigated tree fruits	2.1.0	Grazing natural vegetation	37	0.03
1.2.0	Managed Resource Protection	1.1.4	Natural feature protection	37	0.03
1.3.0	Other Minimal Use	1.1.3	National Park	37	0.03
4.5.4	Irrigated vegetables & herbs	1.3.0	Other Minimal Use	32	0.03
2.1.0	Grazing natural vegetation	5.2.6	Aquaculture	32	0.03
2.1.0	Grazing natural vegetation	1.3.0	Other Minimal Use	31	0.03
4.3.0	Irrigated Cropping	3.3.5	Sugar	29	0.03
3.3.5	Sugar	1.1.3	National Park	22	0.02
1.1.3	National Park	3.3.5	Sugar	21	0.02
4.4.0	Irrigated Perennial Horticulture	2.1.0	Grazing natural vegetation	20	0.02
4.3.0	Irrigated Cropping	5.4.2	Rural residential	16	0.01
1.3.0	Other Minimal Use	2.1.0	Grazing natural vegetation	16	0.01
6.3.0	River	1.1.3	National Park	14	0.01
1.3.3	Residual native cover	1.3.0	Other Minimal Use	13	0.01
1.3.3	Residual native cover	4.4.1	Irrigated tree fruits	8	0.01
1.3.3	Residual native cover	5.4.2	Rural residential	7	0.01
4.4.1	Irrigated tree fruits	4.3.0	Irrigated Cropping	5	<0.01
1.3.0	Other Minimal Use	5.4.2	Rural residential	5	<0.01
1.3.3	Residual native cover	5.3.0	Manufacturing & Industrial	5	<0.01
2.1.0	Grazing natural vegetation	1.1.3	National Park	4	<0.01
3.3.5	Sugar	4.4.0	Irrigated Perennial Horticulture	4	<0.01
4.5.4	Irrigated vegetables & herbs	4.4.5	Irrigated shrub nuts fruits & berries	3	<0.01
1.3.3	Residual native cover	2.1.0	Grazing natural vegetation	3	<0.01
4.5.4	Irrigated vegetables & herbs	2.1.0	Grazing natural vegetation	2	<0.01
1.3.0	Other Minimal Use	4.4.1	Irrigated tree fruits	2	<0.01
2.1.0	Grazing natural vegetation	5.4.2	Rural residential	1	<0.01
4.5.4	Irrigated vegetables & herbs	3.3.5	Sugar	1	<0.01
5.4.0	Residential	5.5.1	Commercial services	1	<0.01
1.3.0	Other Minimal Use	5.3.0	Manufacturing & Industrial	1	<0.01
2.1.0	Grazing natural vegetation	1.3.3	Residual native cover	<1	<0.01
1.1.3	National Park	6.3.0	River	<1	<0.01
1.3.3	Residual native cover	1.2.0	Managed Resource Protection	<1	<0.01
Total				2,938	2.65

Table 3: Summary statistics for land use changes between the years of 1999 and 2004 in the Murray River catchment

A breakdown of the change classes by area is shown in Table 3. The major changes are *irrigated tree fruits* to *sugar* (474 ha), *other minimal use* to *sugar* (417 ha), *residual native* cover to *national park* (302 ha), *grazing natural vegetation* to *sugar* (301 ha), *marsh/wetland* to *national park* (279 ha) and *sugar* to *grazing natural vegetation* (131 ha).

Accuracy assessment

The accuracy assessment provided reference data suitable for assessing the 1999 and 2004 land use maps and the map describing the change in land use between these two dates. For each of the sample points, the true land class was determined (reference data) based on landholder survey, field work, aerial photograph interpretation, landholder contact or expert knowledge. These points were then compared to the mapped class (map data) and the information summarised in the error matrix. The accuracy is summarised in terms of total accuracy, the Kappa statistic and user's and producer's accuracies. Each accuracy parameter is reported using a point estimate and a 95% posterior interval. Accuracy figures are provided as probabilities between 0 and 1. A value of 1 suggests that the map or specific land use class is 100% accurate based on the reference data.

Total accuracy provides an estimate of the overall accuracy of the map and can be expressed as the probability that a point is mapped correctly. However, it can be misleading, particularly when one class dominates the others. The Kappa statistic attempts to overcome this problem by adjusting for chance agreement. A common rule of thumb suggests a value of Kappa between 0.6 and 0.8 represents moderate agreement between the map and the ground truth, a value greater than 0.8 suggests strong agreement. Values less than 0.2 suggest the map is little better than a map produced by random allocation.

User's and producer's accuracies are *per-class* measures of accuracy. User's accuracy for class *A* is the probability that a point mapped as *A* is truly in class *A*. If we estimated the user's accuracy of class *A* to be 0.91, then from a random sample of 100 points chosen from areas on the map in this class, around 91 would be found to be correct when checked in the field. Producer's accuracy for class *B* is the conditional probability that the map will show a site as class *B* given its true state is class *B*. If the producer's accuracy for class *B* were 0.85, then from a random sample of 100 points known to be in class *B* around 85 would also be in class *B* according to the map. An accurate map should have high user's and producer's accuracies.

Within the user and producer accuracy assessment, the per-class estimates of accuracy are often not very precise, since only part of the total sample points are used to estimate them. As a guide, if the upper bound of the interval for either user's or producer's accuracy is less than 0.5, this can indicate a true misclassification problem, rather than one due to inadequacies in sample size.

Sometimes points that differ between the map and the reference data are due to positional or spatial errors. Inaccurate registration of datasets is an example of spatial error. Thematic errors are the incorrect labelling of an area due to difficulties in determining the true land use in that area, or by oversight or other operational errors. Spatial errors can influence thematic accuracy. The purpose here is to assess the thematic accuracy of land use data. However, the separation of spatial and thematic errors can be difficult and has not been undertaken. As a result, the accuracy assessment reflects properties of the land use data as a whole.

1999 land use data

The original version of the 1999 dataset demonstrated an overall accuracy of 0.88. Accuracy assessment was also undertaken for the improved 1999 land use data using 186 points. The estimated overall accuracy is 0.89 using an informative prior with a 95% posterior interval of (0.79, 0.94).The Kappa statistic is 0.86 (0.75, 0.92).

The analysis used an informative prior for the classes *national park* and *natural feature protection*. These features are not targeted for sampling (although occasionally points do fall into these mapped classes). When low sampling intensities are used within a class, the precision of the estimate is also low. In the case of *national park* and *natural feature protection* we have high confidence that these are rarely incorrectly mapped, and a prior which reflects this confidence is used. The strength of the prior is equivalent to placing 10 additional points within these two classes, and increases the precision of the estimates of these classes. When these classes make up a large proportion of the total map there will be a corresponding increase in precision for the overall summaries. A non-informative prior is used for all other classes.

Table 4 provides the error matrix for the accuracy assessment of the 1999 land use data. For the majority of classes, the reference data agreed with the map data. For example, 39 reference points were identified to be *sugar*. For 30 of those points, the map data was also *sugar* and therefore correct. For 9 points, the map data was incorrect with five points falling onto the mapped class *irrigated perennial horticulture*, three points on *other minimal use* and one point on *grazing natural vegetation.* In this particular case, some of the misclassifications are likely to be a result of rotational practices between sugar, grazing and resting the paddock. For example, the mapper may have seen that sugar wasn't planted in a particular year and assigned the class *grazing natural vegetation*. The accuracy assessor may have looked at the point and seen that, whilst sugar was not grown in 1999, it was planted in the following year and hence the primary land use for that paddock in 1999 is still considered to be sugar.

The column 'propn' in Table 4 is the relative proportion in area of the classes that were assessed, not of the catchment as a whole. The areas of other classes that are not amenable to assessment, for example, nature conservation classes, are removed from the total area before the proportions are calculated. This column will thus sum to 100%.

Table 5 provides the user's and producer's accuracy for the 1999 land use data. The majority of land use classes in this catchment have been mapped accurately. The largest assessable land use class in this catchment is *sugar* which has been mapped with a high user's and producer's accuracy. The user's accuracy is 0.97 and there is a 95% probability that the user's accuracy lies between 0.86 and 1. The next largest class by area is *other minimal use* with user's producer's accuracies of 0.66 and 0.98 respectively. This suggests that some areas mapped as *other minimal* use were actually a different land use. The error matrix (Table 4) provides more detail on the misclassifications. The high producer's accuracy suggests that most areas of actual *other minimal use* have been captured in the map.

Some classes with low accuracies have insufficient sample points to provide precise estimates. For example, the user's accuracy for *irrigated perennial horticulture* is 0.48, however, from the 95% interval (0.23, 0.75) we see that more sample points would be required to confidently determine how accurate this class is.

	Reference Data																			
Map Data	National park	Natural feature protection	Other conserved area	Managed resource protection	Other minimal use	Grazing natural vegetation	Production forestry	Plantation forestry	Sugar	Land in transition	Irrigated perennial horticulture	Irrigated seasonal horticulture	Manufacturing & industrial	Residential	Services	Transport & communication	River	Marsh/wetland	Total	propn (%)
National park	**2**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	31.07
Natural feature protection	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.95
Other conserved area	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0.13
Managed resource protection	0	1	1	**8**	0	0	0	1	0	0	0	0	0	0	0	0	0	0	11	3.60
Other minimal use	0	0	0	0	**22**	4	0	0	3	1	0	0	0	2	0	0	0	1	33	9.66
Grazing natural vegetation	0	0	0	0	0	**14**	0	0	1	0	0	0	0	0	0	0	0	0	15	6.41
Production forestry	0	0	0	0	0	0	**12**	0	0	0	0	0	0	0	0	0	0	0	12	0.32
Plantation forestry	0	0	0	0	0	0	1	**14**	0	0	0	0	0	0	0	0	0	0	15	5.50
Sugar	0	0	0	0	0	1	0	0	**30**	0	0	0	0	0	0	0	0	0	31	13.26
Land in transition	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Irrigated perennial horticulture	0	0	0	0	0	1	0	0	5	0	**6**	0	0	0	0	0	0	0	12	2.34
Irrigated seasonal horticulture	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0.19
Manufacturing & industrial	0	0	0	0	0	0	0	0	0	0	0	0	**7**	0	1	0	0	0	8	0.02
Residential	0	0	0	0	2	0	0	0	0	0	0	0	0	**6**	0	1	0	0	9	0.58
Services	0	0	0	0	0	1	0	0	0	0	0	0	0	2	**7**	0	0	0	10	0.09
Transport & communication	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04
River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**8**	0	8	0.85
Marsh/wetland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**17**	17	2.99
Total	2	1	1	8	24	21	13	15	39	1	7	0	7	11	8	1	9	18	186	100

Table 4: Error matrix for the Murray River catchment 1999 land use dataset

Class	User's			Producer's		
	50%	2.50%	97.50%	50%	2.50%	97.50%
National Park	0.92	0.69	1.00	1.00	0.97	1.00
Natural feature protection	1.00	0.78	1.00	0.99	0.94	1.00
Other conserved area	NA	NA	NA	NA	NA	NA
Managed resource protection	0.72	0.43	0.92	1.00	0.61	1.00
Other minimal use	0.66	0.49	0.81	0.98	0.80	1.00
Grazing natural vegetation	0.93	0.72	1.00	0.77	0.59	0.89
Production forestry	1.00	0.79	1.00	0.47	0.14	0.95
Plantation forestry	0.93	0.72	1.00	0.94	0.74	1.00
Sugar	0.97	0.86	1.00	0.85	0.75	0.91
Land in transition	-	-	-	0.00	0.00	0.00
Irrigated Perennial Horticulture	0.48	0.23	0.75	0.85	0.40	0.95
Irrigated Seasonal Horticulture	NA	NA	NA	NA	NA	NA
Manufacturing & Industrial	0.86	0.53	0.99	1.00	0.01	1.00
Residential	0.65	0.33	0.90	0.34	0.12	0.64
Services	0.69	0.38	0.91	0.93	0.04	1.00
Transport & Communication	NA	NA	NA	NA	NA	NA
River	1.00	0.71	1.00	0.31	0.09	0.90
Marsh / Wetland	1.00	0.85	1.00	0.91	0.61	1.00

Table 5: User's and producer's accuracy for the Murray River catchment 1999 land use dataset

Accuracy estimates based on samples with fewer than two points are not considered sufficiently reliable, and are presented as NA (not available) in the table. Examples of this are *irrigated seasonal horticulture* and *transport & communication*. The class *Land in Transition* was identified as being present in the catchment based on the reference data, but this class was not mapped. There can be no user's accuracy for a class that doesn't appear in the map.

2004 land use data

The 2004 land use dataset was accuracy assessed using 188 points. The informative prior total accuracy is 0.89 (0.81, 0.93) and the Kappa is 0.87 (0.78, 0.92). An explanation for the informative prior is provided in the description of the '1999 Land Use Data' accuracy assessment earlier in this report.

Table 6 provides the error matrix for the accuracy assessment of the 2004 land use data. For the majority of classes, the reference data agreed with the map data. For example, 42 reference points were identified to be *sugar*. For 37 of those points, the map data was also *sugar* and therefore correct. For five of the points the map data was incorrect with two points falling onto the mapped class *other minimal use*, two points on *irrigated perennial horticulture* and one point on *grazing natural vegetation.*

Map Data	National park	Natural feature protection	Other conserved area	Managed resource protection	Other minimal use	Grazing natural vegetation	Production forestry	Plantation forestry	Sugar	Land in transition	Irrigated perennial horticulture	Manufacturing & industrial	Residential	Services	Transport & communication	River	Marsh/wetland	Total	propn (%)
	Reference Data																		
National park	**4**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	5	31.71
Natural feature protection	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	23.00
Other conserved area	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0.13
Managed resource protection	0	0	1	**8**	0	0	0	1	0	0	0	0	0	0	0	0	0	10	3.57
Other minimal use	0	0	0	0	**19**	3	0	0	2	2	1	0	1	0	0	0	1	29	8.98
Grazing natural vegetation	0	0	0	0	0	**13**	0	0	1	0	0	0	0	0	0	0	0	14	6.28
Production forestry	0	0	0	0	0	0	**12**	0	0	0	0	0	0	0	0	0	0	12	0.32
Plantation forestry	0	0	0	0	0	0	1	**14**	0	0	0	0	0	0	0	0	0	15	5.51
Sugar	0	0	0	0	2	1	0	0	**37**	0	0	0	0	0	0	0	0	40	14.24
Land in transition	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Irrigated perennial horticulture	0	0	0	0	0	2	0	0	2	0	**3**	0	0	0	0	0	0	7	1.97
Manufacturing & industrial	0	0	0	0	0	0	0	0	0	0	0	**7**	0	2	0	0	0	9	0.02
Residential	0	0	0	0	3	0	0	0	0	0	0	0	**7**	0	1	0	0	11	0.61
Services	0	0	0	0	0	1	0	0	0	0	0	0	2	**7**	0	0	0	10	0.09
Transport & communication	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04
River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**8**	0	8	0.84
Marsh/wetland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**16**	16	2.69
Total	4	0	1	9	24	20	13	15	42	2	4	7	11	9	1	9	17	188	100

Table 6: Error matrix for the Murray River catchment 2004 land use dataset

Table 7 provides the user's and producer's accuracy for the 2004 Murray catchment land use data. The majority of land use classes in this catchment have been mapped accurately. The largest assessable land use class in this catchment is *sugar* which has been mapped with a high user's and producer's accuracy. The next largest class by area is *other minimal use* with user's and producer's accuracies of 0.66 and 0.88 respectively. This suggests that some areas mapped as *other minimal* use were actually a different land use. The error matrix (Table 6) provides more detail on the misclassifications. The high producer's accuracy suggests that most areas of actual *other minimal use* have been captured in the map. The next major class by area is *grazing natural vegetation* with user's and producer's accuracies of 0.95 and 0.77 respectively.

Some classes with low accuracies have insufficient sample points to provide precise estimates. The producer's accuracy for *residential* is 0.50, however, from the 95% interval (0.21, 0.74) we see that more sample points would be required to confidently determine how accurate this class is. Other classes with a relatively low accuracy and very large confidence intervals are *production forestry* (producer's 0.55) and *river* (producer's 0.36).

Class	User's			Producer's		
	50%	2.50%	97.50%	50%	2.50%	97.50%
National park	0.95	0.76	1.00	1.00	1.00	1.00
Natural feature protection	0.93	0.69	1.00	1.00	1.00	1.00
Other conserved area	NA	NA	NA	NA	NA	NA
Managed resource protection	0.82	0.52	0.97	0.64	0.28	0.98
Other minimal use	0.66	0.48	0.82	0.88	0.73	0.96
Grazing natural vegetation	0.95	0.77	1.00	0.77	0.62	0.89
Production forestry	1.00	0.99	1.00	0.55	0.20	0.97
Plantation forestry	0.95	0.76	1.00	0.95	0.81	1.00
Sugar	0.93	0.82	0.98	0.90	0.81	0.96
Land in transition	-	-	-	0.00	0.00	0.00
Irrigated perennial horticulture	0.42	0.12	0.78	0.78	0.33	0.99
Manufacturing & industrial	0.80	0.48	0.97	1.00	1.00	1.00
Residential	0.64	0.34	0.88	0.50	0.21	0.74
Services	0.71	0.40	0.92	0.92	0.80	0.99
Transport & communication	NA	NA	NA	NA	NA	NA
River	1.00	0.98	1.00	0.36	0.10	0.93
Marsh/wetland	1.00	0.99	1.00	0.92	0.70	1.00

Table 7: User's and producer's accuracy for the Murray River catchment 2004 land use dataset

1999 to 2004 land use change data

The accuracy of the change layer was assessed using 183 points. The user's and producer's accuracy for the land use change data is provided in Table 8.

Based on the mapping approximately 2.65% of the catchment has changed. The accuracy of the areas mapped as land use change was estimated to be 0.40 with a 95% credible interval of (0.20, 0.61). This suggests that a considerable proportion mapped as land use change was not actually a change. These estimates are based on 17 reference points in the mapped land use change areas, 6 of those points were considered to be an actual change and 11 points were considered not a land use change. However, differentiating a land use change and a crop rotation (management change) can be subjective. For 3 of the 11 points the mapper identified a change involving *sugar* (from *grazing* or *other minimal use* to *sugar*). The assessor viewed these as a short-term rotation with the field still being managed for *sugar* and classed as such. Similarly, one area mapped as *other minimal* use in 1999 and *grazing* in 2004 was considered to be grazed in both 1999 and 2004 by the assessor. The majority of the land use change map from 1999 to 2004 for the Murray River catchments shows areas which have changed. However, in some cases these changes are likely to be short-term rotations (eg. *sugar* to *grazing*) and not a longer term land use change.

There is a high probability that areas mapped as non-change actually did not change (0.99) with a 95% posterior interval of (0.97, 1). Further, areas that did not change based on the reference data have a high probability of being mapped correctly (0.99) with a 95% posterior interval of (0.98, 0.99).

Data	User's			Producer's		
	50.00%	2.50%	97.50%	50.00%	2.50%	97.50%
Change	0.40	0.20	0.61	0.60	0.22	0.94
No Change	0.99	0.97	1.00	0.99	0.98	0.99

Table 8: User's and producer's accuracy for the Murray River catchment 1999 to 2004 land use change dataset

Metadata

Metadata documents have been produced for the improved 1999 and the 2004 land use datasets, as well as 1999 to 2004 land use change data and can be found on the Australian Spatial Data Directory at http://asdd.ga.gov.au/.

Data format and availability

The land use datasets are stored in raster format (.img files) with a pixel size of 25m.

Digital copies of the 1999 land use data, the 2004 land use data and the 1999 to 2004 land use change data and the metadata documents can be obtained from the NRSc data coordinator (NRScDataCoordinator@nrw.qld.gov.au).

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Appendix 1: ALUM classification version 6

1 Conservation and Natural Environments

1.1.0 Nature conservation
- 1.1.1 Strict nature reserves
- 1.1.2 Wilderness area
- 1.1.3 National park
- 1.1.4 Natural feature protection
- 1.1.5 Habitat/species management area
- 1.1.6 Protected landscape
- 1.1.7 Other conserved area

1.2.0 Managed resource protection
- 1.2.1 Biodiversity
- 1.2.2 Surface water supply
- 1.2.3 Groundwater
- 1.2.4 Landscape
- 1.2.5 Traditional indigenous uses

1.3.0 Other minimal use
- 1.3.1 Defence
- 1.3.2 Stock route
- 1.3.3 Residual native cover
- 1.3.4 Rehabilitation

2 Production from Relatively Natural Environments

2.1.0 Grazing natural vegetation

2.2.0 Production forestry
- 2.2.1 Wood production
- 2.2.2 Other forest production

3 Production from Dryland Agriculture and Plantations

3.1.0 Plantation forestry
- 3.1.1 Hardwood production
- 3.1.2 Softwood production
- 3.1.3 Other forest production
- 3.1.4 Environmental

3.2.0 Grazing modified pastures
- 3.2.1 Native/exotic pasture mosaic
- 3.2.2 Woody fodder plants
- 3.2.3 Pasture legumes
- 3.2.4 Pasture legume/grass mixtures
- 3.2.5 Sown grasses

3.3.0 Cropping
- 3.3.1 Cereals
- 3.3.2 Beverage & spice crops
- 3.3.3 Hay & silage
- 3.3.4 Oil seeds
- 3.3.5 Sugar
- 3.3.6 Cotton
- 3.3.7 Tobacco
- 3.3.8 Legumes

3.4.0 Perennial horticulture
- 3.4.1 Tree fruits
- 3.4.2 Oleaginous fruits
- 3.4.3 Tree nuts
- 3.4.4 Vine fruits
- 3.4.5 Shrub nuts fruits & berries
- 3.4.6 Flowers & bulbs
- 3.4.7 Vegetables & herbs

3.5.0 Seasonal horticulture
- 3.5.1 Fruits
- 3.5.2 Nuts
- 3.5.3 Flowers & bulbs
- 3.5.4 Vegetables & herbs

3.6.0 Land in transition
- 3.6.1 Degraded land
- 3.6.2 Abandoned land
- 3.6.3 Land under rehabilitation
- 3.6.4 No defined use

4 Production from Irrigated Agriculture and Plantations

4.1.0 Irrigated plantation forestry
- 4.1.1 Irrigated hardwood production
- 4.1.2 Irrigated softwood production
- 4.1.3 Irrigated other forest production
- 4.1.4 Irrigated environmental

4.2.0 Irrigated modified pastures
- 4.2.1 Irrigated woody fodder plants
- 4.2.2 Irrigated pasture legumes
- 4.2.3 Irrigated legume/grass mixtures
- 4.2.4 Irrigated sown grasses

4.3.0 Irrigated cropping
- 4.3.1 Irrigated cereals
- 4.3.2 Irrigated beverage & spice crops
- 4.3.3 Irrigated hay & silage
- 4.3.4 Irrigated oil seeds
- 4.3.5 Irrigated sugar
- 4.3.6 Irrigated cotton
- 4.3.7 Irrigated tobacco
- 4.3.8 Irrigated legumes

4.4.0 Irrigated perennial horticulture
- 4.4.1 Irrigated tree fruits
- 4.4.2 Irrigated oleaginous fruits
- 4.4.3 Irrigated tree nuts
- 4.4.4 Irrigated vine fruits
- 4.4.5 Irrigated shrub nuts fruits & berries
- 4.4.6 Irrigated flowers & bulbs
- 4.4.7 Irrigated vegetables & herbs

4.5.0 Irrigated seasonal horticulture
- 4.5.1 Irrigated fruits
- 4.5.2 Irrigated nuts
- 4.5.3 Irrigated flowers & bulbs
- 4.5.4 Irrigated vegetables & herbs

4.6.0 Irrigated land in transition
- 4.6.1 Degraded irrigated land
- 4.6.2 Abandoned irrigated land
- 4.6.3 Irrigated land under rehabilitation
- 4.6.4 No defined use (irrigation)

5 Intensive Uses

5.1.0 Intensive horticulture
- 5.1.1 Shadehouses
- 5.1.2 Glasshouses
- 5.1.3 Glasshouses (hydroponic)

5.2.0 Intensive animal production
- 5.2.1 Dairy
- 5.2.2 Cattle
- 5.2.3 Sheep
- 5.2.4 Poultry
- 5.2.5 Pigs
- 5.2.6 Aquaculture

5.3.0 Manufacturing and industrial

5.4.0 Residential
- 5.4.1 Urban residential
- 5.4.2 Rural residential
- 5.4.3 Rural living

5.5.0 Services
- 5.5.1 Commercial services
- 5.5.2 Public services
- 5.5.3 Recreation and culture
- 5.5.4 Defence facilities
- 5.5.5 Research facilities

5.6.0 Utilities
- 5.6.1 Electricity generation/transmission
- 5.6.2 Gas treatment, storage and transmission

5.7.0 Transport and communication
- 5.7.1 Airports/aerodromes
- 5.7.2 Roads
- 5.7.3 Railways
- 5.7.4 Ports and water transport
- 5.7.5 Navigation and communication

5.8.0 Mining
- 5.8.1 Mines
- 5.8.2 Quarries
- 5.8.3 Tailings

5.9.0 Waste treatment and disposal
- 5.9.1 Stormwater
- 5.9.2 Landfill
- 5.9.3 Solid garbage
- 5.9.4 Incinerators
- 5.9.5 Sewage

6 Water

6.1.0 Lake
- 6.1.1 Lake - conservation
- 6.1.2 Lake - production
- 6.1.3 Lake - intensive use

6.2.0 Reservoir/dam
- 6.2.1 Reservoir
- 6.2.2 Water storage - intensive use/farm dams
- 6.2.3 Evaporation basin
- 6.2.4 Effluent pond

6.3.0 River
- 6.3.1 River - conservation
- 6.3.2 River - production
- 6.3.3 River - intensive use

6.4.0 Channel/aqueduct
- 6.4.1 Supply channel/aqueduct
- 6.4.2 Drainage channel/aqueduct

6.5.0 Marsh/wetland
- 6.5.1 Marsh/wetland - conservation
- 6.5.2 Marsh/wetland - production
- 6.5.3 Marsh/wetland - intensive use

6.6.0 Estuary/coastal waters
- 6.6.1 Estuary/coastal waters - conservation
- 6.6.2 Estuary/coastal waters - production
- 6.6.3 Estuary/coastal waters - intensive use

minimum level of attribution

Note that tertiary level cropping and horticulture classes (e.g. cereals and irrigated tree fruits) are attributed during the change mapping from 1999 to 2004 whenever possible. Dairies and rural residential areas are also attributed at the tertiary level.

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