FARM PRACTICES SURVEY REPORT 2016

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

NATIONAL

Title: **GRDC Farm Practices Survey Report 2016**

This report outlines the adoption of key management practices used in Australian grain-growing regions. Specific practices include:

- **cropped area;**
- **crop sequencing with pastures, oilseeds and pulses;**
- **reduced or no-tillage;**
- **precision agriculture;**
- **fallow management;**
- **stubble retention;**
- **soil management;**
- **fertiliser management and soil testing;**
- **use of soil conditioners;**
- **managing soil water; and**
- **grain storage, herbicide use and quality assurance program use.**

Author

Alan Umbers
Grains Research & Development Corporation (GRDC)
PO Box 5367
KINGSTON ACT 2604

P: 02 6166 4500

Survey data

Pam Watson & Daniel Watson
Down to Earth Research Pty Ltd (DTER)
10 Caladenia Circuit
FRANKSTON SOUTH VICTORIA 3199

P: 03 9708 8008
E: pam@dter.com.au

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Enquiries to:

Ms Maureen Cribb
GRDC Manager Integrated Publications
PO Box 5367
KINGSTON ACT 2604

T: 02 6166 4500
E: maureen.cribb@grdc.com.au

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Foreword

Australian grain growers continue to demonstrate their resourcefulness and success in managing what has been a run of challenging seasons. Farming practices are constantly changing to match the challenge of seasonal conditions and commodity markets.

The adoption of sustainable practices in tillage, fertiliser application, crop residue management, integrated pest, disease and weed management, rotations, precision agriculture, and others has contributed to the profitability and resilience of grain growing farm businesses.

The Grains Research and Development Corporation (GRDC), invests around $190 million of grain grower levies and government funds each year in research, development and extension (RD&E) to create enduring profitability for Australian grain growers. Of this, around $40 million is invested in farm management practice RD&E to provide grain growers with better tools and information to enhance farm profit, productivity and sustainability through the development and adoption of improved technology on-farm, implemented by growers in their farming system.

This is the fourth GRDC Farm Practice Survey report. The GRDC with the assistance of Down to Earth Research conducted a national survey of growers to capture information about the farming practices currently in use on grain and mixed farms across Australia.

The report provides quantitative data to monitor and evaluate the adoption levels of farming systems and key on-farm management practices by grain growers across Australia. These practices are important to drive profitability, productivity, sustainability and environmental improvements on grain farms. It helps the GRDC identify successes and gaps, and assists the GRDC direct future investments and modify existing projects.

The GRDC will continue to work with growers, advisers and research partners to improve adoptionof research and development. We do this to ensure that this investment in RD&E creates enduring profibability for Australian grain growers.

Brondwen MacLean
General Manager, Applied Research and Development
Grains Research and Development Corporation

Contents

FOREWORD	3
CONTENTS	4
INDEX OF TABLES	7
INDEX OF FIGURES	9
EXECUTIVE SUMMARY	12
FARM SIZE IN 2016	12
AREA OF CROP PER FARM IN 2016	12
PROPORTION OF CROP PER FARM IN 2016	12
CROP MIX IN 2016	12
TILLAGE IN 2016	12
PRECISION AGRICULTURE IN 2016	12
FALLOW MANAGEMENT IN 2016	12
STUBBLE MANAGEMENT IN 2016	12
CROP SEQUENCING IN 2016	12
SOIL MANAGEMENT IN 2016	13
LIME USE	13
SOIL TESTING (NUTRITION)	13
FERTILISER PLANNING AND USE	13
SOIL MOISTURE MANAGEMENT	13
MISCELLANEOUS QUESTIONS IN 2016	13
GRAIN FARM STATISTICS	14
NUMBER OF GRAIN FARMS AND TOTAL AREA OF FARMLAND	14
FARM SIZE	15
AREA OF CROP IN THE SURVEY	15
AREA OF CROP PER FARM	17
USE OF FARMLAND	18
PROPORTION OF CROP PER FARM	18
PROPORTION OF PASTURE PER FARM	19
PROPORTION OF NATIVE VEGETATION PER FARM	20
FARMLAND WITH A VEGETATION PLAN	22
PURPOSE OF VEGETATION PLAN	22
Vegetation plan to assist with crop production	22
Vegetation plan to provide additional income	22
Vegetation plan to conserve native vegetation for biodiversity or amenity value	22
CROP MIX IN 2016	23
WHEAT	23
BARLEY	24
OTHER WINTER CEREALS	25
SUMMER CEREALS	26
OILSEEDS	27
PULSES	27
TOTAL CROP MIX	29
NATIONAL TRENDS	29

TILLAGE IN 2016	34
ZERO-TILLAGE	34
NO-TILLAGE	35
ZERO AND NO-TILLAGE COMBINED	37
DIRECT-DRILL	38
ZERO-TILLAGE, NO-TILLAGE AND DIRECT-DRILL COMBINED ('ONE-PASS' PLANTING)	40
MINIMUM-TILLAGE	43
MULTIPLE TILLAGE (CONVENTIONAL CULTIVATION)	43
PRECISION AGRICULTURE IN 2016	44
CONTROLLED TRAFFIC	44
AUTOSTEER	44
VARIABLE RATE TECHNOLOGY	45
VARIABLE RATE SEED TECHNOLOGY	47
VARIABLE RATE FERTILISER TECHNOLOGY	47
YIELD MAPPING	48
USE OF OTHER REMOTE-SENSING TECHNOLOGIES.	50
FALLOW MANAGEMENT IN 2016	52
PROPORTION OF GRAIN FARMS WHERE A FALLOW WAS A FEATURE OF THE 2014 CROP	53
Fallow managed without tillage through the fallow period	54
Fallow managed by herbicide only	56
Fallow managed by cultivation	56
LIVESTOCK GRAZING OF THE FALLOW	56
STUBBLE MANAGEMENT IN 2016	57
STUBBLE RETAINED THROUGH TO PLANTING	57
Stubble retained intact (standing) through to planting	58
Stubble retained (not necessarily standing)	59
STUBBLE BURNT	60
Stubble burnt early ('hot' burn)	62
Stubble burnt late prior to planting ('cool' burn)	63
WINDROW BURNING	64
STUBBLE INCORPORATED BY CULTIVATION	64
CROP SEQUENCING IN 2016	65
PREVIOUS CROP TYPE WHERE A CEREAL WAS PLANTED IN 2016 (OR OTHER SURVEY YEAR)	65
Summary	65
CEREAL PLANTED FOLLOWING A CANOLA CROP	66
CEREAL SOWN FOLLOWING A PREVIOUS PULSE CROP	66
CEREALS SOWN FOLLOWING A PREVIOUS LEGUME-DOMINANT PASTURE	67
PLANTED FOLLOWING A LONG FALLOW	68
PERCENTAGE OF CROP PLANTED TO ASSIST WITH WEED CONTROL	71
PERCENTAGE OF CROP PLANTED TO ASSIST WITH DISEASE CONTROL	72
PERCENTAGE OF CROP PLANTED (BREAK CROP) SOWN FOR NUTRITIONAL REASONS	73
SOIL MANAGEMENT IN 2016	76
CROPS SOWN IN 2016 WHERE LIME WAS APPLIED IN THE PERIOD LEADING TO SOWING	77
Percentage of grain farms applying lime in 2016	77
AMOUNT OF LIME APPLIED	78

SOIL TESTING FOR NUTRITION MANAGEMENT 80
Average percentage of cropped area soil tested 80
Average percentage of winter cereal crop area soil tested 81
Average percentage of pulse crop area soil tested 82
Average percentage of oilseed crop area soil tested 82
Average percentage of cropped area soil tested only to 10cm deep in 2016 82
Average percentage of cropped area having a deep soil test in the past 5 years 83
Average percentage of crop area where the fertiliser program in 2016 was informed by soil testing 85
Average percentage of crop area where fertiliser rates applied in 2016 were based on estimates of nutrient removal by the crop 86
Average percentage of crop area having an in-season soil test in 2016 87
Average percentage of crop area with plant testing in 2016 88
Average percentage of crop area receiving an in-season application (top-dressing) of fertiliser in 2016 88

SOIL MOISTURE MANAGEMENT IN 2016 89

ASSESSMENT OF SOIL MOISTURE AT PLANTING TO ASSIST IN CROP DECISIONS 89
PROPORTION OF CROP WHERE PLANT-AVAILABLE WATER WAS ASSESSED THROUGH THE CROP PERIOD 90

MISCELLANEOUS QUESTIONS IN 2016 92

AVERAGE GRAIN STORAGE CAPACITY ON FARMS IN 2016 92
AVERAGE PERCENTAGE OF FARM AREA TESTED FOR PRESENCE OF NEMATODES IN THE PAST 5 YEARS 92
AVERAGE PERCENTAGE OF FARM AREA KNOWN TO BE AFFECTED BY HERBICIDE-RESISTANT WEEDS 93
AVERAGE PERCENTAGE OF CROP AREA PLANTED IN SUCH A WAY TO ASSIST WITH WEED COMPETITION 94
AVERAGE PERCENTAGE OF THE FALLOW AREA WHERE THE DOUBLE-KNOCK WEED MANAGEMENT TECHNIQUE HAS BEEN USED 95
AVERAGE PERCENTAGE OF FALLOW AREA WHERE TILLAGE HAS BEEN THE SECOND KNOCK WHERE DOUBLE KNOCK WAS USED 96
AVERAGE PERCENTAGE OF FARM AREA WHERE NON-HERBICIDE TECHNIQUES WERE USED FOR MANAGEMENT OF HERBICIDE-RESISTANT WEEDS 96
AVERAGE PERCENTAGE OF FALLOW AREA WHERE RESIDUAL HERBICIDES HAVE BEEN USED 97
AVERAGE PERCENTAGE OF CROP AREA WHERE GROUP A HERBICIDES WERE USED IN 2016 98
AVERAGE PERCENTAGE OF CROP AREA WHERE GROUP B HERBICIDES HAVE BEEN USED IN 2016 99
AVERAGE PERCENTAGE OF FARMS WITH A QUALITY OR ENVIRONMENTAL ASSURANCE PROGRAM THAT ASSISTS IN MARKET ACCESS OR DERIVING A PRICE PREMIUM 99

NOTES 101

GRDC

Index of tables

TABLE 1 SAMPLE SIZE AND TOTAL FARMLAND AREA (HA) REPRESENTED IN THE SURVEY DATA BY AGRO-ECOLOGICAL ZONE IN 2008, 2011, 2015 AND 2016. 14

TABLE 2 AVERAGE FARM SIZE (HA) WITHIN AGRO-ECOLOGICAL ZONES IN 2008, 2011, 2014 AND 2016. 15

TABLE 3 TOTAL CROP AREA (HA) IN 2008, 2011, 2014 AND 2016 GRDC SURVEYS. 17

TABLE 5 AVERAGE AREA (HA) OF CROP PER FARM. 17

TABLE 4 TOTAL CROP AREA (HA) IN 2016, SURVEYED IN 2014 AND 2016 SURVEYED AREA AS % OF 2016 CROP AREA BY AGRO-ECOLOGICAL ZONE. 17

TABLE 7 AVERAGE PERCENTAGE OF FARM AREA MAINTAINED AS PASTURE. 19

TABLE 6 AVERAGE PERCENTAGE OF FARM AREA CROPPED. 19

TABLE 8 PERCENTAGE OF FARMS WITH A VEGETATION PLAN. 21

TABLE 9 PERCENTAGE OF FARMS WITH A VEGETATION PLAN TO ASSIST WITH CROP PRODUCTION. 21

TABLE 10 PERCENTAGE OF FARMS WITH A VEGETATION PLAN TO PROVIDE ADDITIONAL INCOME. 22

TABLE 11 PERCENTAGE OF FARMS WITH A VEGETATION PLAN TO CONSERVE AN AREA OF NATIVE VEGETATION FOR BIODIVERSITY OR AMENITY BENEFIT. 22

TABLE 12 AVERAGE PERCENTAGE OF CROP AREA PLANTED TO WHEAT. 23

TABLE 13 AVERAGE PERCENTAGE OF CROP AREA PLANTED TO BARLEY. 24

TABLE 14 AVERAGE PERCENTAGE OF CROP AREA PLANTED TO OTHER WINTER CEREALS. 26

TABLE 15 AVERAGE PERCENTAGE OF CROP AREA PLANTED TO SUMMER CEREALS. 27

TABLE 16 AVERAGE PERCENTAGE OF CROP AREA PLANTED TO WINTER OILSEEDS. 27

TABLE 17 AVERAGE PERCENTAGE OF CROP AREA PLANTED TO PULSES. 28

TABLE 18 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED WITH THE MAJOR CROPS IN 2008. 29

TABLE 19 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED WITH THE MAJOR CROPS IN 2011. 30

TABLE 20 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED WITH THE MAJOR CROPS IN 2014. 31

TABLE 21 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED WITH THE MAJOR CROPS IN 2016. 32

TABLE 22 AVERAGE NATIONAL PERCENTAGE OF CROPPED AREA PLANTED WITH THE MAJOR CROPS IN 2008, 2011, 2014 AND 2016. 32

TABLE 23 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED USING ZERO-TILLAGE (LESS THAN 10% SOIL DISTURBANCE). 35

TABLE 24 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED USING NO-TILLAGE (BETWEEN 10% AND 30% SOIL DISTURBANCE). 36

TABLE 25 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED USING ZERO-TILLAGE OR NO-TILLAGE (LESS THAN 30% SOIL DISTURBANCE). 37

TABLE 26 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED USING DIRECT DRILL. 38

TABLE 27 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED USING ONE PASS PLANTING (ZERO-TILLAGE, NO-TILLAGE OR DIRECT-DRILL). 39

TABLE 28 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED USING MINIMUM TILLAGE TECHNIQUES. 40

TABLE 29 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED USING MULTIPLE-TILLAGE TECHNIQUES. 42

TABLE 30 AVERAGE PERCENTAGE OF CROPPED AREA WHERE CONTROLLED TRAFFIC (CT) WAS USED. 45

TABLE 31 AVERAGE PERCENTAGE OF CROPPED AREA WHERE AUTOSTEER WAS USED. 46

TABLE 32 AVERAGE PERCENTAGE OF CROPPED AREA WHERE VARIABLE RATE SEED TECHNOLOGY WAS USED. 47

TABLE 33 AVERAGE PERCENTAGE OF CROPPED AREA WHERE VARIABLE RATE FERTILISER TECHNOLOGY WAS USED. 47

TABLE 34 AVERAGE PERCENTAGE OF CROPPED AREA WHERE YIELD MAPPING WAS USED IN 2008, 2011, 2014 AND 2016. 48

TABLE 35 AVERAGE PERCENTAGE OF CROPPED AREA WHERE REMOTE SENSING (USING EM38 OR NDVI) WAS USED IN 2014 AND 2016. 49

TABLE 36 AVERAGE PERCENTAGE OF FARMS USING A FALLOW PERIOD. 52

TABLE 37 AVERAGE PERCENTAGE OF FALLOW AREA MANAGED WITHOUT TILLAGE. 54

TABLE 38 AVERAGE PERCENTAGE OF FALLOW AREA MANAGED ONLY WITH HERBICIDES. 54

TABLE 39 AVERAGE PERCENTAGE OF FALLOW AREA MANAGED BY CULTIVATION (BASE: USED FALLOW PERIOD). 55

TABLE 40 AVERAGE PERCENTAGE OF FALLOW AREA MANAGED BY GRAZING WITH LIVESTOCK (BASE: USED FALLOW PERIOD). 55

TABLE 41 AVERAGE PERCENTAGE OF CROPPED AREA WHERE STUBBLE WAS RETAINED THROUGH TO PLANTING AS REPORTED IN THE SURVEYS OF 2011 AND 2014. 57

TABLE 42 AVERAGE PERCENTAGE OF CROPPED AREA WHERE STUBBLE WAS RETAINED INTACT THROUGH TO PLANTING 2011 TO 2016. 58
TABLE 43 AVERAGE PERCENTAGE OF CROPPED AREA WHERE STUBBLE WAS RETAINED (NOT STANDING) THROUGH TO PLANTING. 59
TABLE 44 AVERAGE PERCENTAGE OF CROPPED AREA WHERE STUBBLE WAS BURNT EARLY (HOT BURN). 60
TABLE 45 AVERAGE PERCENTAGE OF CROPPED AREA WHERE STUBBLE WAS BURNT LATE (COOL BURN). 61
TABLE 46 AVERAGE PERCENTAGE OF CROPPED AREA WHERE STUBBLE WAS HARVESTED TO PRODUCE WINDROWS, THEN BURNT LATER. 62
TABLE 47 AVERAGE PERCENTAGE OF CROPPED AREA WHERE STUBBLE WAS INCORPORATED INTO SOIL USING TILLAGE. 62
TABLE 48 AVERAGE PERCENTAGE OF CEREAL CROP AREA PLANTED IN 2011 FOLLOWING CANOLA, PULSES OR LEGUME-BASED PASTURE. 66
TABLE 49 AVERAGE PERCENTAGE OF CEREAL CROP AREA PLANTED IN 2014 FOLLOWING CANOLA, PULSES OR LEGUME-BASED PASTURE. 66
TABLE 50 AVERAGE PERCENTAGE OF CEREAL CROP AREA PLANTED IN 2016 FOLLOWING CANOLA, PULSES OR LEGUME-BASED PASTURE. 67
TABLE 51 AVERAGE PERCENTAGE OF CEREAL CROP AREA PLANTED FOLLOWING CANOLA OR PULSES OR LEGUME-BASED PASTURE IN 2011, 2014 AND 2016. 67
TABLE 52 AVERAGE PERCENTAGE OF CEREAL CROP AREA PLANTED FOLLOWING CANOLA IN PREVIOUS YEAR. 68
TABLE 53 AVERAGE PERCENTAGE OF CEREAL CROP AREA PLANTED FOLLOWING A PULSE CROP IN PREVIOUS YEAR. 70
TABLE 54 AVERAGE PERCENTAGE OF CEREAL CROP AREA PLANTED FOLLOWING A LEGUME-DOMINANT PASTURE IN PREVIOUS YEAR. 71
TABLE 55 AVERAGE PERCENTAGE OF CEREAL CROP AREA PLANTED AFTER LONG FALLOW. 71
TABLE 56 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED WITH A BREAK CROP SPECIFICALLY FOR WEED CONTROL 73
TABLE 57 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED WITH A BREAK CROP SPECIFICALLY FOR DISEASE CONTROL. 73
TABLE 58 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED WITH A BREAK CROP SPECIFICALLY FOR NUTRITIONAL BENEFITS IN 2014 AND 2016. 75
TABLE 59 AVERAGE PERCENTAGE OF CROP AREA WHERE LIME WAS APPLIED. 76
TABLE 60 AVERAGE USE RATE OF LIME (T/HA) ON AREA WHERE IT WAS APPLIED. 77
TABLE 61 AVERAGE PERCENTAGE OF CROP AREA SOIL TESTED. 78
TABLE 62 AVERAGE PERCENTAGE OF WINTER CEREAL CROP AREA SOIL TESTED. 78
TABLE 63 AVERAGE PERCENTAGE OF PULSE CROP AREA SOIL TESTED. 80
TABLE 64 AVERAGE PERCENTAGE OF OILSEED CROP AREA SOIL TESTED. 80
TABLE 65 AVERAGE PERCENTAGE OF CROPPED AREA SOIL TESTED ONLY TO A DEPTH OF 10CM. 82
TABLE 66 AVERAGE PERCENTAGE OF CROPPED AREA HAVING DEEP SOIL TEST IN THE PAST 5 YEARS. 82
TABLE 67 AVERAGE PERCENTAGE OF CROP AREA WHERE THE FERTILISER PROGRAM WAS INFORMED BY SOIL TESTING. 84
TABLE 68 AVERAGE PERCENTAGE OF CROP AREA TREATED WITH FERTILISER AT RATES BASED ON ESTIMATES OF NUTRIENT REMOVAL RATES BY THE CROP. 85
TABLE 69 AVERAGE PERCENTAGE OF CROP AREA HAVING AN IN-SEASON SOIL TEST IN 2014 AND 2016. 86
TABLE 70 AVERAGE PERCENTAGE OF CROP AREA HAVING A LEAF OR PETIOLE TEST. 87
TABLE 71 AVERAGE PERCENTAGE OF CROP AREA HAVING AN IN-SEASON APPLICATION OR TOP-DRESSING OF FERTILISER. 88
TABLE 72 AVERAGE PERCENTAGE OF CROP AREA WHERE PLANT-AVAILABLE WATER WAS ASSESSED AT PLANTING. 89
TABLE 73 AVERAGE PERCENTAGE OF CROP AREA WHERE SOIL MOISTURE WAS MEASURED OR ASSESSED THROUGH THE SEASON. 90
TABLE 74 AVERAGE TONNES OF GRAIN THAT CAN BE STORED ON-FARM. 92
TABLE 75 AVERAGE PERCENTAGE OF FARM AREA TESTED FOR NEMATODES IN THE PAST FIVE YEARS. 93
TABLE 76 AVERAGE PERCENTAGE OF FARM AREA KNOWN TO BE AFFECTED BY HERBICIDE-RESISTANT WEEDS. 93
TABLE 77 AVERAGE PERCENTAGE OF CROP AREA PLANTED TO ASSIST WITH WEED COMPETITION (E.G. HIGHER SEEDING RATE OR NARROWER ROW SPACING) IN 2016. 94
TABLE 78 AVERAGE PERCENTAGE OF FALLOW AREA WHERE THE DOUBLE-KNOCK HERBICIDE TECHNIQUE HAS BEEN USED. 94
TABLE 79 AVERAGE PERCENTAGE OF FALLOW AREA WHERE TILLAGE HAS BEEN USED AS THE SECOND KNOCK IN A DOUBLE KNOCK. 96

TABLE 80 AVERAGE PERCENTAGE OF FARM AREA WHERE NON-HERBICIDE TECHNIQUES HAVE BEEN USED TO HELP MANAGEMENT OF HERBICIDE-RESISTANT WEEDS. 97
TABLE 81 AVERAGE PERCENTAGE OF FALLOW AREA WHERE RESIDUAL HERBICIDES HAVE BEEN USED. 97
TABLE 82 AVERAGE PERCENTAGE OF CROP AREA WHERE GROUP A HERBICIDES WERE USED. 98
TABLE 83 AVERAGE PERCENTAGE OF CROP AREA WHERE GROUP B HERBICIDES WERE USED. 98
TABLE 84 AVERAGE PERCENTAGE OF FARMS WITH A QUALITY OR ENVIRONMENTAL ASSURANCE PROGRAM THAT ASSISTS IN MARKET ACCESS OR DERIVING A PRICE PREMIUM. 100

Index of Figures

FIGURE 1 FARM SIZE TRENDS (HA) WITHIN AGRO-ECOLOGICAL ZONES FOR 2008, 2011 AND 2016. 15
FIGURE 2 AVERAGE FARM SIZE IN 2016. 16
FIGURE 3 AVERAGE AREA OF CROP (HA) PER FARM 2008–16. 16
FIGURE 4 AREA OF CROP PER FARM (HA) BY AGRO-ECOLOGICAL ZONE. 16
FIGURE 5 AVERAGE PERCENTAGE OF FARM AREA CROPPED. 18
FIGURE 6 PROPORTION OF FARM AREA CROPPED IN 2016. 18
FIGURE 7 AVERAGE PROPORTION (%) OF LAND UNDER PASTURE ON GRAIN FARMS, 2008–14. 20
FIGURE 8 PROPORTION OF PASTURE (% OF FARM AREA) WITHIN AGRO-ECOLOGICAL ZONES IN 2014. 20
FIGURE 9 PERCENTAGE OF GRAIN/MIXED FARMS WITH A VEGETATION PLAN IN 2014. 21
FIGURE 10 AVERAGE PERCENTAGE OF CROP AREA PLANTED TO WHEAT 2008–16. 24
FIGURE 11 PERCENTAGE OF CROPPED AREA PLANTED TO WHEAT IN 2016. 25
FIGURE 12 AVERAGE PERCENTAGE OF BARLEY (% OF CROPPED AREA) IN 2008, 2011, 2014 AND 2016. 25
FIGURE 13 PERCENTAGE OF CROPPED AREA PLANTED TO BARLEY IN 2016. 25
FIGURE 14 AVERAGE PERCENTAGE OF OTHER WINTER CEREALS IN 2008, 2011, 2014 AND 2016. 26
FIGURE 15 AVERAGE PERCENTAGE OF SUMMER CEREALS IN 2008, 2011 AND 2014. 28
FIGURE 16 AVERAGE PERCENTAGE OF CROP AREA PLANTED TO WINTER OILSEEDS 2008, 2011, 2014 AND 2016. 29
FIGURE 17 PERCENTAGE OF CROP AREA PLANTED TO OILSEEDS IN 2016. 30
FIGURE 19 PERCENTAGE OF CROPPED ARE PLANTED TO PULSES IN 2016. 30
FIGURE 18 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED TO PULSES IN 2008, 2011, 2014 AND 2016. 31
FIGURE 20 AVERAGE PERCENTAGE OF CROP AREA AS PLANTED WITH THE MAJOR CROPS IN 2008, 2011, 2014 AND 2016 BY AEZS. 32
FIGURE 20B AVERAGE PERCENTAGE OF CROP AREA AS PLANTED WITH THE MAJOR CROPS IN 2008, 2011, 2014 AND 2016 BY AEZS. 33
FIGURE 22 AVERAGE NATIONAL PERCENTAGE OF CROPPED AREA PLANTED WITH THE MAJOR CROPS 2008, 2011, 2014 AND 2016. 33
FIGURE 24 PERCENTAGE OF CROP AREA PLANTED USING ZERO-TILLAGE IN 2016. 34
FIGURE 23 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED USING ZERO-TILLAGE (LESS THAN 10% SOIL DISTURBANCE). 35
FIGURE 25 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED USING NO-TILLAGE (BETWEEN 10% AND 30% SOIL DISTURBANCE). 36
FIGURE 26 PERCENTAGE OF CROP AREA PLANTED USING NO-TILLAGE IN 2016. 37
FIGURE 27 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED USING ZERO-TILLAGE OR NO-TILLAGE (LESS THAN 30% SOIL DISTURBANCE). 38
FIGURE 28 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED USING DIRECT DRILL. 39
FIGURE 29 PERCENTAGE OF CROPPED AREA PLANTED USING DIRECT-DRILL IN 2016. 40
FIGURE 31 PROPORTION OF CROP AREA PLANTED USING ZERO OR NO-TILLAGE OR DIRECT-DRILL IN 2016. 40
FIGURE 30 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED USING ZERO-TILLAGE, NO-TILLAGE OR DIRECT-DRILL IN 2008, 2011, 2014 AND 2016. 41
FIGURE 32 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED USING MINIMUM TILLAGE TECHNIQUES. 41
FIGURE 33 PROPORTION OF CROP AREA PLANTED USING MINIMUM-TILLAGE TECHNIQUES IN 2016. 42
FIGURE 35 PERCENTAGE OF CROP AREA PLANTED USING MULTIPLE-TILLAGE TECHNIQUES IN 2016. 42
FIGURE 34 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED USING MULTIPLE-TILLAGE TECHNIQUES. 43

FIGURE 37 PERCENTAGE OF CROP AREA USING CONTROLLED TRAFFIC BY AGRO-ECOLOGICAL ZONE IN 2016. 44
FIGURE 36 AVERAGE PERCENTAGE OF CROPPED AREA WHERE CONTROLLED TRAFFIC WAS USED. 45
FIGURE 38 AVERAGE PERCENTAGE OF CROPPED AREA WHERE AUTOSTEER WAS USED AS REPORTED IN SURVEYS OF 2008, 2011, 2014 AND 2016. 46
FIGURE 39 AVERAGE PERCENTAGE OF CROPPED AREA WHERE AUTOSTEER WAS USED IN 2016. 47
FIGURE 40 AVERAGE PERCENTAGE OF CROPPED AREA WHERE VARIABLE RATE SEED TECHNOLOGY WAS USED IN 2014 AND 2016. 48
FIGURE 41 AVERAGE PERCENTAGE OF CROPPED AREA WHERE VARIABLE RATE FERTILISER TECHNOLOGY WAS USED IN 2014 AND 2016. 49
FIGURE 42 AVERAGE PERCENTAGE OF CROPPED AREA WHERE VARIABLE RATE FERTILISER TECHNOLOGY WAS USED IN 2016. 49
FIGURE 43 AVERAGE PERCENTAGE OF CROPPED AREA WHERE YIELD MAPPING WAS USED IN 2008, 2011, 2014 AND 2016. 50
FIGURE 44 AVERAGE PERCENTAGE OF CROPPED AREA WHERE YIELD MAPPING WAS USED IN 2016. 50
FIGURE 45 AVERAGE PERCENTAGE OF CROPPED AREA WHERE REMOTE SENSING USING EM38 OR NDVI WAS USED IN 2016. 51
FIGURE 46 PERCENTAGE OF FARMS USING A FALLOW PERIOD OVER THE PAST 12 MONTHS IN 2016. 53
FIGURE 47 PERCENTAGE OF RESPONDENTS REPORTING A FALLOW PERIOD BEING USED IN THE PAST 12 MONTHS, IN 2016. 53
FIGURE 48 PERCENTAGE OF FALLOW MAINTAINED WITHOUT TILLAGE IN 2014 AND 2016. 54
FIGURE 49 AVERAGE PERCENTAGE OF FALLOW AREA MANAGED BY HERBICIDES ONLY IN 2016. 55
FIGURE 50 AVERAGE PERCENTAGE OF FALLOW AREA MANAGED BY CULTIVATION IN 2016. 55
FIGURE 51 PROPORTION OF CROP AREA IN 2016 WHERE GRAZING OCCURRED IN THE INTER-CROP PERIOD. 56
FIGURE 52 AVERAGE PERCENTAGE OF CROPPED AREA WHERE STUBBLE WAS RETAINED INTACT THROUGH TO PLANTING. 58
FIGURE 53 AVERAGE PERCENTAGE OF CROPPED AREA WHERE STUBBLE WAS RETAINED (NOT STANDING) THROUGH TO PLANTING. 59
FIGURE 54 AVERAGE PERCENTAGE OF CROPPED AREA WHERE STUBBLE WAS BURNT EARLY (HOT BURN). 60
FIGURE 55 PERCENTAGE OF CROPPED ARE WHERE STUBBLE WAS BURNT EARLY (HOT BURN) IN 2016. 61
FIGURE 57 PERCENTAGE OF CROPPED AREA WHERE STUBBLE WAS BURNT LATE (COOL BURN) IN 2016. 61
FIGURE 56 AVERAGE PERCENTAGE OF CROPPED AREA WHERE STUBBLE WAS BURNT LATE (COOL BURN). 62
FIGURE 58 AVERAGE PERCENTAGE OF CROPPED AREA WHERE STUBBLE WAS WINDROWED THEN BURNT. 63
FIGURE 59 AVERAGE PERCENTAGE OF CROPPED AREA WHERE STUBBLE WAS INCORPORATED INTO SOIL USING TILLAGE IN 2014 AND 2016. 63
FIGURE 60 AVERAGE PERCENTAGE OF CEREAL CROP AREA PLANTED FOLLOWING CANOLA IN PREVIOUS YEAR. 68
FIGURE 61 PERCENTAGE OF CEREAL CROP SOWN IN 2016 FOLLOWING A CANOLA CROP IN 2015. 69
FIGURE 62 AVERAGE PERCENTAGE OF CEREAL CROP AREA PLANTED FOLLOWING A PULSE CROP IN PREVIOUS YEAR. 69
FIGURE 63 PERCENTAGE OF CEREAL CROP SOWN IN 2016 FOLLOWING A PULSE CROP IN 2015. 69
FIGURE 64 AVERAGE PERCENTAGE OF CEREAL CROP AREA PLANTED FOLLOWING A LEGUME-DOMINANT PASTURE IN THE PREVIOUS YEAR. 70
FIGURE 65 PERCENTAGE OF CEREAL CROP PLANTED IN 2016 FOLLOWING A LEGUME-DOMINANT PASTURE IN 2015. 71
FIGURE 66 AVERAGE PERCENTAGE OF CEREAL CROP AREA PLANTED INTO LONG FALLOW. 72
FIGURE 68 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED IN 2014 AND 2016 WITH A BREAK CROP SPECIFICALLY FOR WEED CONTROL. 72
FIGURE 67 PERCENTAGE OF CEREAL CROP PLANTED IN 2016 FOLLOWING A LONG FALLOW. 73
FIGURE 69 CROP AREA PLANTED IN 2016 WITH A BREAK CROP FOR WEED CONTROL. 73
FIGURE 70 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED IN 2014 AND 2016 WITH A BREAK CROP SPECIFICALLY FOR DISEASE CONTROL. 74
FIGURE 72 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED IN 2014 AND 2016 WITH A BREAK CROP SPECIFICALLY FOR NUTRITIONAL BENEFITS. 74
FIGURE 71 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED IN 2016 WITH A BREAK CROP SPECIFICALLY FOR DISEASE MANAGEMENT. 75
FIGURE 73 AVERAGE PERCENTAGE OF CROPPED AREA PLANTED IN 2014 WITH A BREAK CROP SPECIFICALLY FOR NUTRITIONAL BENEFITS IN 2016. 75
FIGURE 74 AVERAGE PERCENTAGE OF CROP AREA WHERE LIME WAS APPLIED. 77
FIGURE 75 PERCENTAGE OF GRAIN FARMS APPLYING LIME IN 2016. 78

FIGURE 77 PERCENTAGE OF CROPPED AREA SOIL TESTED IN 2016. 78
FIGURE 76 AVERAGE PERCENTAGE OF CROP AREA SOIL TESTED. 79
FIGURE 78 AVERAGE PERCENTAGE OF WINTER CEREAL CROP AREA SOIL TESTED. 79
FIGURE 79 PERCENTAGE OF WINTER CEREAL CROP AREA SOIL TESTED IN 2016. 80
FIGURE 81 PERCENTAGE OF PULSE CROP AREA SOIL TESTED IN 2016. 80
FIGURE 80 AVERAGE PERCENTAGE OF PULSE CROP AREA SOIL TESTED. 81
FIGURE 82 AVERAGE PERCENTAGE OF OILSEED CROP AREA SOIL TESTED. 81
FIGURE 83 PERCENTAGE OF WINTER OILSEED CROP AREA SOIL TESTED IN 2016. 82
FIGURE 84 AVERAGE PERCENTAGE OF CROP AREA SOIL TESTED TO 10CM DEPTH IN 2014 AND 2016. 83
FIGURE 85 AVERAGE PERCENTAGE OF CROP AREA HAVING DEEP SOIL TEST IN THE PAST 5 YEARS. 83
FIGURE 86 AVERAGE PERCENTAGE OF CROP AREA WHERE THE FERTILISER PROGRAM WAS INFORMED BY SOIL TESTING. 84
FIGURE 87 AVERAGE PERCENTAGE OF CROP AREA WHERE THE FERTILISER PROGRAM IN 2016 WAS INFORMED BY SOIL TESTING. 85
FIGURE 88 AVERAGE PERCENTAGE OF CROP AREA TREATED WITH FERTILISER AT RATES BASED ON ESTIMATES OF NUTRIENT REMOVAL RATES BY THE CROP. 85
FIGURE 89 AVERAGE PERCENTAGE OF CROP AREA HAVING AN IN-SEASON SOIL TEST. 86
FIGURE 90 AVERAGE PERCENTAGE OF CROP AREA HAVING A LEAF OR PETIOLE TEST. 87
FIGURE 91 AVERAGE PERCENTAGE OF CROP AREA HAVING A LEAF OR PETIOLE TEST IN 2016. 87
FIGURE 92 AVERAGE PERCENTAGE OF CROP AREA HAVING AN IN-SEASON APPLICATION OR TOP-DRESSING OF FERTILISER. 88
FIGURE 93 AVERAGE PERCENTAGE OF CROP AREA WHERE PLANT-AVAILABLE WATER WAS ASSESSED AT PLANTING. 90
FIGURE 94 PERCENTAGE OF CROP AREA WHERE PLANT-AVAILABLE WATER WAS ASSESSED AT PLANTING IN 2016. 91
FIGURE 95 AVERAGE PERCENTAGE OF CROP AREA WHERE SOIL MOISTURE WAS MEASURED OR ASSESSED THROUGH THE SEASON. 91
FIGURE 96 PERCENTAGE OF CROP AREA WHERE SOIL MOISTURE WAS ASSESSED THOUGH. 91
FIGURE 97 AVERAGE TONNES OF GRAIN THAT CAN BE STORED ON-FARM. 93
FIGURE 98 AVERAGE PERCENTAGE OF FARM AREA TESTED FOR NEMATODES IN THE PAST FIVE YEARS. 94
FIGURE 99 AVERAGE PERCENTAGE OF FARM AREA KNOWN TO BE AFFECTED BY HERBICIDE-RESISTANT WEEDS. 95
FIGURE 100 AVERAGE PERCENTAGE OF FALLOW AREA WHERE THE DOUBLE-KNOCK HERBICIDE TECHNIQUE WAS USED IN 2014 AND 2016. 95
FIGURE 101 AVERAGE PERCENTAGE OF FALLOW AREA WHERE TILLAGE WAS USED AS THE SECOND KNOCK IN A DOUBLE KNOCK TREATMENT. 96
FIGURE 102 AVERAGE PERCENTAGE OF FARM AREA WHERE NON-HERBICIDE TECHNIQUES HAVE BEEN USED TO HELP MANAGEMENT OF HERBICIDE-RESISTANT WEEDS. 97
FIGURE 103 AVERAGE PERCENTAGE OF FALLOW AREA WHERE RESIDUAL HERBICIDES WERE USED IN 2016. 98
FIGURE 104 AVERAGE PERCENTAGE OF CROP AREA WHERE GROUP A HERBICIDES WERE USED. 99
FIGURE 105 AVERAGE PERCENTAGE OF CROP AREA WHERE GROUP B HERBICIDES WERE USED. 99
FIGURE 106 AVERAGE PERCENTAGE OF FARMS WITH A QUALITY ASSURANCE OR ENVIRONMENTAL ASSURANCE PROGRAM THAT ASSISTS IN MARKET ACCESS OR DERIVING A PRICE PREMIUM. 100

Executive summary

Farm size in 2016

Average farm size based on 2016 survey data is 3991 hectares (ha) per farm. This is up from previous survey results in 2014 (3475 ha). These changes may be within the margins of error for the survey. Notwithstanding this, it is evident that farm size continues to grow in agro-ecological zones (AEZs) in Western Australia (WA), the Eyre Peninsula, Mid North and Upper South East of South Australia (SA), the Wimmera in Victoria and northern New South Wales (NSW)/ southern Queensland.

Area of crop per farm in 2016

The largest crop areas per farm are in WA, western NSW, the Mallee region of SA and Victoria, and northern NSW/southern Queensland. There has been an increase in the proportion of farmland that was cropped in 2016 in survey results, with this now in many cases similar to, or higher than, in 2008. This is also the situation in much of WA, SA / Victoria and in NSW. The greatest average areas per farm planted to grain crops since the survey commenced in 2008 are seen in WA, much of SA and Victoria and north-west NSW/south-west Queensland.

Proportion of crop per farm in 2016

On a national basis, the average proportion of cropped area has returned to just over 60 per cent of the total farm area, which is a 6 per cent increase since 2014.

Crop mix in 2016

While wheat remains the dominant crop planted, a significant decrease in wheat as a proportion of the total crop area was recorded in 2016, with wheat now 38 per cent of the cropped area as a national average. In contrast, wheat was more than 58 per cent of the cropped area in 2011.

There was a slight increase in barley plantings in 2016, now averaging 17.2 per cent nationally, highest in southern WA, much of SA and Victoria at up to 30 per cent of the cropped area in some AEZs.

The proportion of oilseeds in the crop mix also declined to less than 10 per cent of the cropped area nationally in 2016, although higher in southern central and northern WA and NSW / Victorian slopes.

There has been a significant increase in pulses as a proportion of the total crop area in 2016, averaging almost 14 per cent of the cropped area nationally, and at (or over) 20 per cent in some AEZs in NSW, Queensland and SA / Victoria. This is attributed to pulses almost doubling as a proportion of the cropped area over the period 2014 to 2016 nationally, mostly at the expense of wheat.

2016 is the first survey (over the period 2008 to 2016) where pulses represent a higher proportion of the total cropped area than oilseeds nationally (13.8 per cent pulses compared to 9.2 per cent oilseeds).

Tillage in 2016

Survey results for 2016 show a modest (but statistically significant) increase in the use of 'zero-tillage' since 2014 in the Victorian high-rainfall zone, and also in 'no-tillage' in SA Mid North/Lower Eyre Peninsula, SA/Victorian Mallee, Tasmania and Victorian high-rainfall zones. Taken together these represent 73.8 per cent of the cropped area nationally, and over 90 per cent in parts of WA.

Precision agriculture in 2016

The use of 'controlled traffic' has increased in 2016 to almost 30 per cent of the cropped area, higher in much of NSW and Queensland. Adoption of 'autosteer' for guiding cropping machinery has continued to increase, with the technology being used on more than 85 per cent of the cropped area nationally in 2016 and over 90 per cent in much of WA and parts of SA.

Variable rate technology is reported by growers in the SA/Victorian Mallee to be used on approximately 23 per cent of the cropped area, more than 15 per cent of eastern WA and more than 5 per cent in other parts of WA.

In the survey of 2016 data for the use of both variable rate seed and fertiliser applications were collected.

Yield mapping has increased modestly since 2014, now used on almost 35 per cent of the cropped area, and the use of remote sensing technology is growing slightly form a low base, now at 5.1 per cent of the cropped area nationally.

Fallow management in 2016

The number of growers reporting the use of some fallow has increased since the survey of 2014 in most AEZs, notably in northern NSW and southern Qld. Almost two-thirds of growers reportedly use some fallow in their crop sequence.

Nationally, the proportion of fallow (where used) maintained without tillage has grown from 30 per cent to 50 per cent since 2014.

Herbicides were responsible for the majority (although not all) of the weed management on fallow areas in 2014 (60 per cent), however this has declined markedly in 2016 to 37 per cent.

Stubble management in 2016

The proportion of the cropped area where stubble is retained intact right through sowing had remained relatively stable across the three previous surveys (2008, 2011 and 2014), at approximately 45 per cent of the cropped area nationally.

The data from respondents in the 2016 survey shows a general increase in the proportion of the cropped area where stubble has been retained intact through until sowing, now at almost 50 per cent of the area.

When the proportions of retained stubble standing and not standing are added, it comes to over 60 per cent of the cropped area in 2016. This is an increase over the levels reported in 2014.

Crop sequencing in 2016

The proportion of cereals sown following 'break crops' (for example, canola, pulses or a legume-dominant pasture) has increased somewhat since the survey of 2014 (which recorded a decline since 2011). The proportion of cereal sown following canola and legume pasture appears to show more stability than that following pulses, notably in NSW and much of WA, with more variability in Victoria and SA.

However, cereal crops (nationally) planted in 2016 following a pulse crop in 2015 showed an increase over that reported in 2014.

GRDC

The national average area of cereals sown following a legume-dominant pasture increased in 2016, returning to an area close to where it was in 2011.

The proportion of cereals sown following 'break crops' (for example, canola, pulses or a legume dominant pasture) decreased between 2011 and 2014, with the proportion of cereals following all of the break crops declining in proportion nationally.

The data show 10.4 per cent of the cereal crop was sown into a long fallow in 2016 on a national basis (higher in the GRDC northern region). This is a reduction from 12.9 per cent in 2014.

Reasons stated by growers for the use of break crops were weed management (17 per cent of crop area), disease management (15 per cent) and nutrition (15 per cent).

SOIL MANAGEMENT IN 2016

Lime use

The percentage of crop area where lime was applied in 2016 was 19.1 per cent, down modestly from the results of the 2014 survey (21.7 per cent). Nationally the amount of lime applied (tonnes per hectare) in 2016 increased significantly to 1.9t/ha, being up from 1.0t/ha in 2014.

Soil testing (nutrition)

Nationally, 21.9 per cent of the cropped area was soil tested in 2016, a decrease compared to 2014 data (27.3 per cent) although higher levels of soil testing were noted in several AEZs (north-east NSW/ south-east Queensland, eastern WA and WA Mallee / Sandplain).

A decrease in soil testing prior to sowing cereals and oilseeds occurred in 2016. In contrast there was an increase in soil testing prior to sowing pulses.

Utilisation of deep soil testing (generally to a depth of 60 centimetres) bv growers increased in 2016.

Fertiliser planning and use

The data for 2016 confirms that a relatively high proportion of the crop has fertiliser usage informed by estimates of nutrient removal from the current and previous crops, averaging just over 67 per cent nationally, and higher in some AEZs (e.g. parts of SA and WA, and NSW Central).

When considered in conjunction with the data for whether the fertiliser program was informed by soil test data, it is likely that growers are determining their fertiliser program based on a combination of soil tests in combination with estimates of nutrient removal by crop performance prior to this year, along with estimates of crop need in 2016.

In-season soil testing in 2016 remained at low levels, as did plant testing (4.6 per cent and 7.9 per cent total crop area, respectively).

Soil moisture management

A significant increase in the proportion of crop area where plant available water is measured at planting has occurred since 2008 (9.4 per cent in 2008 compared with 43.1 per cent in 2016). However, 2016 levels are below that found in the 2014 survey (57.8 per cent).

Miscellaneous questions in 2016

On-farm grain storage capacity has increased, with survey results showing that nationally, an average of 1522 tonnes capacity per farm. The highest amounts of on-farm storage are in the GRDC northern region, where many AEZs have average on-farm storage greater than 4000 tonnes.

Herbicide-resistant weeds are known by growers to occupy well over 20 per cent of the farm area in some AEZs (for example, much of SA and central, eastern and northern WA). However, more than 20 per cent of the cropped area nationally is planted in a way to assist with weed competition, with over 30 per cent of the cropped area in central Queensland, and WA central and Mallee/Sandplain.

The 'double herbicide knock' herbicide-resistance management tactic was applied to 29.4 per cent of the fallow area nationally in 2016. The proportion was notably higher in all AEZs in WA compared to elsewhere nationally.

Usage of Group A and Group B herbicides in 2016 has declined from levels in 2014, with Group A used on 25.2 per cent of the cropped area and Group B on 30.6 per cent, both falling approximately 5 per cent to 6 per cent since 2014.

Nationally, 16.6 per cent of farms are using some form of quality assurance or environmental assurance program, with notably higher levels in AEZs in WA.

Grain farm statistics

Within the survey, growers were asked a number of questions about their farm:

- What is the total area of your farm, including all leased land and any unused land?
- In 2016, how many hectares of crop/pasture/native vegetation did you have?; and
- Do you have a vegetation plan for your farm? What purpose is this used for?

Number of grain farms and total area of farmland

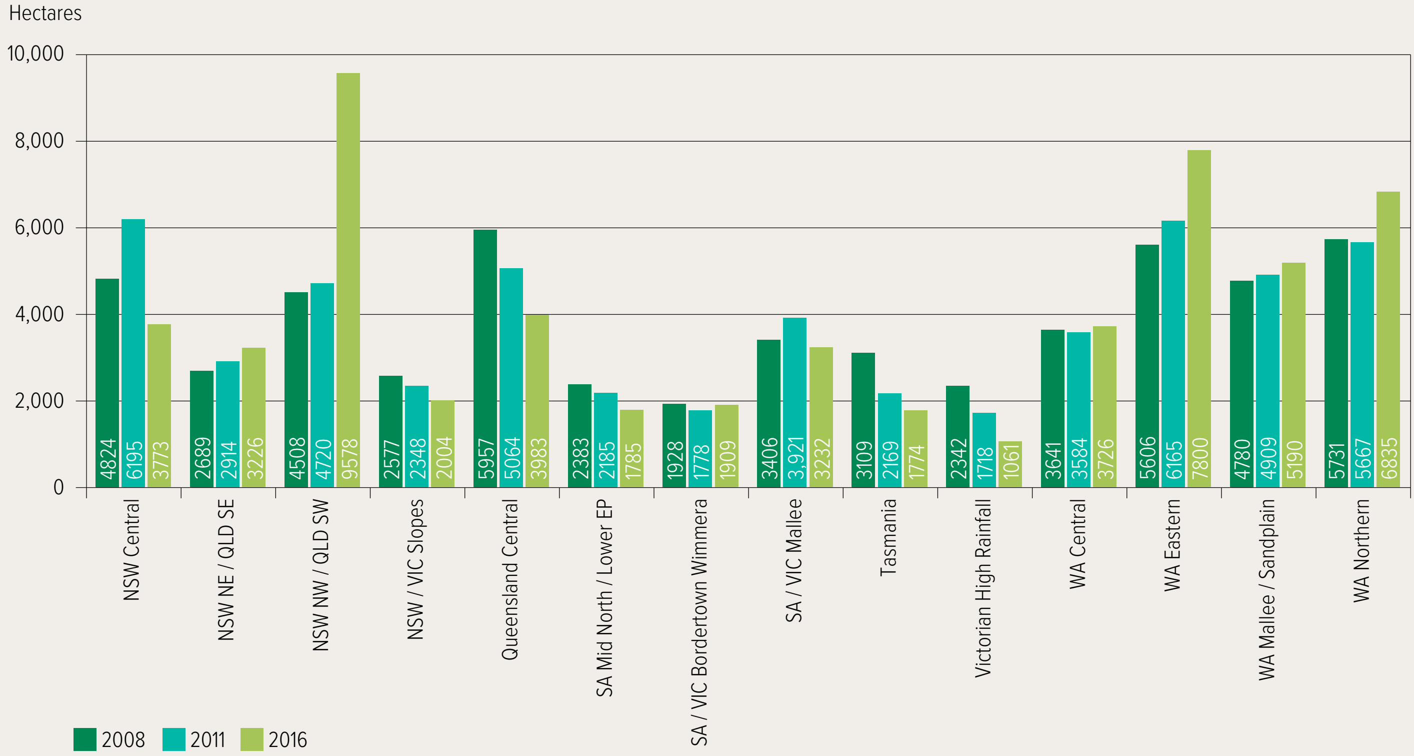
In both 2008 and 2011, the survey comprised approximately 1300 farms, representing 4.3 per cent of the total estimated number of grain-producing farms in Australia. In 2014 1283 farms responded and participated in the survey. In 2016 1301 farms participated in the survey.

The number of grain farms in Australia is difficult to estimate accurately. Data from the Australian Bureau of Statistics (ABS) has been analysed by Neil Clark & Associates, with the results suggesting that there were 20,717 grain farms in Australia in 2016,

TABLE 1 Sample size and total farmland area (ha) represented in the survey data by agro-ecological zone in 2008, 2011, 2015 and 2016.

Agro-ecological zone	Sample size (farm numbers)				Total farm area surveyed (ha)			
	2008	2011	2014	2016	2008	2011	2014	2016
NSW Central	75	95	100	95	361,822	588,559	446,303	358,438
NSW North-East / QLD South-East	158	86	127	227	424,831	250,633	364,221	732,192
NSW North-West / QLD South-West	60	94	53	53	270,496	443,651	293,073	507,651
NSW / VIC Slopes	124	160	167	160	319,586	375,633	390,612	320,612
QLD Central	23	35	32	35	137,003	177,243	117,820	139,400
SA Mid North / Lower Eyre Peninsula	97	118	122	118	231,131	257,819	194,033	210,617
SA / VIC Bordertown, Wimmera	126	106	113	106	242,981	188,513	178,006	202,310
SA / VIC Mallee	180	160	167	160	613,059	627,427	521,416	517,044
TAS	4	7	7	7	12,435	15,185	16,488	12,420
VIC High Rainfall	37	65	71	65	86,636	111,685	73,899	68,940
WA Central	200	185	191	184	728,108	663,131	660,269	685,589
WA Eastern	62	62	47	31	347,584	382,235	335,648	241,788
WA Mallee/Sandplain	68	57	44	30	325,016	279,801	191,872	150,506
WA Northern	86	82	42	30	492,904	464,709	215,367	205,058
TOTALS	1300	1312	1283	1301	4,593,592	4,826,224	3,999,028	4,352,566

FIGURE 1 Farm size trends (ha) within agro-ecological zones for 2008, 2011 and 2016.



comprising both grain-only and mixed grain and livestock farms. Based on the total number of farms as per the analysis by Neil Clark & Associates, the number of farms surveyed in 2016 was approximately 6.3 per cent of total grain farms.

In the previous surveys, survey participants represented a farm area between 4.0 million (in 2014) and 4.5 million hectares (2008 and 2011). In 2016 the farm area represented by the survey totalled just over 4.35 million hectares (ha).

Table 1 shows the survey sample size and total farm area represented by the survey participants by agro-ecological zone (AEZ) for all surveys (2008, 2011, 2014 and 2016).

TABLE 2 Average farm size (ha) within agro-ecological zones in 2008, 2011, 2014 and 2016.

Agro-ecological zone	Average area per farm (ha)				Significant difference between years	
	2008 (ha)	2011 (ha)	2014 (ha)	2016 (ha)	2014 to 2016	2011 to 2016
NSW Central	4824	6195	4463	3773		**
NSW NE / QLD SE	2689	2914	2868	3226		
NSW NW / QLD SW	4508	4720	5530	9578		
NSW / VIC Slopes	2577	2348	2339	2004		
QLD Central	5957	5064	3682	3983		
SA Mid North / Lower EP	2383	2185	1590	1785		
SA / VIC Bordertown, Wimmera	1928	1778	1575	1909		
SA / VIC Mallee	3406	3921	3122	3232		
TAS	3109	2169	2355	1774		
VIC High Rainfall	2342	1718	1041	1061		***
WA Central	3641	3584	3457	3726		
WA Eastern	5606	6165	7141	7800		
WA Mallee/Sandplain	4780	4909	4361	5190		
WA Northern	5731	5667	5128	6835		
NATIONAL AVERAGES	3768	3810	3475	3991		

Farm size

There are considerable differences in the average farm area of grain farms across the various AEZs, with larger farms located in many grain-production zones in WA, Central Qld, NSW Central and NW NSW/SW Qld (Table 2, Figure 1 and Figure 2). Smaller farm sizes are found in the high-rainfall zones of Victoria, much of SA and Victoria, the NSW/Victorian slopes and NE NSW/SE Qld.

In 2008 the average farm area of grain farms surveyed was 3768ha, in 2011 it was 3810ha, in 2014 it was 3475 and in 2016 it was 3991ha (Table 2).

While the reported average farm size shows an increasing trend between years, this is not statistically significant, apart from in one AEZ. This trend is not uniform, and more evident in the AEZs of WA and the western zones of northern NSW and southern Qld. The trend to increased farm size in WA is consistent and ongoing. Conversely, there appear to be decreases in farm size in the 2016 survey data in most of the southern region, central Qld and the balance of NSW, with these generally being more modest and variable across years.

In AEZs characterised by larger farms, farm size is continuing to increase between years.

Area of crop in the survey

Table 3 (page 17) shows the area of crop represented by the respondents in the surveys. The area of crop covered by the survey in 2016 is similar to that represented in the survey of 2008, and greater than in the surveys of 2011 and 2014. This is possibly a result of the slightly higher farm area represented by the growers responding to the 2016 survey.

FIGURE 2 Average farm size in 2016.

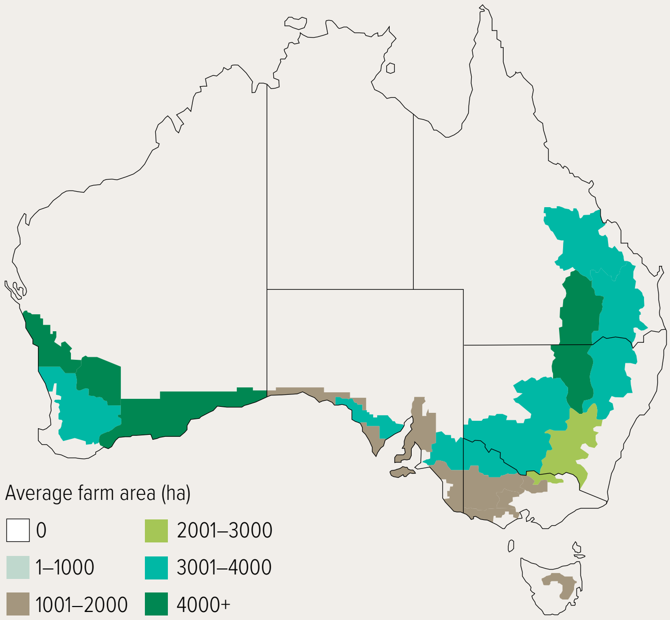
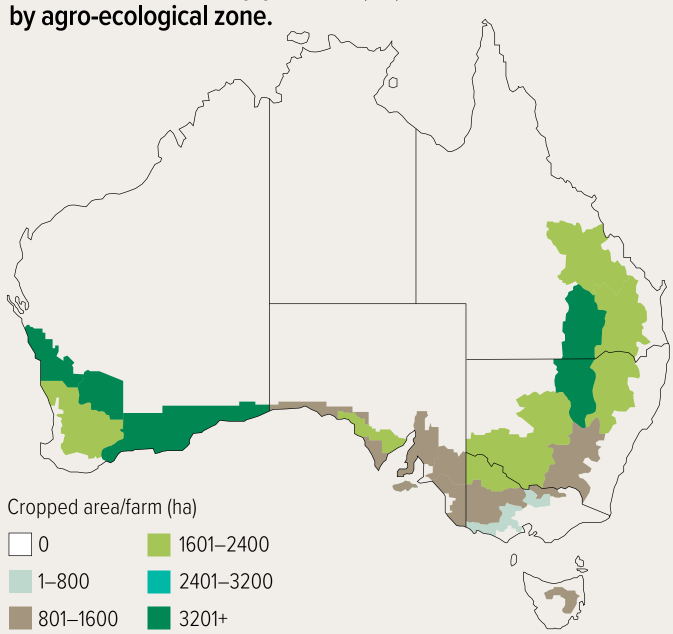


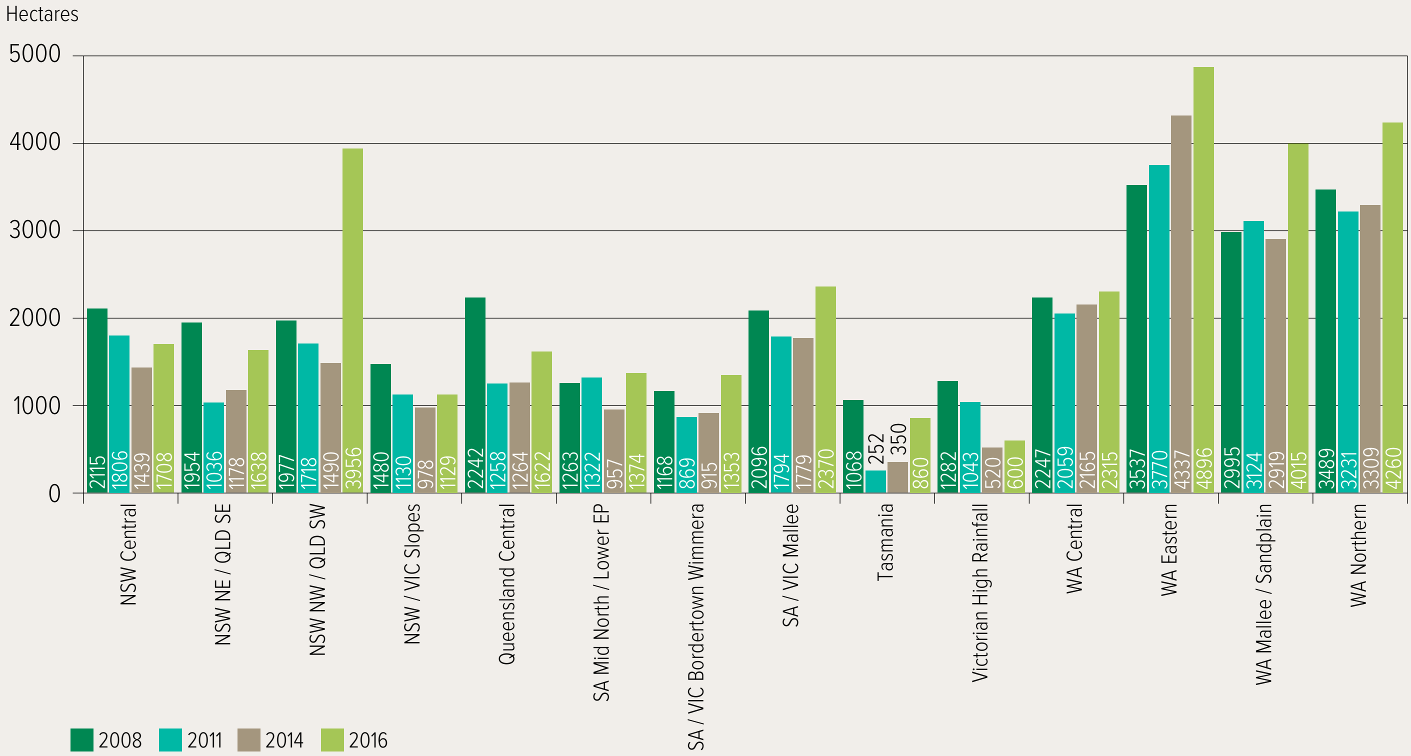
FIGURE 4 Area of crop per farm (ha) by agro-ecological zone.



The total area of crop grown in Australia in 2016 was approximately 19 million ha comprising cereal, pulse, sorghum and oilseed crops (data as provided by Neil Clark & Associates). The crop area within in the 2016 survey (Table 3) represents approximately 13.3 per cent of the Australian total crop area.

The percentage of total crop area as represented by the survey varies between AEZs (Table 4) and averaged 13.3 per cent in the 2016 survey. The proportion of crop area surveyed in the 2016 survey is calculated from comparing the survey data with those from Neil Clark & Associates for total cropped area in 2016. The percentage for some AEZs, such as Tasmania and central Queensland, is considered to be erroneous due to the small sample size. Excluding these results, the survey represents 9.0 per cent to 32.2 per cent of the total crop area by individual AEZs.

FIGURE 3 Average area of crop (ha) per farm 2008–16.



GRDC

TABLE 3 Total crop area (ha) in 2008, 2011, 2014 and 2016 GRDC surveys.

Agro-ecological zone	2008 (ha)	2011 (ha)	2014 (ha)	2016 (ha)
NSW Central	129,205	171,572	143,906	162,269
NSW NE / QLD SE	189,031	88,814	149,601	371,922
NSW NW / QLD SW	112,443	161,461	78,953	209,660
NSW / VIC Slopes	237,149	180,828	163,380	180,625
QLD Central	51,793	44,020	40,450	56,783
SA Mid North / Lower EP	152,396	156,052	116,713	162,099
SA / VIC Bordertown, Wimmera	174,060	92,102	103,420	143,379
SA / VIC Mallee	399,534	287,024	297,100	379,186
TAS	4453	1767	2452	6018
VIC High Rainfall	59,308	67,777	36,904	38,983
WA Central	502,201	380,849	413,516	425,909
WA Eastern	265,492	233,744	203,839	151,761
WA Mallee/Sandplain	222,949	178,059	128,440	120,444
WA Northern	313,473	311,067	138,981	127,801
TOTAL IN SURVEY	2,813,487	2,355,135	2,017,654	2,536,838

TABLE 4 Total crop area (ha) in 2016, surveyed in 2014 and 2016 surveyed area as % of 2016 crop area by agro-ecological zone.

Agro-ecological zone	2014 (ha)	2016 (ha in survey)	2016 (% crop of 2016 area)
NSW Central	143,906	162,269	11.1%
NSW NE / QLD SE	149,601	371,922	30.0%
NSW NW / QLD SW	78,953	209,660	23.2%
NSW / VIC Slopes	163,380	180,625	9.0%
QLD Central	40,450	56,783	47.3%
SA Mid North / Lower EP	116,713	162,099	10.9%
SA / VIC Bordertown, Wimmera	103,420	143,379	10.4%
SA / VIC Mallee	297,100	379,186	14.1%
TAS	2452	6018	135.8%
VIC High Rainfall	36,904	38,983	32.2%
WA Central	413,516	425,909	10.4%
WA Eastern	203,839	151,761	12.0%
WA Mallee/Sandplain	128,440	120,444	9.9%
WA Northern	138,981	127,801	13.9%
TOTAL IN SURVEY	2,017,654	2,536,838	13.3%

Area of crop per farm

The average area of crop per farm in the survey is shown in Table 5, Figure 3 and Figure 4. The largest crop areas per farm within the survey were in WA, western NSW, the Mallee region of SA and Victoria, and northern NSW/southern Queensland.

A significant increase in average crop area per farm between years is evident in the survey results for some agro-ecological zones, notably those AEZs in the GRDC southern region.

2014 survey results show an apparent decrease in area of crop per farm (compared to results of 2011 survey) in several AEZs, notably NSW Central, NSW/Victorian Slopes, Central Queensland, much of SA and Victoria high-rainfall. However, this trend has been reversed in almost all AEZs in the 2016 survey results. The area of crop per farm in many cases for 2016 is similar to, or higher than, that in 2008.

This seems the case in much of WA, SA/Victoria and in NSW. The greatest average areas per farm planted with grain crops since the survey commenced in 2008 are in WA, much of SA and Victoria and north-west NSW / south-west Queensland.

The above trends are likely to reflect changes in seasonal conditions, expected prices for grain crops and the changes in enterprise mix driven by the relative profitability of grain and

TABLE 5 Average area (ha) of crop per farm.

Agro-ecological zone	Average area per farm (ha)				Significant difference between years	
	2008 (ha)	2011 (ha)	2014 (ha)	2016 (ha)	2014 to 2016	2011 to 2016
NSW Central	2115	1806	1439	1708		
NSW NE / QLD SE	1954	1036	1178	1638		**
NSW NW / QLD SW	1977	1718	1490	3956	**	
NSW / VIC Slopes	1480	1130	978	1129		
QLD Central	2242	1258	1264	1622		
SA Mid North / Lower EP	1263	1322	957	1374	***	
SA / VIC Bordertown, Wimmera	1168	869	915	1353	***	***
SA / VIC Mallee	2096	1794	1779	2370	***	***
TAS	1068	252	350	860		
VIC High Rainfall	1282	1043	520	600		***
WA Central	2247	2059	2165	2315		
WA Eastern	3537	3770	4337	4896		
WA Mallee/Sandplain	2995	3124	2919	4015		
WA Northern	3489	3231	3309	4260		
NATIONAL AVERAGES	2065	1744	1686	2292		

livestock enterprises. The seasonal conditions in early 2016 were generally favourable, and prices received for the 2015 winter crop were relatively high, possibly giving growers increased confidence about planting additional areas with grain in 2016.

Use of farmland

Land use on grain and mixed crop and livestock farms generally consists of areas of crop, pasture and native or remnant vegetation. Together, these components should approximate the total farm area. Not all grain farms have all of these land uses represented, due to their management or other reasons. Some grain farms are essentially 'grain only', some have little or no native vegetation present and, in some cases, areas of 'fallow' may be described in statistics as either a pasture (if grazing of the fallow occurs) or crop area not yet planted. Some growers identify areas of native or remnant vegetation as 'available' for some grazing and often listing these areas also as 'pasture'.

Proportion of crop per farm

The proportions (expressed as a percentage) of farmland used for grain production on the farms in the three surveys are shown in Table 6, Figure 5 and Figure 6.

There has been some change in the average total area of farms that have been allocated by growers to either cropping or pasture in 2016 compared to 2014, which corresponds to an overall increase in cropped area as discussed in the section above. This increase in proportion of the farmland cropped was most notable in parts of SA and Victoria, but in general has increased relative to the previous two surveys across the industry.

As a national average the proportion of cropped area has returned to just over 60 per cent of the farm area, which is an increase of 6 per cent since 2014. This follows a decline from 2011 to 2014 (60.8 per cent and 54.2 per cent, respectively).

FIGURE 6 Proportion of farm area cropped in 2016.

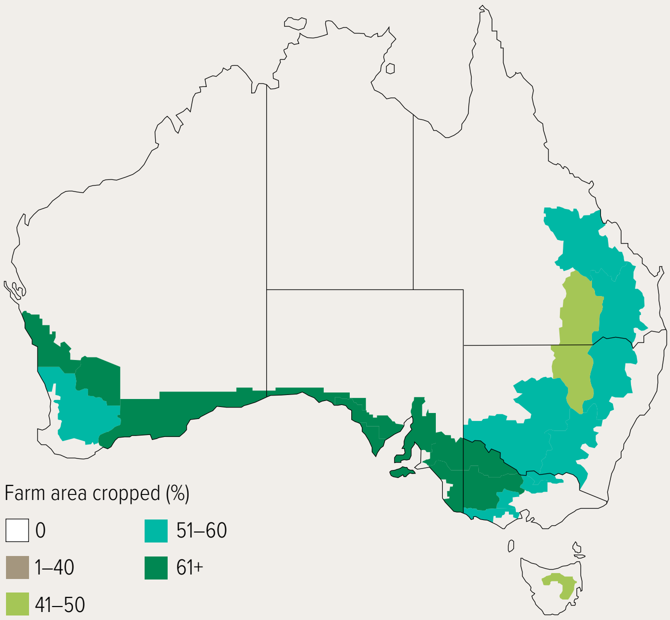
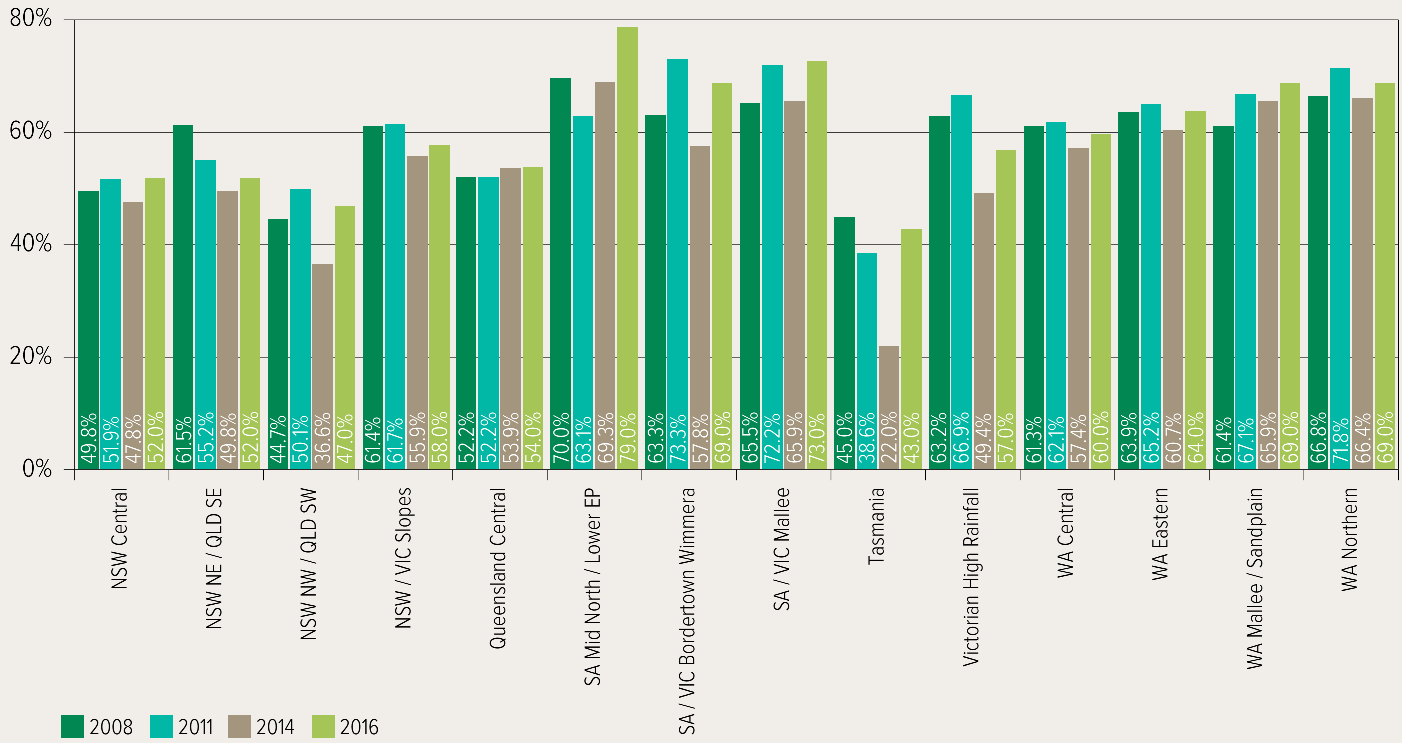


FIGURE 5 Average percentage of farm area cropped.



Proportion of pasture per farm

Some pasture land use is present on most grain-producing farms.

Survey data on pasture land use is often complicated by the definition of a 'pasture'. Pastures can be described as:

- perennial;
- annual;
- 'improved' (i.e. planted and managed as a dedicated pasture);
- 'unimproved' (i.e. volunteer plants or native species that simply emerge on land otherwise not managed); or
- combinations of the above.

In some areas there is uncertainty about the difference between 'native vegetation' and unimproved, extensive 'pastures'. Livestock on some farms can graze some areas of native vegetation and therefore these areas can be reported as 'unimproved pasture', or 'remnant/native vegetation' or sometimes both.

For these reasons data about pastures often fluctuates widely between surveys and therefore it can be difficult to make confident interpretations about changes presented by survey results. However, as a general rule where the area of crop is increased, pasture area is expected to be decreased and vice versa.

Data here is presented as the proportion of the farm that is described by survey respondents to be pasture, expressed as a percentage of the total farm area. The data is presented in summary form in Table 7, Figure 7 and Figure 8.

There appears to have been some minor changes to the proportion of the farmed area that is described as pasture since the last survey although these are not significant. Changes in the pasture area as a percentage of total farm area in the 2016 survey results are generally minor.

TABLE 6 Average percentage of farm area cropped.

Agro-ecological zone	Average crop area per as % of total farm area				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	49.8	51.9	47.8	51.9		
NSW NE / QLD SE	61.5	55.2	49.8	52.2		
NSW NW / QLD SW	44.7	50.1	36.6	47.1	**	
NSW / VIC Slopes	61.4	61.7	55.9	57.8		
QLD Central	52.2	52.2	53.9	53.9		
SA Mid North / Lower EP	70.0	63.1	69.3	78.7	***	***
SA / VIC Bordertown, Wimmera	63.3	73.3	57.8	69.2	***	
SA / VIC Mallee	65.5	72.2	65.9	73.4	***	
TAS	45.0	38.6	22.0	42.8		
VIC High Rainfall	63.2	66.9	49.4	57.0		
WA Central	61.3	62.1	57.4	59.6		
WA Eastern	63.9	65.2	60.7	63.9		
WA Mallee/Sandplain	61.4	67.1	65.9	69.4		
WA Northern	66.8	71.8	66.4	69.0		
NATIONAL AVERAGES	59.3	60.8	54.2	60.4		

TABLE 7 Average percentage of farm area maintained as pasture.

Agro-ecological zone	Average pasture area as % of total farm area				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	38.7	37.4	30.5	33.0		
NSW NE / QLD SE	32.4	37.6	27.4	31.3		
NSW NW / QLD SW	48.8	41.3	48.5	37.8		
NSW / VIC Slopes	35.1	33.5	36.2	38.4		
QLD Central	45.7	40.3	41.9	43.8		
SA Mid North / Lower EP	26.3	23.1	26.6	24.4		
SA / VIC Bordertown, Wimmera	33.7	33.5	34.2	37.7		
SA / VIC Mallee	30.7	23.1	25.1	29.2		
TAS	52.5	52.1	48.1	49.5		
VIC High Rainfall	34.0	30.3	41.8	40.8		
WA Central	34.4	32.4	32.8	36.1		
WA Eastern	28.0	30.2	29.2	27.1		
WA Mallee/Sandplain	34.8	29.2	26.3	31.1		
WA Northern	28.1	20.3	18.9	18.1		
NATIONAL AVERAGES	35.9	33.2	33.4	34.2		

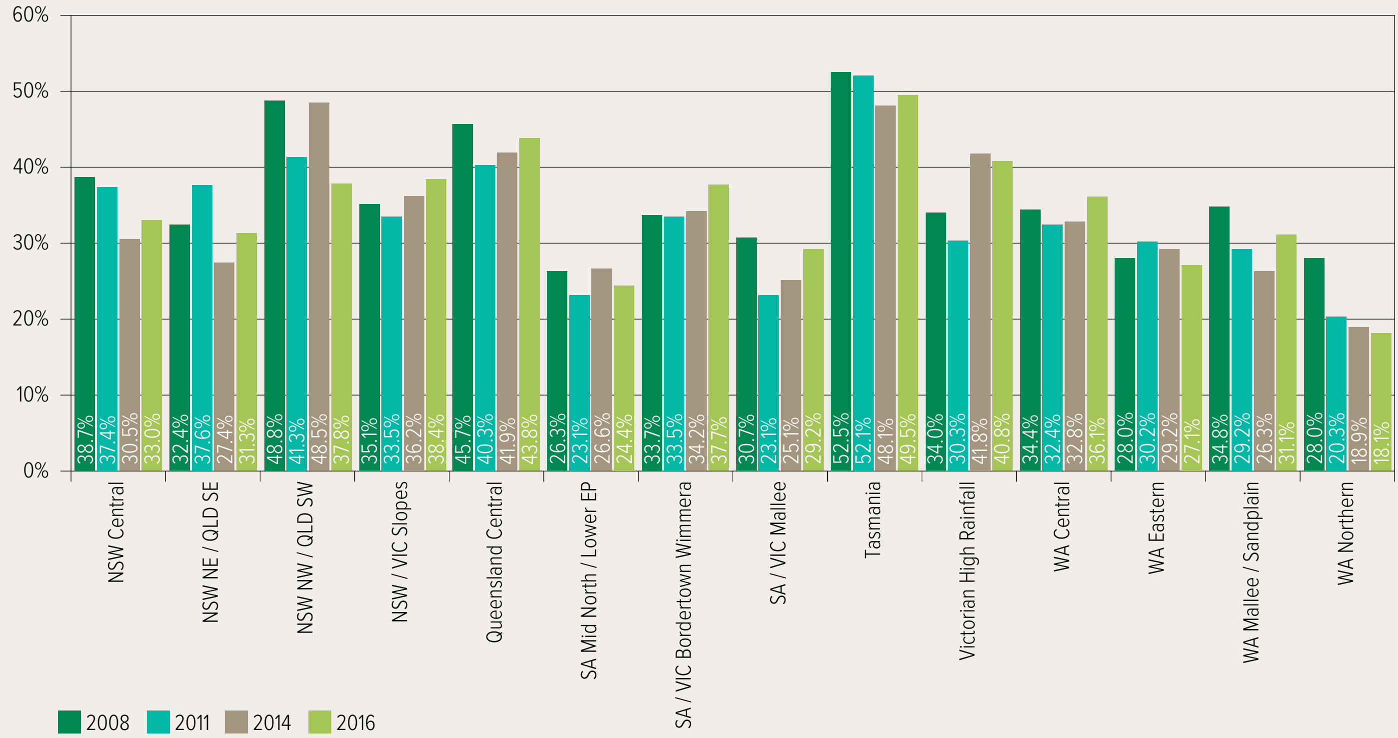


FIGURE 7 Average proportion (%) of land under pasture on grain farms, 2008–14.

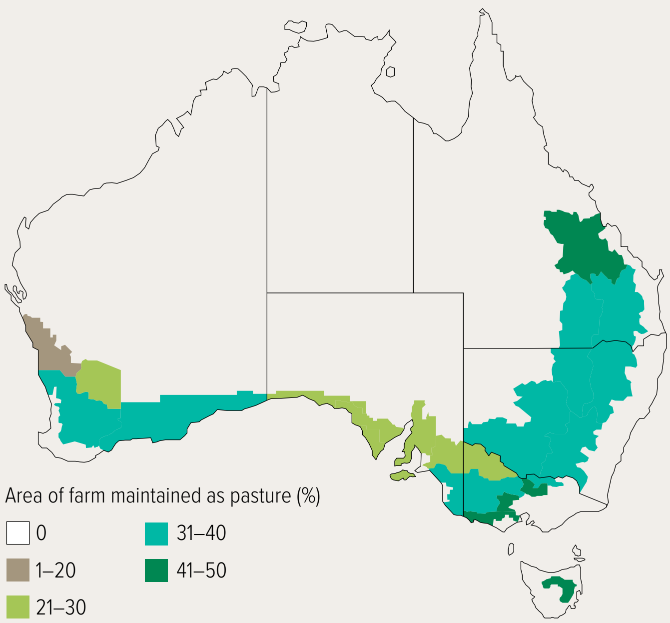


FIGURE 8 Proportion of pasture (% of farm area) within agro-ecological zones in 2014.

Proportion of native vegetation per farm

In previous surveys respondents were asked to estimate the proportion of their farm area that could be described as native vegetation or remnant vegetation. Many growers were unsure how to identify the various types of non-crop or non-pasture areas on their land and whether it should be described as native vegetation. Many growers with areas of native or remnant vegetation allow livestock to graze some of these areas, and so were unsure if this should be described as 'pasture' or native vegetation.

Additionally, in some areas, for example in Queensland, regrowth of what was native vegetation can also be difficult to describe definitively.

Reflecting the uncertainties in interpreting the data arising from the above factors, native vegetation was excluded from the survey in 2014 and in 2016. Based on previous survey results, areas of native and remnant vegetation on farms generally change very little over time as they are usually not part of the productive area and so preserved.

FIGURE 9 Percentage of grain/mixed farms with a vegetation plan in 2014.

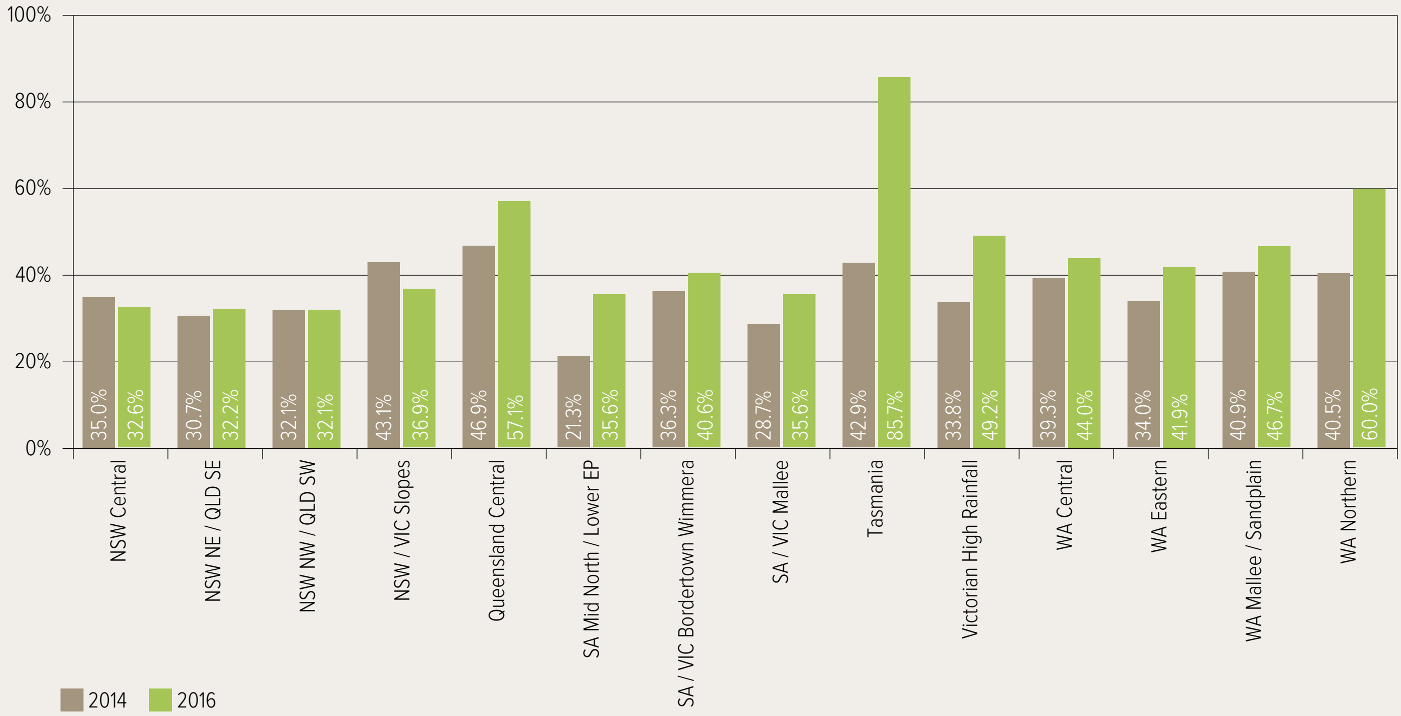


TABLE 8 Percentage of farms with a vegetation plan.

Agro-ecological zone	Farms with a vegetation plan (%)		Significant difference between agro-ecological zones	
	2014	2016	2014 to 2016	2011 to 2016
NSW Central	35	33		
NSW NE / QLD SE	31	32		
NSW NW / QLD SW	32	32		
NSW / VIC Slopes	43	37		
QLD Central	47	57		
SA Mid North / Lower EP	21	36	**	
SA / VIC Bordertown, Wimmera	36	41		
SA / VIC Mallee	29	36		
TAS	43	86		
VIC High Rainfall	34	49		
WA Central	39	44		
WA Eastern	34	42		
WA Mallee/Sandplain	41	47		
WA Northern	40	60		
NATIONAL AVERAGES	35	39		

TABLE 9 Percentage of farms with a vegetation plan to assist with crop production.

Agro-ecological zone	Farms with a vegetation plan to assist with crop production (%)		Significant difference between agro-ecological zones	
	2014	2016	2014 to 2016	2011 to 2016
NSW Central	36	32		
NSW NE / QLD SE	38	32		
NSW NW / QLD SW*	53	18	**	
NSW / VIC Slopes	46	32		
QLD Central*	27	30		
SA Mid North / Lower EP	42	7	***	
SA / VIC Bordertown, Wimmera	20	9		
SA / VIC Mallee	24	14		
TAS*	67	33		
VIC High Rainfall	46	6	***	
WA Central	29	20		
WA Eastern*	38	15		
WA Mallee/Sandplain*	33	14		
WA Northern*	18	0		
NATIONAL AVERAGES	37	19		

Information about whether farms have vegetation management plans, and for what purpose these may be used, was considered to be an activity of interest to sustainable land management on grain farms. As a result, questions about whether farms have vegetation plans and for what reason these were used have been included in the last two surveys (2014 and 2016).

Farmland with a vegetation plan

Survey respondents were asked if they had a vegetation plan for their farm. In the context of this survey, a 'vegetation plan' refers to a plan for establishing or managing areas of vegetation (remnant native or newly established) with a longer term view for enhancing the amount and quality of vegetation on farms.

The percentage of farms with vegetation plans is shown in Table 8 and Figure 9. There has been modest growth in the proportion of farms with a vegetation plan, now approaching 40 per cent nationally, since 2014. The proportion of farms with vegetation plans is considerably higher than the national average in AEZs within Qld, Tasmania, Victorian high-rainfall zone and northern WA.

Purpose of vegetation plan

When asked about the purpose of their vegetation plan, survey respondents were offered options that included: to assist with crop production, as an additional income source, or to conserve an area of native or remnant vegetation for biodiversity or amenity purposes. Multiple reasons were able to be selected by survey respondents.

Vegetation plan to assist with crop production

When asked about the purpose of the vegetation plan, on average 19 per cent of farms reported that it had some use in assisting crop production (Table 9). This result was considerably lower than in 2014, and may reflect some confusion with survey respondents about the linkage between a vegetation plan and assistance with crop production.

Vegetation plan to provide additional income

Nationally, an average of 14 per cent of growers with a vegetation plan listed the purpose of their plan as being to provide some additional farm income source (Table 10). This is lower than in the previous survey. The response varied considerably between AEZs. The actual income from the vegetation plan was not determined, and could have been direct (such as from firewood or carbon credit) or indirect (such as the provision of livestock shelter, windbreaks or similar).

Vegetation plan to conserve native vegetation for biodiversity or amenity value

Table 11 shows the proportion of survey respondents that described their vegetation plan as being to 'assist with conserving vegetation for biodiversity or amenity value'. The proportions are quite high, reaching 100 per cent in Tasmania, although the figures are generally lower than the previous survey (2014).

This suggests that growers with vegetation plans value vegetation primarily for biodiversity or amenity.

TABLE 10 Percentage of farms with a vegetation plan to provide additional income.

Agro-ecological zone	Farms with a vegetation plan for additional farm income (%)		Significant difference between agro-ecological zones	
	2014	2016	2014 to 2016	2011 to 2016
NSW Central	19	10		
NSW NE / QLD SE	26	26		
NSW NW / QLD SW*	29	12		
NSW / VIC Slopes	35	22		
QLD Central*	13	15		
SA Mid North / Lower EP	15	7		
SA / VIC Bordertown, Wimmera	20	9		
SA / VIC Mallee	10	7		
TAS*	67	33		
VIC High Rainfall	33	9	**	
WA Central	17	14		
WA Eastern*	25	15		
WA Mallee/Sandplain*	17	21		
WA Northern*	24	0	**	
NATIONAL AVERAGES	25	14		

TABLE 11 Percentage of farms with a vegetation plan to conserve an area of native vegetation for biodiversity or amenity benefit.

Agro-ecological zone	Farms with a vegetation plan for biodiversity or amenity (%)		Significant difference between agro-ecological zones	
	2014	2016	2014 to 2016	2011 to 2016
NSW Central	97	65	***	
NSW NE / QLD SE	77	77		
NSW NW / QLD SW*	88	82		
NSW / VIC Slopes	72	81		
QLD Central*	73	85		
SA Mid North / Lower EP	88	83		
SA / VIC Bordertown, Wimmera	100	88	**	
SA / VIC Mallee	88	77		
TAS*	100	100		
VIC High Rainfall	83	84		
WA Central	92	81		
WA Eastern*	88	54	**	
WA Mallee/Sandplain*	83	71		
WA Northern*	94	94		
NATIONAL AVERAGES	87	80		

Crop mix in 2016

Survey respondents were asked: 'What area of (various crops) were planted/sown in 2016?'.

The data for crop areas on farms are reported against the main crop types in the following sections of the report.

Wheat

Wheat as a proposition of total crop area reported by the survey respondents in 2016 is presented in Table 12, Figure 10 and Figure 11 (page 25).

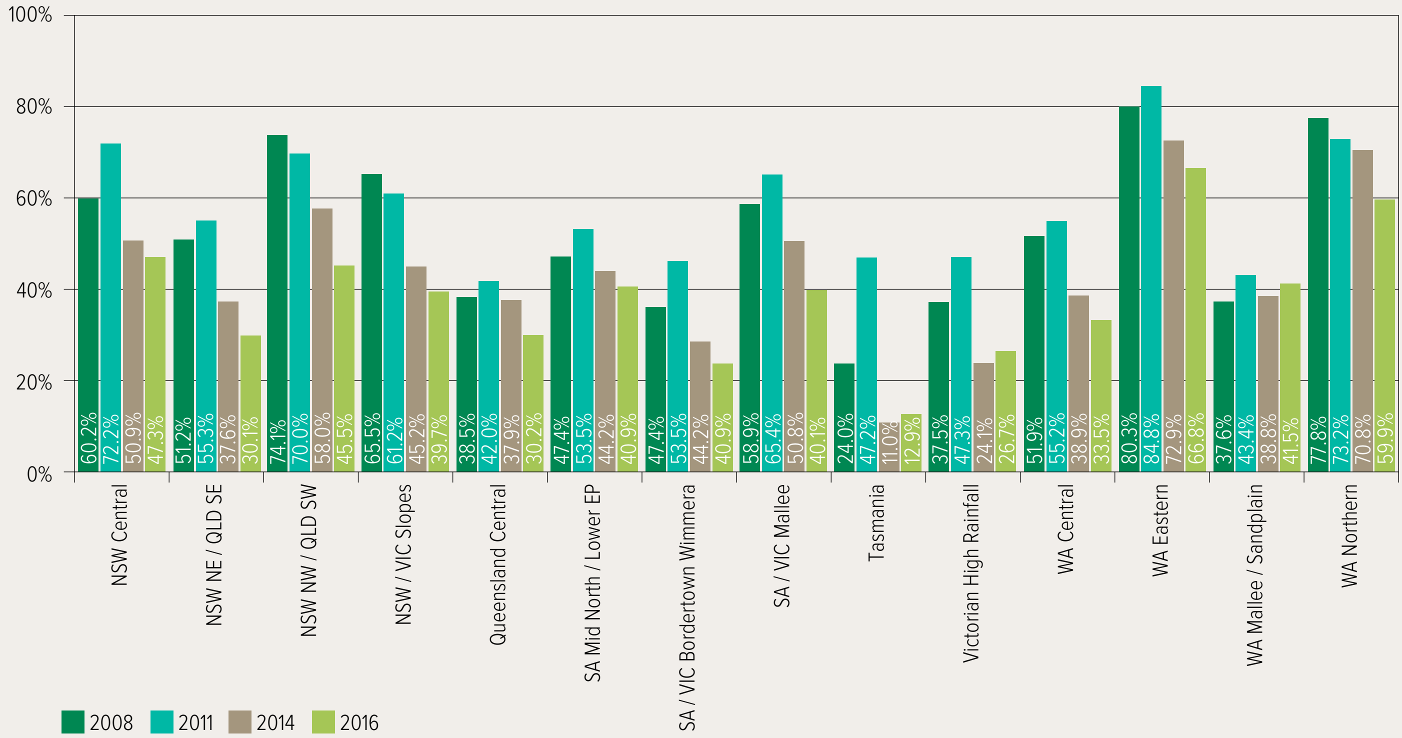
The highest proportion of wheat is grown in AEZs characterised by moderate or low rainfall. These include eastern and northern WA, central NSW, north-west NSW/south-west Queensland, the SA/Victorian Mallee and SA's Mid North and Eyre Peninsula, where 40 per cent or more of the crop area is sown to wheat.

A general decrease in wheat as a proportion of total crop area as reported by survey respondents in 2014 has continued in 2016. The decrease between 2011 and 2016 in wheat was significant in all AEZs, with the exception of Queensland central and WA Mallee/Sandplain.

TABLE 12 Average percentage of crop area planted to wheat.

Agro-ecological zone	Average wheat % of total crop area				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	60.2	72.2	50.9	47.3		***
NSW NE / QLD SE	51.2	55.3	37.6	30.1	**	***
NSW NW / QLD SW	74.1	70.0	58.0	45.5		***
NSW / VIC Slopes	65.5	61.2	45.2	39.7	**	***
QLD Central	38.5	42.0	37.9	30.2		
SA Mid North / Lower EP	47.4	53.5	44.2	40.9		***
SA / VIC Bordertown, Wimmera	36.3	46.4	28.8	24.0		***
SA / VIC Mallee	58.9	65.4	50.8	40.1	**	***
TAS	24.0	47.2	11.0	12.9		**
VIC High Rainfall	37.5	47.3	24.1	26.7		***
WA Central	51.9	55.2	38.9	33.5	**	***
WA Eastern	80.3	84.8	72.9	66.8		***
WA Mallee/Sandplain	37.6	43.4	38.8	41.5		
WA Northern	77.8	73.2	70.8	59.9	**	***
NATIONAL AVERAGES	52.9	58.4	43.6	38.5		

FIGURE 10 Average percentage of crop area planted to wheat 2008–16.



The reduction in wheat as a proportion of total crop area is suggested to be driven by seasonal conditions during the planting period and/or growers' perceptions of potential relative prices, (that is, expected returns from wheat as compared with other crop choices, notably pulses and oilseeds in 2016).

In 2016, on a national basis, the proportion of wheat planted is now less than 40 per cent of the total cropped area.

Barley

The highest proportions of barley as a percentage of the total cropped area are found in the more southern AEZs: SA, Victoria and the WA Mallee/Sandplain. In these AEZs barley is generally greater than 20 per cent of the cropped area in most years (Table 13, Figure 12 and Figure 13).

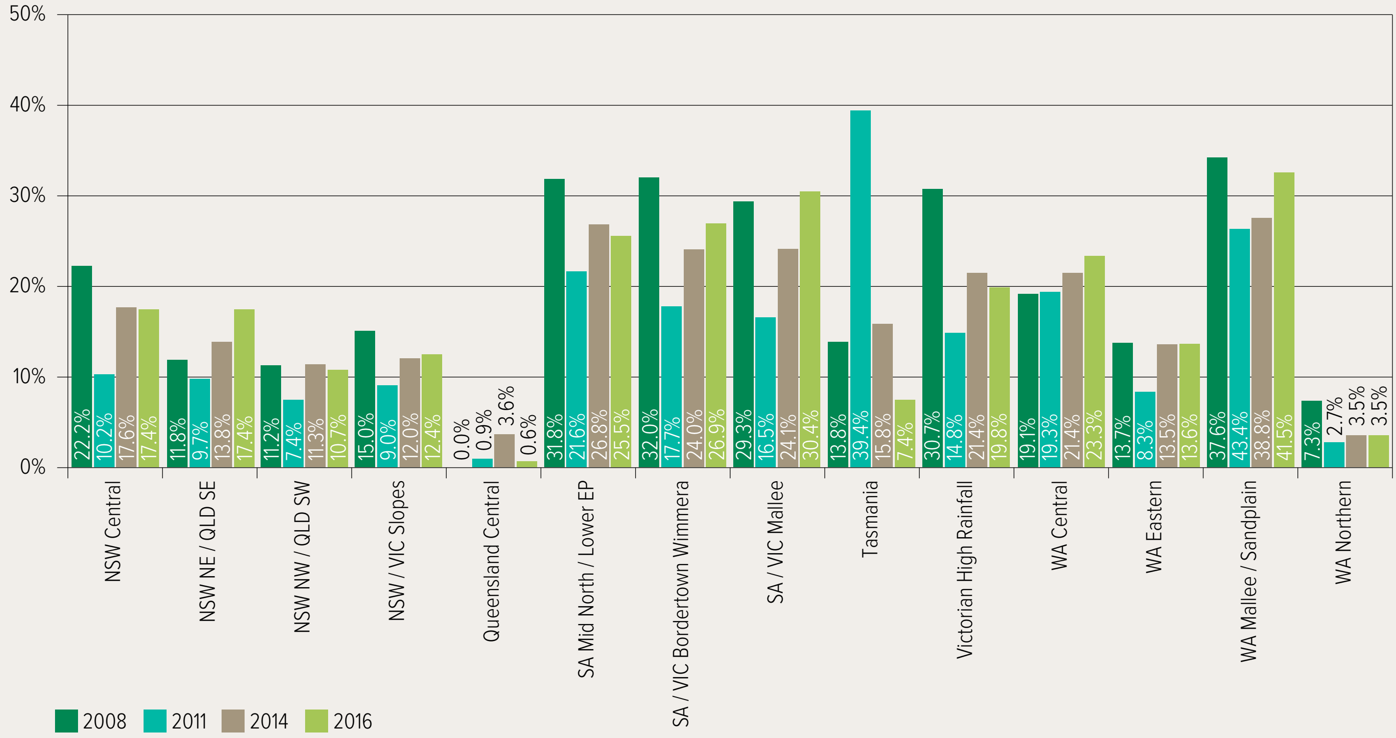
Overall there has been an increase in barley as a proportion of total crop area in 2016, continuing a trend seen in 2014 as compared with 2011. However, in 2016 barley generally remained at levels

TABLE 13 Average percentage of crop area planted to barley.

Agro-ecological zone	Average of total crop area planted to barley (%)				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	22.2	10.2	17.6	17.4		**
NSW NE / QLD SE	11.8	9.7	13.8	17.4		***
NSW NW / QLD SW	11.2	7.4	11.3	10.7		
NSW / VIC Slopes	15.0	9.0	12.0	12.4		**
QLD Central	0.0	0.9	3.6	0.6		
SA Mid North / Lower EP	31.8	21.6	26.8	25.5		
SA / VIC Bordertown, Wimmera	32.0	17.7	24.0	26.9		***
SA / VIC Mallee	29.3	16.5	24.1	30.4	***	***
TAS	13.8	39.4	15.8	7.4		**
VIC High Rainfall	30.7	14.8	21.4	19.8		
WA Central	19.1	19.3	21.4	23.3		**
WA Eastern	13.7	8.3	13.5	13.6		**
WA Mallee/Sandplain	34.2	26.3	27.5	32.5		
WA Northern	7.3	2.7	3.5	3.5		
NATIONAL AVERAGES	19.4	14.5	16.9	17.2		

GRDC

FIGURE 12 Average percentage of barley (% of cropped area) in 2008, 2011, 2014 and 2016.



below that reported in 2008. The reasons for changes in barley as a proportion of total crop area are likely to be varied, but are thought to be primarily driven by the:

- seasonal conditions in the year, especially at the time planting decisions are made;
- relative price prospects for barley (both for malt and feed); and
- grain prices for other alternative winter grain crops, notably canola and pulses.

Other winter cereals

Within the survey, the 'other winter cereal' category includes oats, triticale and cereal rye. These crops are mainly used either for grazing or for producing grain to be retained on-farm for feeding livestock. For this reason it is common to find a high proportion of these crops in AEZs where mixed grain/livestock farming is a widely practised farming system. The proportions of each individual crop (oats, cereal rye and triticale) were not recorded in the 2016 survey.

FIGURE 11 Percentage of cropped area planted to wheat in 2016.

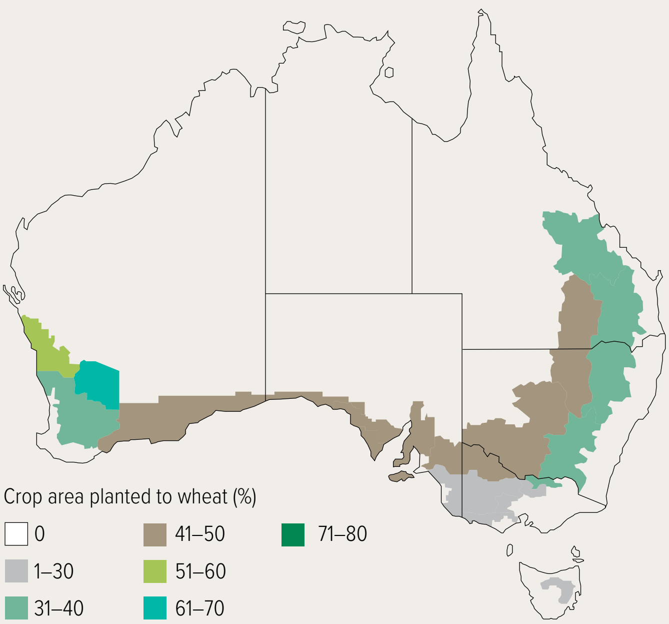


FIGURE 13 Percentage of cropped area planted to barley in 2016.

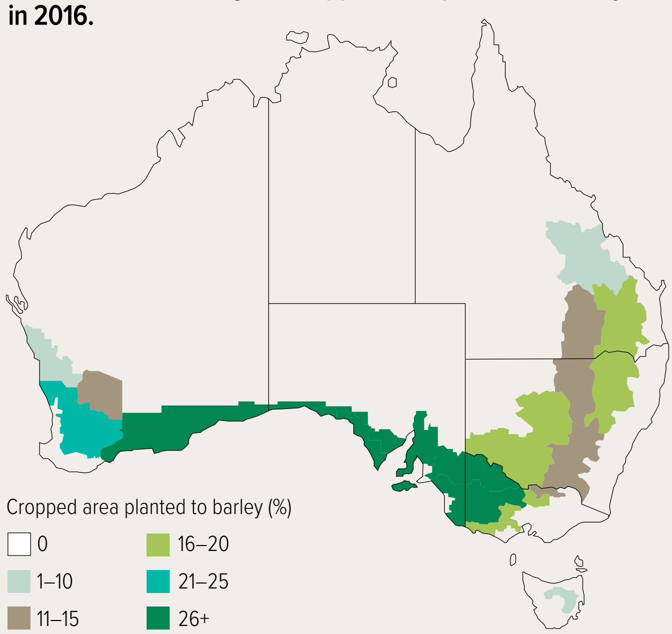
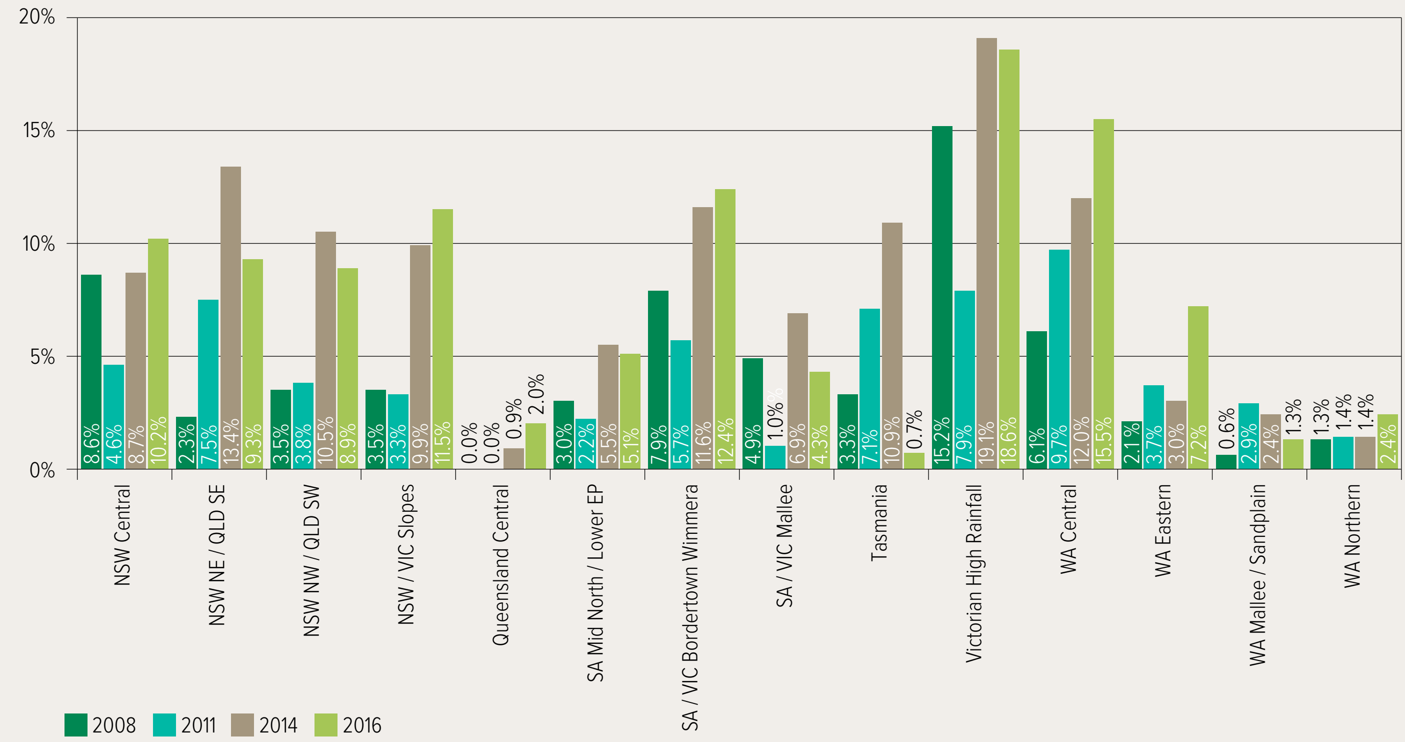


FIGURE 14 Average percentage of other winter cereals in 2008, 2011, 2014 and 2016.



Nationally, the area of other winter cereals of total crop areaas a proportion of total crop area is relatively minor compared with wheat and barley. There was a minor decrease in other winter cereal crops in 2016 compared with the previous survey (Table 14, Figure 14).

Summer cereals

Summer cereals (principally grain sorghum and maize) form a significant component of crop sequences in the northern AEZs, especially Queensland central and north-east NSW/south-east Queensland.

In 2016 details of summer cereals were not included in the survey. While a significant crop in crop sequences for growers that grow summer cereals, nationally the areas are generally minor and fluctuate markedly with seasonal conditions. The data reported here (Table 15, Figure 15 (page 28)) are from the 2014 survey.

TABLE 14 Average percentage of crop area planted to other winter cereals.

Agro-ecological zone	Average proportion crop area planted to other winter cereals (%)				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	8.6	4.6	8.7	10.2		***
NSW NE / QLD SE	2.3	7.5	13.4	9.3		
NSW NW / QLD SW	3.5	3.8	10.5	8.9		**
NSW / VIC Slopes	3.5	3.3	9.9	11.5		***
QLD Central	0.0	0.0	0.9	2.0		
SA Mid North / Lower EP	3.0	2.2	5.5	5.1		***
SA / VIC Bordertown, Wimmera	7.9	5.7	11.6	12.4		***
SA / VIC Mallee	4.9	1.0	6.9	4.3		***
TAS	3.3	7.1	10.9	0.7		
VIC High Rainfall	15.2	7.9	19.1	18.6		**
WA Central	6.1	9.7	12.0	15.5		***
WA Eastern	2.1	3.7	3.0	7.2	***	
WA Mallee/Sandplain	0.6	2.9	2.4	1.3		
WA Northern	1.3	1.4	1.4	2.4		
NATIONAL AVERAGES	4.4	4.3	8.3	7.8		

TABLE 15 Average percentage of crop area planted to summer cereals.

Agro-ecological zone	Average of total crop area planted to summer cereals (%)			Significant difference between years	
	2008	2011	2014	2011 to 2014	2008 to 2014
NSW Central	0.4	1.2	1.2		
NSW NE / QLD SE	25.6	18.2	17.1		**
NSW NW / QLD SW	3.4	2.4	0.8		
NSW / VIC Slopes	0.0	0.1	0.1		
QLD Central	49.1	28.0	23.5		***
SA Mid North / Lower EP	0.0	0.0	0.0		
SA / VIC Bordertown, Wimmera	0.0	0.0	0.4		
SA / VIC Mallee	0.0	0.0	0.1		
TAS	2.8	0.0	0.0		
VIC High Rainfall	0.5	0.2	1.9		
WA Central	0.0	0.0	0.0		
WA Eastern	0.0	0.0	0.0		
WA Mallee/Sandplain	0.0	0.0	0.0		
WA Northern	0.0	0.0	0.0		
NATIONAL AVERAGES	5.8	3.6	3.2		

Oilseeds

Oilseeds (predominantly canola) tend to be more commonly grown in southern NSW, the higher-rainfall zones and the Bordertown/Wimmera areas of Victoria and SA, and the central and southern cropping areas of WA (Table 16, Figure 16, Figure 17 (see pages 29, 30)).

There was an increase in the proportion of oilseeds (expected to be mainly canola) recorded in 2014 compared with between 2008 and 2011, mostly in the NSW/Victorian slopes, SA/Victorian Mallee, WA Eastern and Northern and to a lesser extent WA Mallee/Sandplain. However, this trend was not continued in 2016, with a slight decrease in several AEZs, notably in WA, SA and Victoria.

The increase in the proportion of oilseeds in the crop areas in 2016 within these AEZs is likely to be due to the expected relative financial returns from the use of these crops, along with an assessment of seasonal conditions approaching the ideal sowing times for canola, which were less than ideal in parts of WA, SA and Victoria, yet more favourable in NSW in 2016.

Pulses

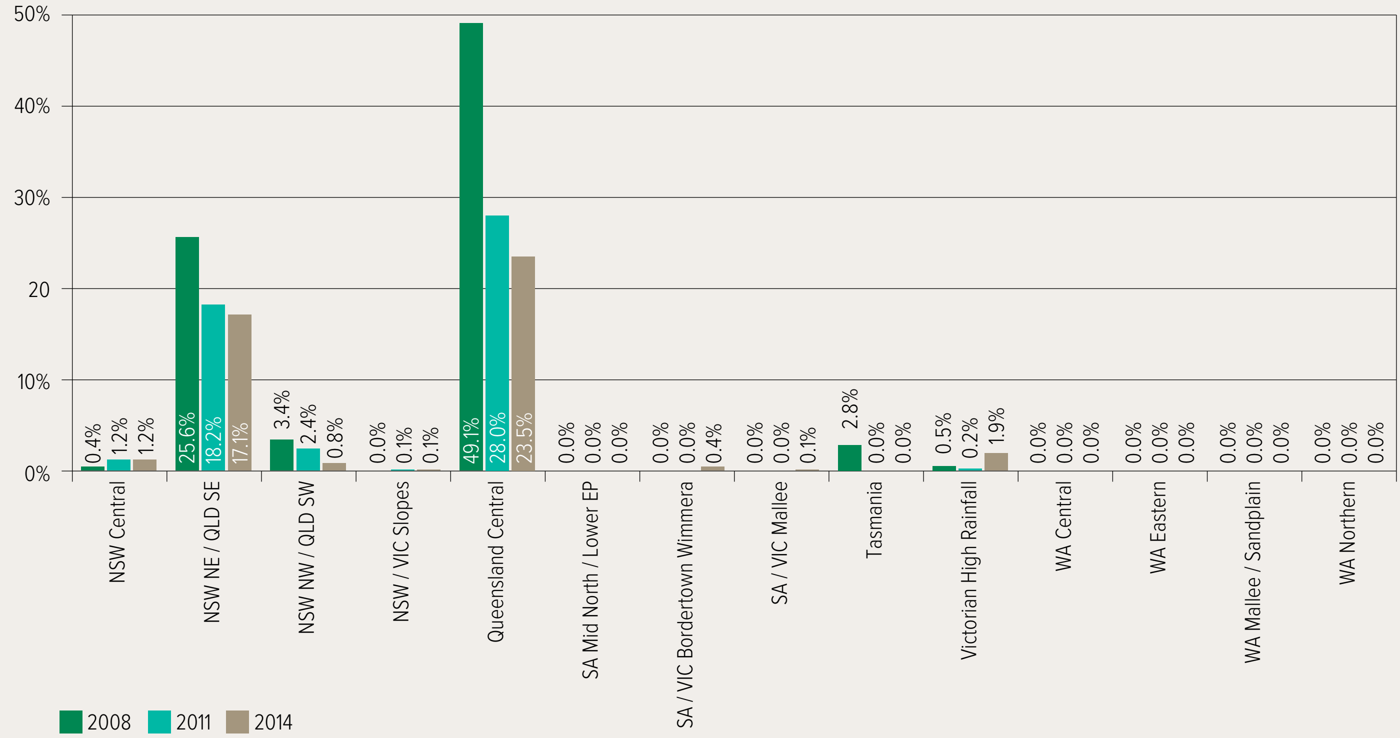
Pulses have made up a relatively minor proportion (frequently well under 10 per cent) of the total crop area for most AEZs during the period 2008 to 2016, with the exception of:

- north-west NSW/south-west Queensland (likely due to chickpeas plantings);

TABLE 16 Average percentage of crop area planted to winter oilseeds.

Agro-ecological zone	Average % of crop area				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	1.6	6.7	8.6	8.7		
NSW NE / QLD SE	0.8	1.8	2.2	3.2		
NSW NW / QLD SW	1.0	3.8	4.4	4.0		
NSW / VIC Slopes	11.3	22.7	22.2	23.3		
QLD Central	0.0	0.0	0.0	0.0		
SA Mid North / Lower EP	6.0	8.3	7.3	5.5		**
SA / VIC Bordertown, Wimmera	15.0	18.2	15.5	9.3	***	***
SA / VIC Mallee	1.4	8.6	7.5	3.3	***	***
TAS	23.9	2.6	1.2	3.9		
VIC High Rainfall	16.1	22.3	21.9	15.3	**	**
WA Central	15.0	10.0	18.1	15.3		***
WA Eastern	1.4	1.7	5.5	5.7		**
WA Mallee/Sandplain	23.4	19.8	26.1	19.4		
WA Northern	6.4	7.7	12.7	12.6		**
NATIONAL AVERAGES	8.8	9.6	10.9	9.2		

FIGURE 15 Average percentage of summer cereals in 2008, 2011 and 2014.



- central Queensland (likely due to both mungbean and chickpea plantings);
- Mid North/Lower Eyre Peninsula of SA (likely to be combination of lentil, chickpea, field pea, faba bean and vetch plantings);
- Wimmera region of SA/Victoria (likely to be combination of lentils, faba beans, chickpeas and vetch plantings); and
- northern Western Australia (likely due to narrowleaf lupin plantings).

However, the proportion of pulses in the crop mix in 2016 generally showed a very strong increase across the country. In several AEZs the proportion of pulses in 2016 was close to or more than 20 per cent of the cropped area including: Queensland and northern NSW, much of SA and Victoria and northern WA.

Overall, the increase in the use of pulses was almost a doubling of the proportion of these in the crop mix. See Table 17, Figures 18 and 19.

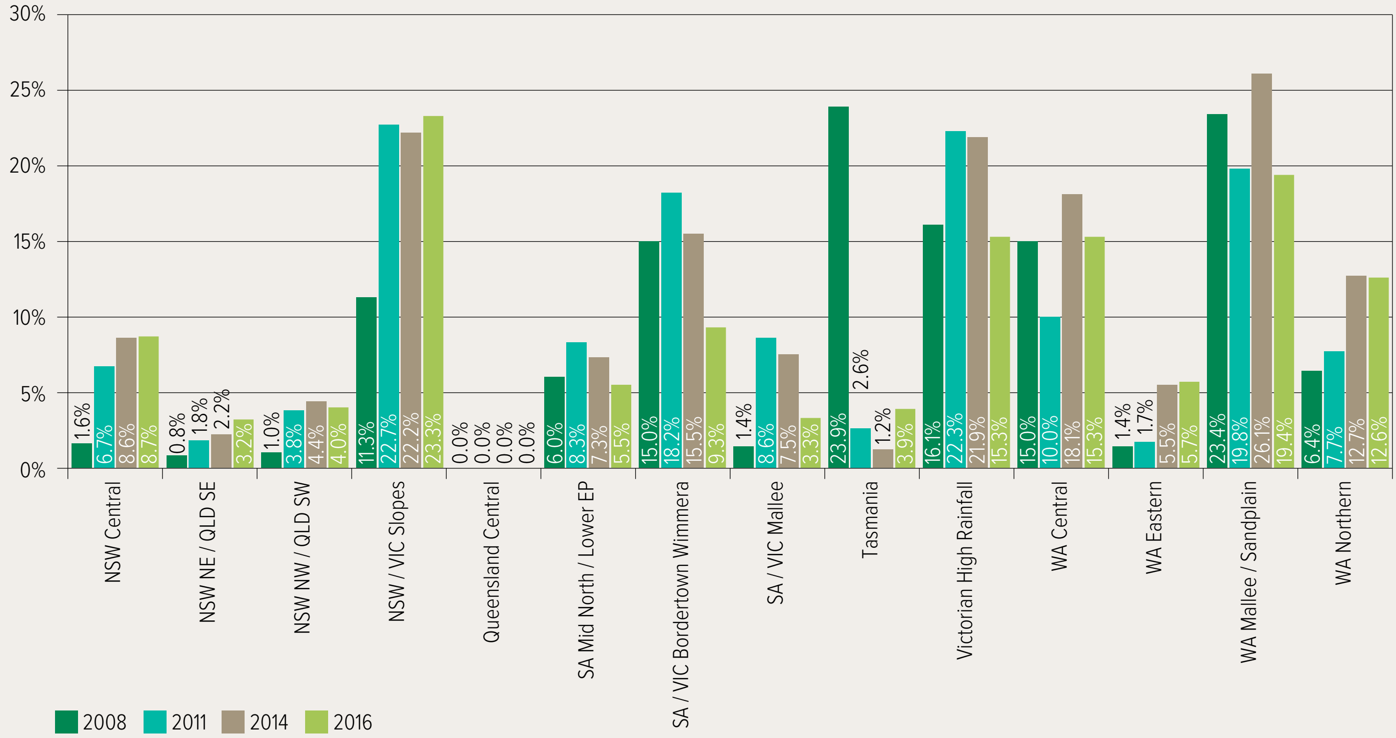
Reasons for these changes are likely to be due to seasonal conditions coupled with grower perceptions of risk and price

TABLE 17 Average percentage of crop area planted to pulses.

Agro-ecological zone	Average total crop area planted to pulses (%)				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	0.3	1.0	5.1	8.3	**	***
NSW NE / QLD SE	5.2	3.0	7.0	26.5	***	***
NSW NW / QLD SW	5.2	11.4	8.9	27.8	***	***
NSW / VIC Slopes	3.1	2.1	4.5	5.4		***
QLD Central	12.4	8.1	10.4	29.5	***	***
SA Mid North / Lower EP	6.7	12.8	14.8	19.7	***	***
SA / VIC Bordertown, Wimmera	7.1	10.4	13.8	19.1	***	***
SA / VIC Mallee	2.8	8.6	10.4	15.4	***	***
TAS	7.1	3.7	2.6	1.5		
VIC High Rainfall	0.0	4.2	4.2	5.7		
WA Central	5.9	5.8	4.3	7.2	***	
WA Eastern	2.6	1.6	2.9	4.1		***
WA Mallee/Sandplain	2.8	7.7	1.8	5.3	**	
WA Northern	6.1	14.7	10.2	18.3	**	
NATIONAL AVERAGES	4.8	6.8	7.2	13.8		

GRDC

FIGURE 16 Average percentage of crop area planted to winter oilseeds 2008, 2011, 2014 and 2016.



prospects. Prices received for crops such as chickpeas, faba beans and lentils were particularly strong in 2016.

Total crop mix

Tables 18, 19 and 20 (pages 30, 31) and Figures 20 and 21 (pages 32, 33) summarise the proportion of the major crops as a percentage of the cropped area on farms as recorded in the surveys of 2008, 2011, 2014 and 2016. These tables and figures represent the data shown in the earlier sections of this chapter.

As discussed in the section describing wheat, the data for Tasmania is likely unreliable due to small sample size.

National trends

When the survey data is considered on a national basis, some trends can be noted (Table 22 and Figure 22, pages 32, 33).

Trends in the national proportion of cropped area planted with major crops 2008 to 2016 include:

- Despite an increase over the period 2008 to 2011, a significant decrease in the proportion of wheat over the period 2008 to 2016.
- The proportion of barley decreased between 2008 and 2011, then increased as a proportion of the cropped area in 2014 and remained relatively static in 2016.

TABLE 18 Average percentage of cropped area planted with the major crops in 2008.

Agro-ecological zone	Wheat (%)	Barley (%)	Other cereals (%)	Summer cereals (%)	Oilseeds (%)	Pulses (%)
NSW Central	60.2	22.2	8.6	0.4	1.6	0.3
NSW North-East / QLD South-East	51.2	11.8	2.3	25.6	0.8	5.2
NSW North-West / QLD South-West	74.1	11.2	3.5	3.4	1.0	5.2
NSW / VIC Slopes	65.5	15.0	3.5	0.0	11.3	3.1
QLD Central	38.5	0.0	0.0	49.1	0.0	12.4
SA Mid North / Lower Eyre Peninsula	47.4	31.8	3.0	0.0	6.0	6.7
SA / VIC Bordertown, Wimmera	36.3	32.0	7.9	0.0	15.0	7.1
SA / VIC Mallee	58.9	29.3	4.9	0.0	1.4	2.8
TAS	24.0	13.8	3.3	2.8	23.9	7.1
VIC High Rainfall	37.5	30.7	15.2	0.5	16.1	0.0
WA Central	51.9	19.1	6.1	0.0	15.0	5.9
WA Eastern	80.3	13.7	2.1	0.0	1.4	2.6
WA Mallee/Sandplain	37.6	34.2	0.6	0.0	23.4	2.8
WA Northern	77.8	7.3	1.3	0.0	6.4	6.1

FIGURE 17 Percentage of crop area planted to oilseeds in 2016.

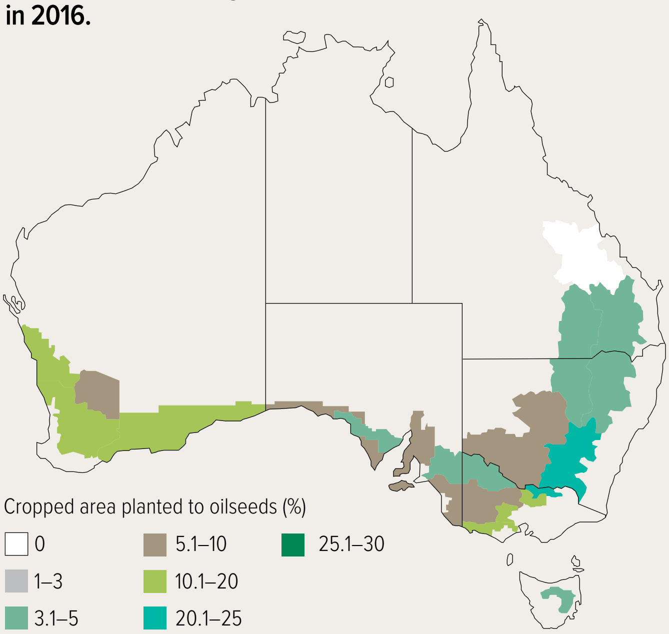


FIGURE 19 Percentage of cropped are planted to pulses in 2016.

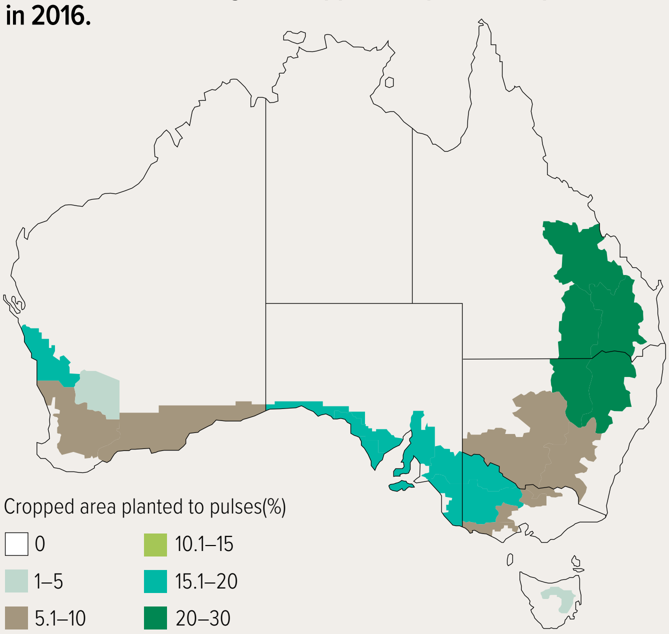


TABLE 19 Average percentage of cropped area planted with the major crops in 2011.

Agro-ecological zone	Wheat (%)	Barley (%)	Other cereals (%)	Summer cereals (%)	Oilseeds (%)	Pulses (%)
NSW Central	72.2	10.2	4.6	1.2	6.7	1.0
NSW North-East / QLD South-East	55.3	9.7	7.5	18.2	1.8	3.0
NSW North-West / QLD South-West	70.0	7.4	3.8	2.4	3.8	11.4
NSW / VIC Slopes	61.2	9.0	3.3	0.1	22.7	2.1
QLD Central	42.0	0.9	0.0	28.0	0.0	8.1
SA Mid North / Lower Eyre Peninsula	53.5	21.6	2.2	0.0	8.3	12.8
SA / VIC Bordertown, Wimmera	46.4	17.4	5.7	0.0	18.2	10.4
SA / VIC Mallee	65.4	16.5	1.0	0.0	8.6	8.6
TAS	47.2	39.4	7.1	0.0	2.6	3.7
VIC High Rainfall	47.3	14.8	7.9	0.2	22.3	4.2
WA Central	55.2	19.3	9.7	0.0	10.0	5.8
WA Eastern	84.8	8.3	3.7	0.0	1.7	1.6
WA Mallee/Sandplain	43.4	26.3	2.9	0.0	19.8	7.7
WA Northern	73.2	2.7	1.4	0.0	7.7	14.7

FIGURE 18 Average percentage of cropped area planted to pulses in 2008, 2011, 2014 and 2016.

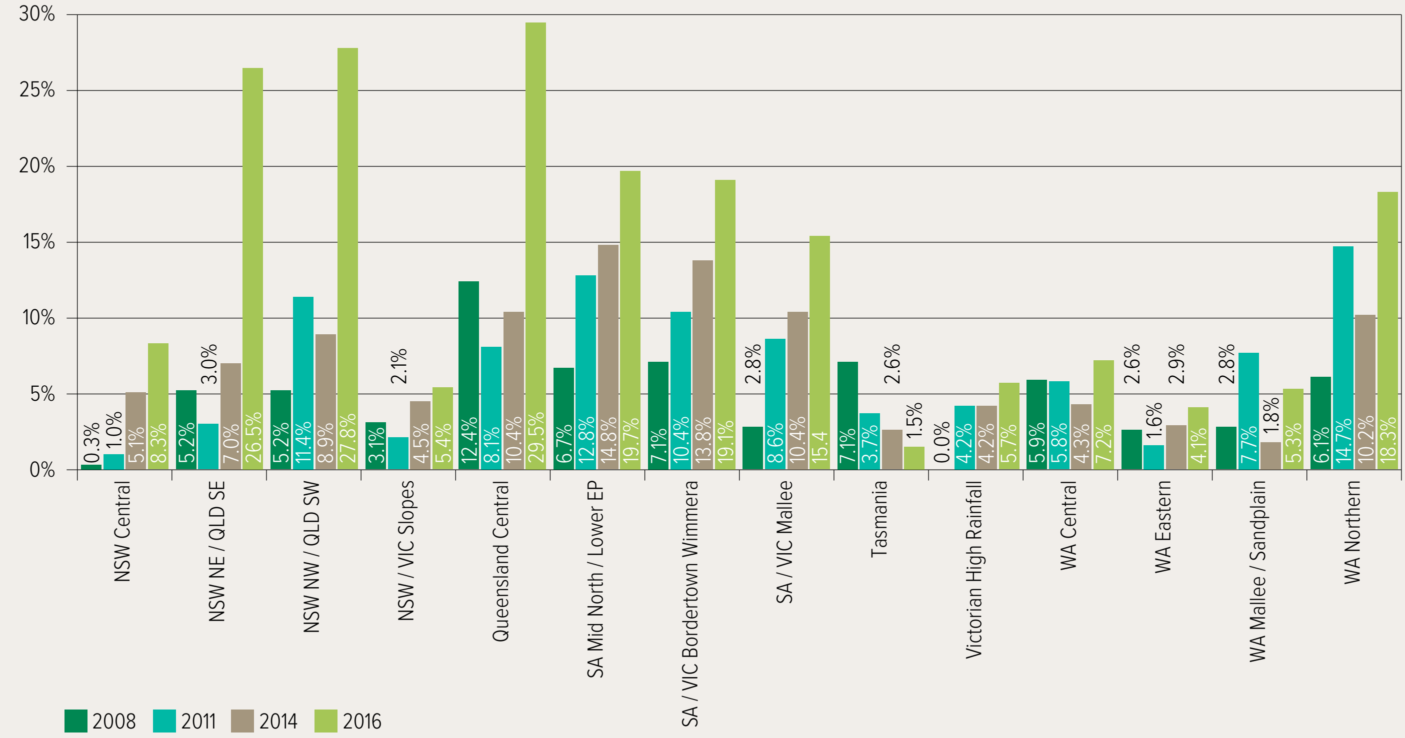


TABLE 20 Average percentage of cropped area planted with the major crops in 2014.

Agro-ecological zone	Wheat (%)	Barley (%)	Other cereals (%)	Summer cereals (%)	Oilseeds (%)	Pulses (%)
NSW Central	50.9	17.6	6.5	1.2	8.6	5.1
NSW North-East / QLD South-East	37.6	13.8	11.7	17.1	2.2	7.0
NSW North-West / QLD South-West	58.0	11.3	10.5	0.8	4.4	8.9
NSW / VIC Slopes	45.2	12.0	9.8	0.1	22.2	4.5
QLD Central	37.9	3.6	0.9	23.5	0.0	10.4
SA Mid North / Lower Eyre Peninsula	44.2	26.8	4.8	0.0	7.3	14.8
SA / VIC Bordertown, Wimmera	28.8	24.0	11.2	0.4	15.5	13.8
SA / VIC Mallee	50.8	24.1	5.7	0.1	7.5	10.4
TAS	11.0	15.8	10.9	0.0	1.2	2.6
VIC High Rainfall	24.1	21.4	17.7	1.9	21.9	4.2
WA Central	38.9	21.4	11.3	0.0	18.1	4.3
WA Eastern	72.9	13.5	2.2	0.0	5.5	2.9
WA Mallee/Sandplain	38.8	27.5	2.4	0.0	26.1	1.8
WA Northern	70.8	3.5	1.4	0.0	12.7	10.2

FIGURE 20 Average percentage of crop area as planted with the major crops in 2008, 2011, 2014 and 2016 by AEZs.

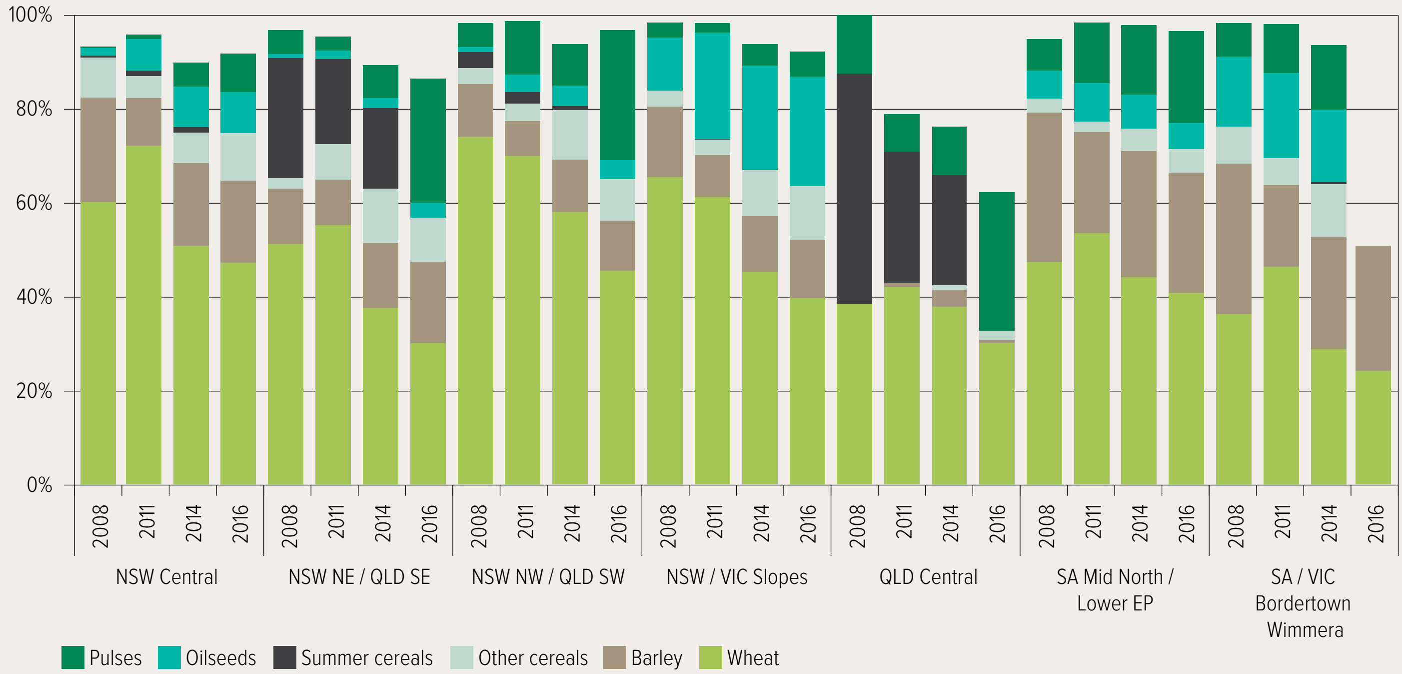


TABLE 21 Average percentage of cropped area planted with the major crops in 2016.

Agro-ecological zone	Wheat (%)	Barley (%)	Other cereals (%)	Summer cereals (%)	Oilseeds (%)	Pulses (%)
NSW Central	47.3	17.4	10.2	n/a	8.7	8.3
NSW North-East / QLD South-East	30.1	17.4	9.3	n/a	3.2	26.5
NSW North-West / QLD South-West	45.5	10.7	8.9	n/a	4.0	27.8
NSW / VIC Slopes	39.7	12.4	11.5	n/a	23.3	5.4
QLD Central	30.2	0.6	2.0	n/a	0.0	29.5
SA Mid North / Lower Eyre Peninsula	40.9	25.5	5.1	n/a	5.5	19.7
SA / VIC Bordertown, Wimmera	24.0	26.9	12.4	n/a	9.3	19.1
SA / VIC Mallee	40.1	30.4	4.3	n/a	3.3	15.4
TAS	12.9	7.4	0.7	n/a	3.9	1.5
VIC High Rainfall	26.7	19.8	18.6	n/a	15.3	5.7
WA Central	33.5	23.3	15.5	n/a	15.3	7.2
WA Eastern	66.8	13.6	7.2	n/a	5.7	4.1
WA Mallee/Sandplain	41.5	32.5	1.3	n/a	19.4	5.3
WA Northern	59.9	3.5	2.4	n/a	12.6	18.3

TABLE 22 Average national percentage of cropped area planted with the major crops in 2008, 2011, 2014 and 2016.

Crop type	2008	2011	2014	2016	Significance between years	
					2014 to 2016	2011 to 2016
Wheat	55.3	59.8	43.6	38.5	***	***
Barley	21.0	13.8	16.9	17.2		**
Other cereals	4.5	4.5	7.6	7.8		***
Oilseeds	8.0	10.9	10.9	9.2		
Pulses	4.6	6.8	7.2	13.8	***	***
Summer cereals	4.2	2.2	3.2	n/a	n/a	n/a

FIGURE 21 Average percentage of crop area as planted with the major crops in 2008, 2011, 2014 and 2016 by AEZs.

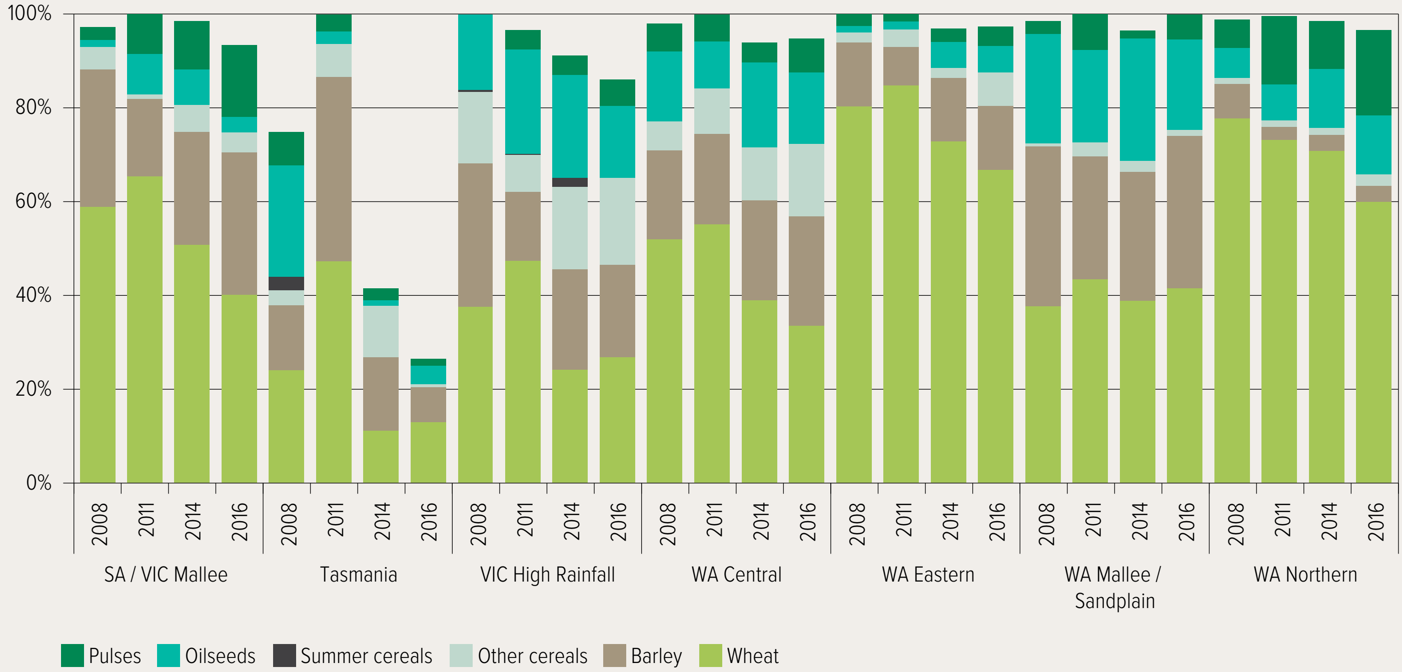
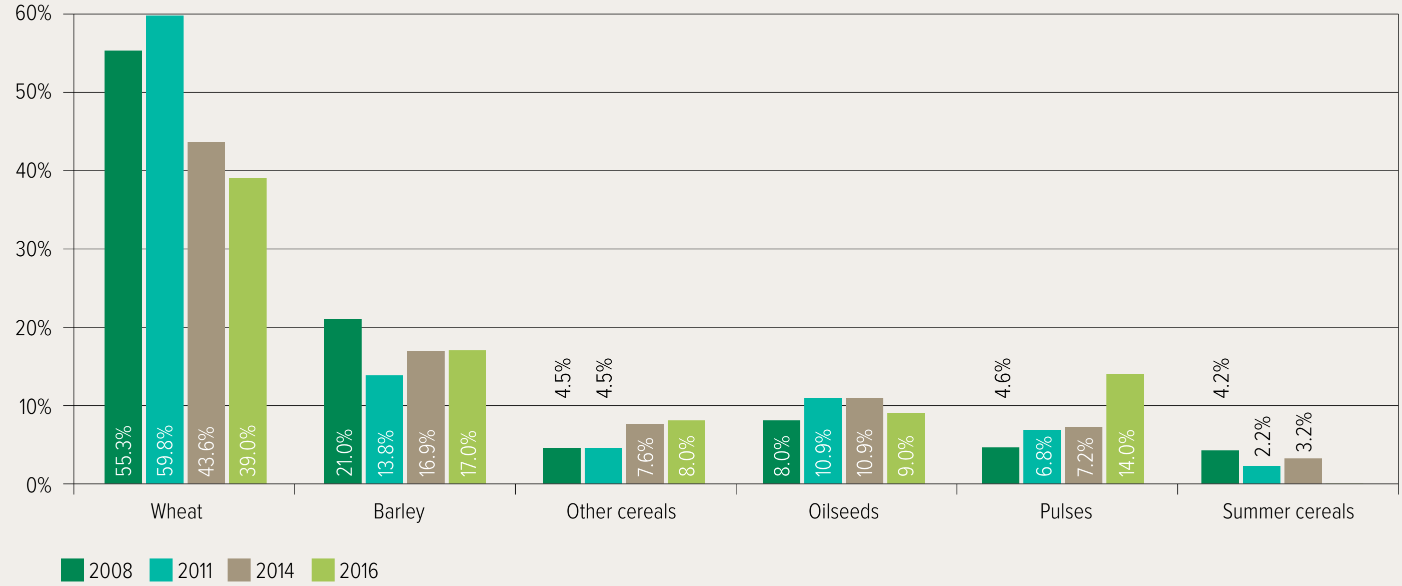


FIGURE 22 Average national percentage of cropped area planted with the major crops 2008, 2011, 2014 and 2016.



Tillage in 2016

Survey respondents were asked the following questions about the use of tillage systems for crop and pasture establishment on their farm:

- In the sowing of your crops in 2016, what area of your crop (converted to a percentage in this report), was sown using:
  - zero-tillage – < 10 per cent soil disturbance, e.g. disc planters;
  - no-tillage – between 10 per cent and 30 per cent soil disturbance, e.g. knife or spear points;
  - direct drill – one pass at sowing, with full cut planting;
  - minimum tillage – one cultivation prior to planting operation; or
  - multiple tillage – more than one cultivation before sowing.

Zero-tillage

In the context of this survey, 'zero-tillage' is where no cultivation of the soil occurs and less than 10 per cent of the soil is disturbed in the planting operation.

Typically, machinery used to achieve less than 10 per cent soil disturbance would be a disc-based implement, where vertical or near-vertical discs (several combinations are available, often with leading coulter discs followed by pairs of discs forming a narrow 'v' shape) effectively 'slice' through the soil, placing seed and fertiliser at the desired depth, and leaving very little soil actually disturbed. Press wheels of one or other design are often also used.

Nationally, the proportion of the crop reported by 2016 survey participants as planted using zero-tillage has decreased significantly compared to 2008. See Table 23, Figure 23 and Figure 24. The decline was most pronounced in the period 2008 to 2014, with some recovery in 2016. The trends vary widely between individual AEZs.

As noted in previous survey reports, it is possible that some confusion has occurred among survey respondents regarding terminology used, which may have seen areas of no-tillage reported by growers as zero-tillage. With modifications to survey questions for 2016, it is expected that this confusion has now been addressed. On a national basis, this may explain the decline in zero-tillage from 2008 to 2011 and continued decline to 2014, with a minor recovery in 2016.

It is considered most likely that the increases reported in northern NSW and Queensland are real, with growers increasingly using disc machines on the more clay-based soils in these AEZs with summer crop production.

FIGURE 24 Percentage of crop area planted using zero-tillage in 2016.

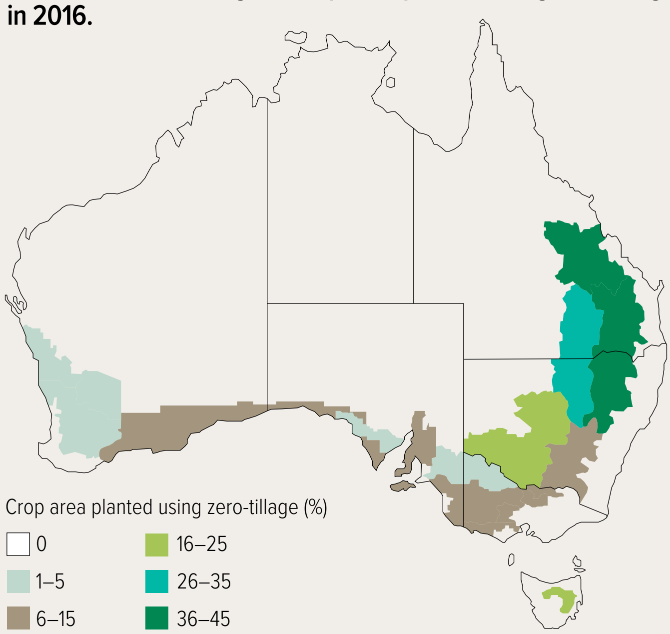
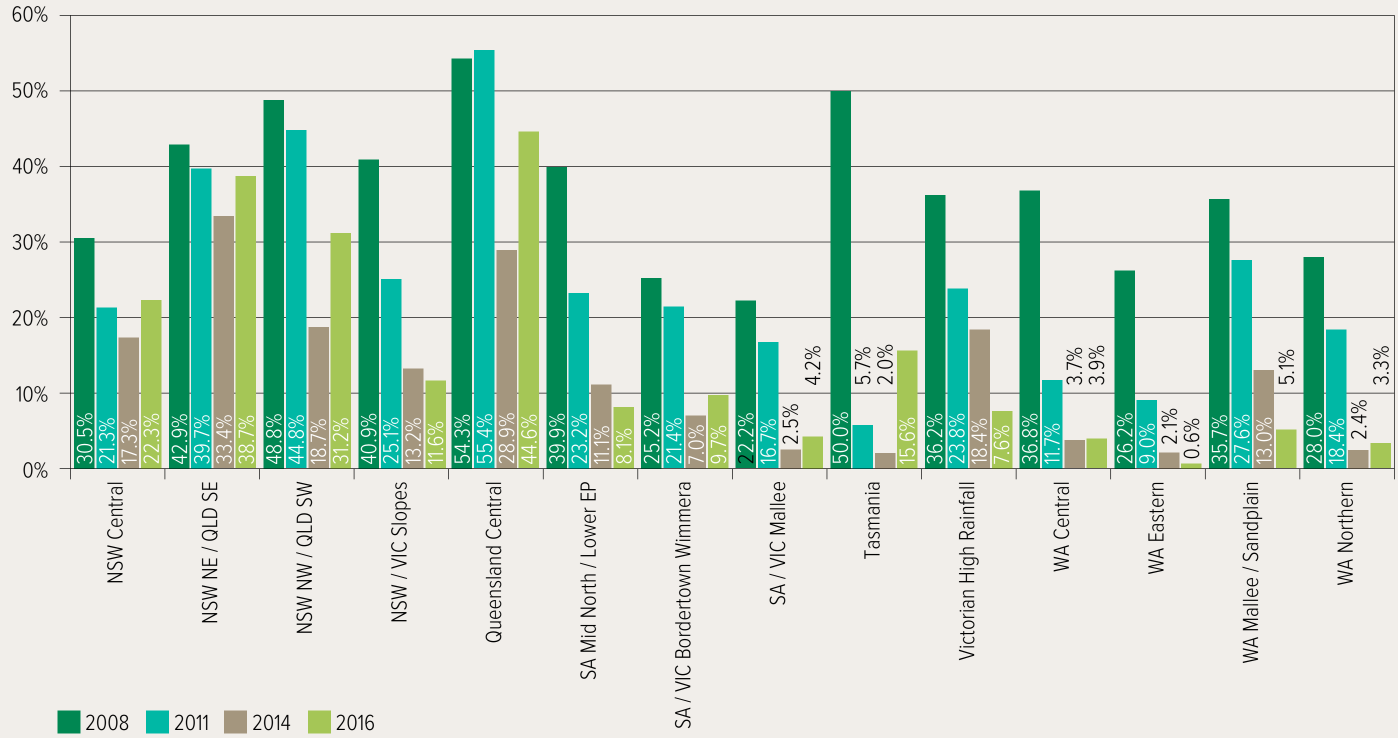


FIGURE 23 Average percentage of cropped area planted using zero-tillage (less than 10% soil disturbance).



The decline in the reported use of zero-tillage in WA is significant in all AEZs and is thought to reflect growers moving back to no-tillage and away from the use disc-based machines.

Reasons for variation in the use of zero-tillage between AEZs is likely due to soil types (very light sandy soils tend not to suit the use of discs as much as sandy and clay loams do,) as well as individual growers trialling these systems to determine the suitability for their circumstances.

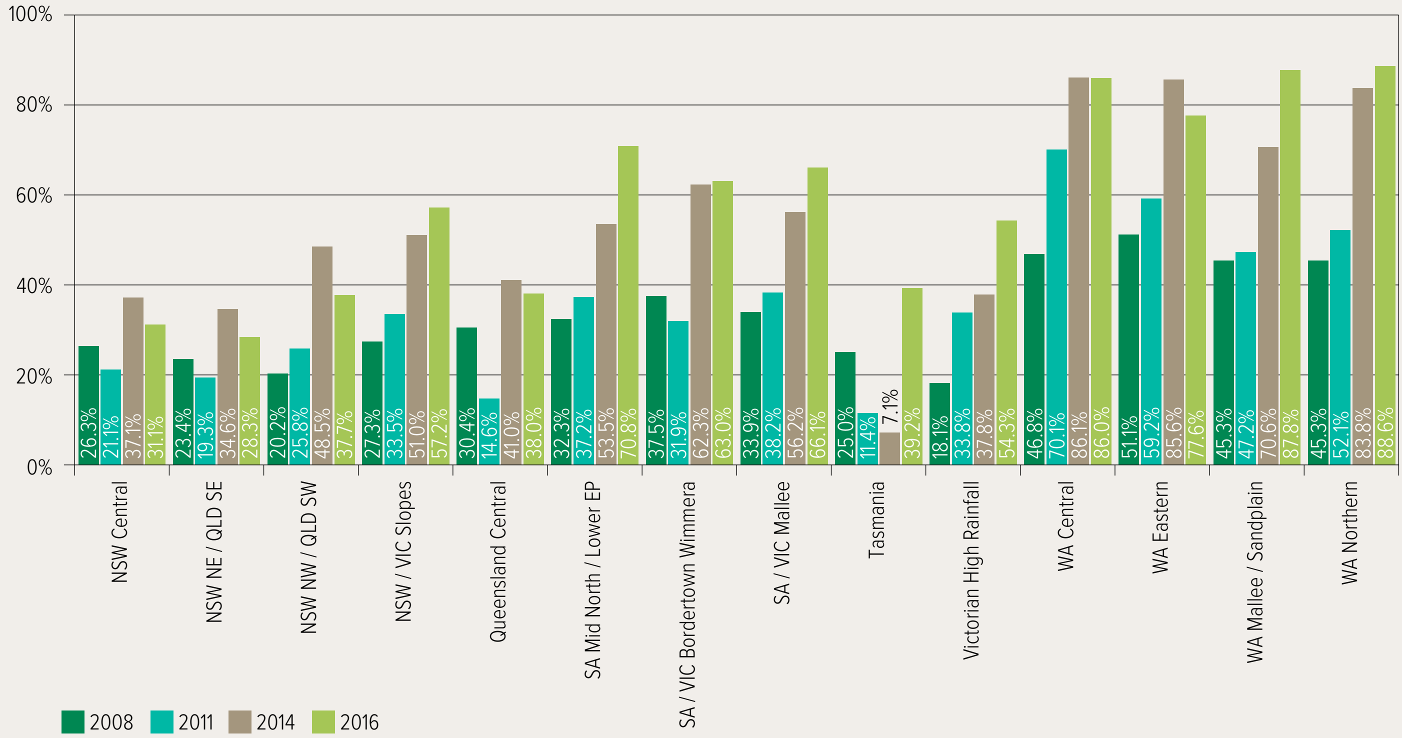
No-tillage

For the purpose of this survey, 'no-tillage' is defined as where machinery disturbs more than 10 per cent but less than 30 per cent of the soil surface across the planting width. Typically, such machinery consists of very narrow (or 'knife') soil-engaging tools, where a relatively narrow area of soil is moved aside allowing seed and fertiliser to be placed in the 'trench' or 'slot'. Loosened soil then falls, or is pushed, back in to cover the seed and press wheels are commonly used to firm the soil over the seed. Row spacing is often set to allow for ease of crop residue flow. Similarly, speed of travel is often adjusted to avoid over-aggressive soil throw into the adjoining furrow, which can result in uneven depth

TABLE 23 Average percentage of cropped area planted using zero-tillage (less than 10% soil disturbance).

Agro-ecological zone	Average cropped area planted using zero-tillage (%)				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	30.5	21.3	17.3	22.3		
NSW NE / QLD SE	42.9	39.7	33.4	38.7		
NSW NW / QLD SW	48.8	44.8	18.7	31.2		
NSW / VIC Slopes	40.9	25.1	13.2	11.6		***
QLD Central	54.3	55.4	28.9	44.6		
SA Mid North / Lower EP	39.9	23.2	11.1	8.1		***
SA / VIC Bordertown, Wimmera	25.2	21.4	7.0	9.7		***
SA / VIC Mallee	22.2	16.7	2.5	4.2		***
TAS	50.0	5.7	2.0	15.6		
VIC High Rainfall	36.2	23.8	18.4	7.6	**	***
WA Central	36.8	11.7	3.7	3.9		***
WA Eastern	26.2	9.0	2.1	0.6		**
WA Mallee/Sandplain	35.7	27.6	13.0	5.1		***
WA Northern	28.0	18.4	2.4	3.3		***
NATIONAL AVERAGES	37.0	24.6	12.4	14.8		

FIGURE 25 Average percentage of cropped area planted using no-tillage (between 10% and 30% soil disturbance).



of seed placement and uneven incorporation or mixing of soil-applied herbicides where these are used.

The data as reported by growers for the 2016 season shows a general increase, significant in some AEZs, in the use of no-tillage techniques as compared to previous survey data (see Table 24, Figure 25 and Figure 26).

There appears to have been a decrease in the use of no-tillage over the period 2014 to 2016 in much of Queensland and northern NSW. This possibly reflects the noted increase in zero-tillage reported in the previous section.

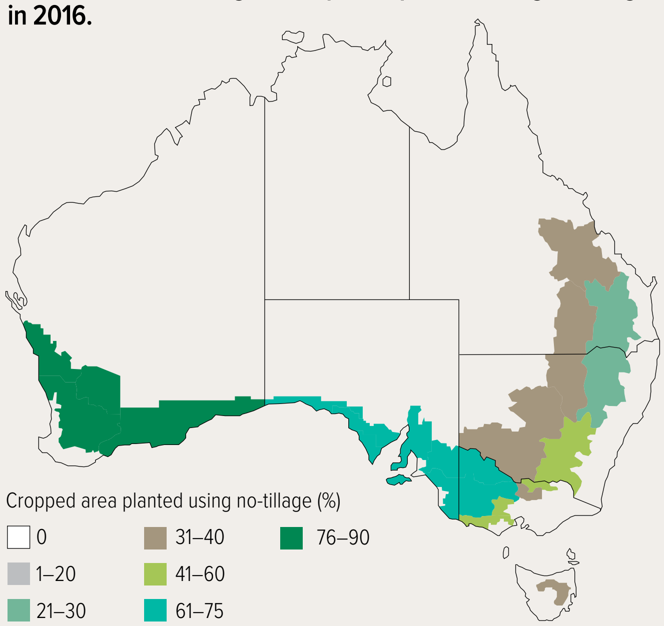
In line with the 2008 and 2011 data, the adoption of both zero-tillage and no-tillage, cover a high proportion of the crop area, indicating that growers seek to disturb their soil as little as possible (described in the section below). The adoption of zero-tillage was highest in much of NSW and Queensland, in the high-rainfall areas of Victoria and WA's Mallee/Sandplain.

In WA the use of knife-type planting systems remains high. It has continued to increase over the levels reported in 2014 and is now used on more than 80 per cent of the cropped area in that state. Again, this may reflect the decrease in reported zero-tillage in WA.

TABLE 24 Average percentage of cropped area planted using no-tillage (between 10% and 30% soil disturbance).

Agro-ecological zone	Average cropped area planted using no-tillage (%)				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	26.3	21.1	37.1	31.1		
NSW NE / QLD SE	23.4	19.3	34.6	28.3		
NSW NW / QLD SW	20.2	25.8	48.5	37.7		
NSW / VIC Slopes	27.3	33.5	51.0	57.2		***
QLD Central	30.4	14.6	41.0	38.0		**
SA Mid North / Lower EP	32.3	37.2	53.5	70.8	***	***
SA / VIC Bordertown, Wimmera	37.5	31.9	62.3	63.0		***
SA / VIC Mallee	33.9	38.2	56.2	66.1	**	***
TAS	25.0	11.4	7.1	39.2	**	
VIC High Rainfall	18.1	33.8	37.8	54.3	**	**
WA Central	46.8	70.1	86.1	86.0		***
WA Eastern	51.1	59.2	85.6	77.6		
WA Mallee/Sandplain	45.3	47.2	70.6	87.8		***
WA Northern	45.3	52.1	83.8	88.6		***
NATIONAL AVERAGES	33.1	35.4	53.9	59.0		

FIGURE 26 Percentage of crop area planted using no-tillage in 2016.



Reasons for this may lie in soil type and user experience with the use of zero-tillage. However, this cannot be determined from this survey, and would require detailed interviews with growers and advisers to confirm.

Overall, the adoption of no-tillage has grown over the levels reported in 2014, being used on 59 per cent of cropped hectares in 2016.

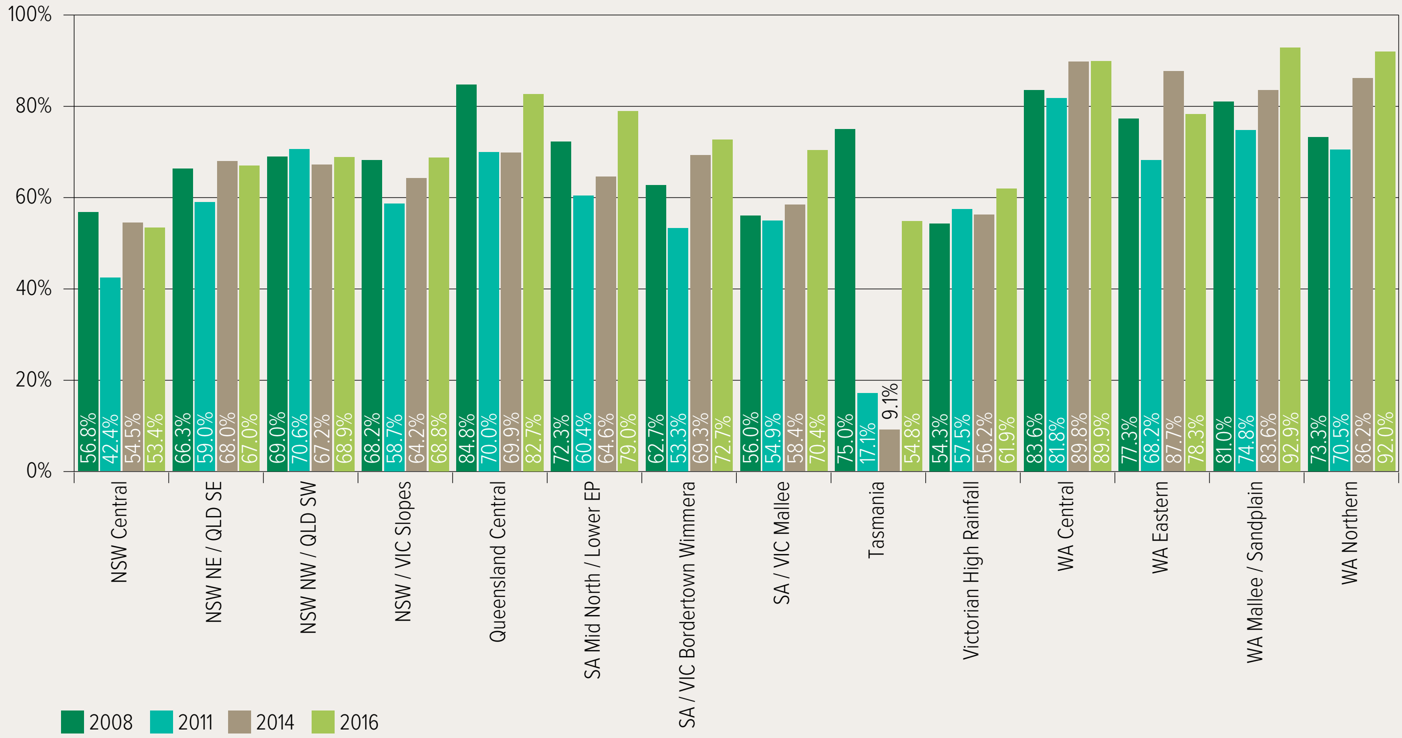
Zero and no-tillage combined

One way of considering the adoption of conservation farming techniques is to consider the combination of 'zero-tillage' and 'no-tillage' together, and consider the combined changes in levels of adoption of these practices. The rationale is that in the interest of maintaining soil structure, and minimising soil erosion, reducing tillage and employing zero-tillage or no-tillage are practices are shared by growers using both methods. The data for the combination of these practices is presented in an amalgamated form in Table 25 and Figure 27. This allows some consideration to be made between the levels of adoption of the combined zero-

TABLE 25 Average percentage of cropped area planted using zero-tillage or no-tillage (less than 30% soil disturbance).

Agro-ecological zone	Average cropped area planted using zero-tillage or no-tillage (%)				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	56.8	42.4	54.5	53.4		
NSW NE / QLD SE	66.3	59.0	68.0	67.0		
NSW NW / QLD SW	69.0	70.6	67.2	68.9		
NSW / VIC Slopes	68.2	58.7	64.2	68.8		**
QLD Central	84.8	70.0	69.9	82.7		
SA Mid North / Lower EP	72.3	60.4	64.6	79.0	***	***
SA / VIC Bordertown, Wimmera	62.7	53.3	69.3	72.7		***
SA / VIC Mallee	56.0	54.9	58.4	70.4	**	***
TAS	75.0	17.1	9.1	54.8	**	**
VIC High Rainfall	54.3	57.5	56.2	61.9		
WA Central	83.6	81.8	89.8	89.9		**
WA Eastern	77.3	68.2	87.7	78.3		
WA Mallee/Sandplain	81.0	74.8	83.6	92.9		**
WA Northern	73.3	70.5	86.2	92.0		***
NATIONAL AVERAGES	70.0	59.9	66.3	73.7		

FIGURE 27 Average percentage of cropped area planted using zero-tillage or no-tillage (less than 30% soil disturbance).



tillage and no-tillage (that is, any practice that disturbs less than 30 per cent of soil when planting) and how these may have changed in the absence of any effect of the way the two practices are understood to be defined by survey respondents.

The adoption of zero-till and no-till combined remains high and has grown, with almost three-quarters of the national crop area planted using of these techniques in 2016. In all four of the AEZs in WA, adoption is greater than 75 per cent in all four AEZs in WA, and over 90 per cent in two of these zones.

Survey results show that there has been an increase in the use of these two planting techniques since 2011, to a peak now in 2016.

Direct-drill

In the context of this survey, 'direct-drill' is where there are no cultivations prior to planting. However, the crop is planted in a single pass with full soil disturbance across the full width of the machine.

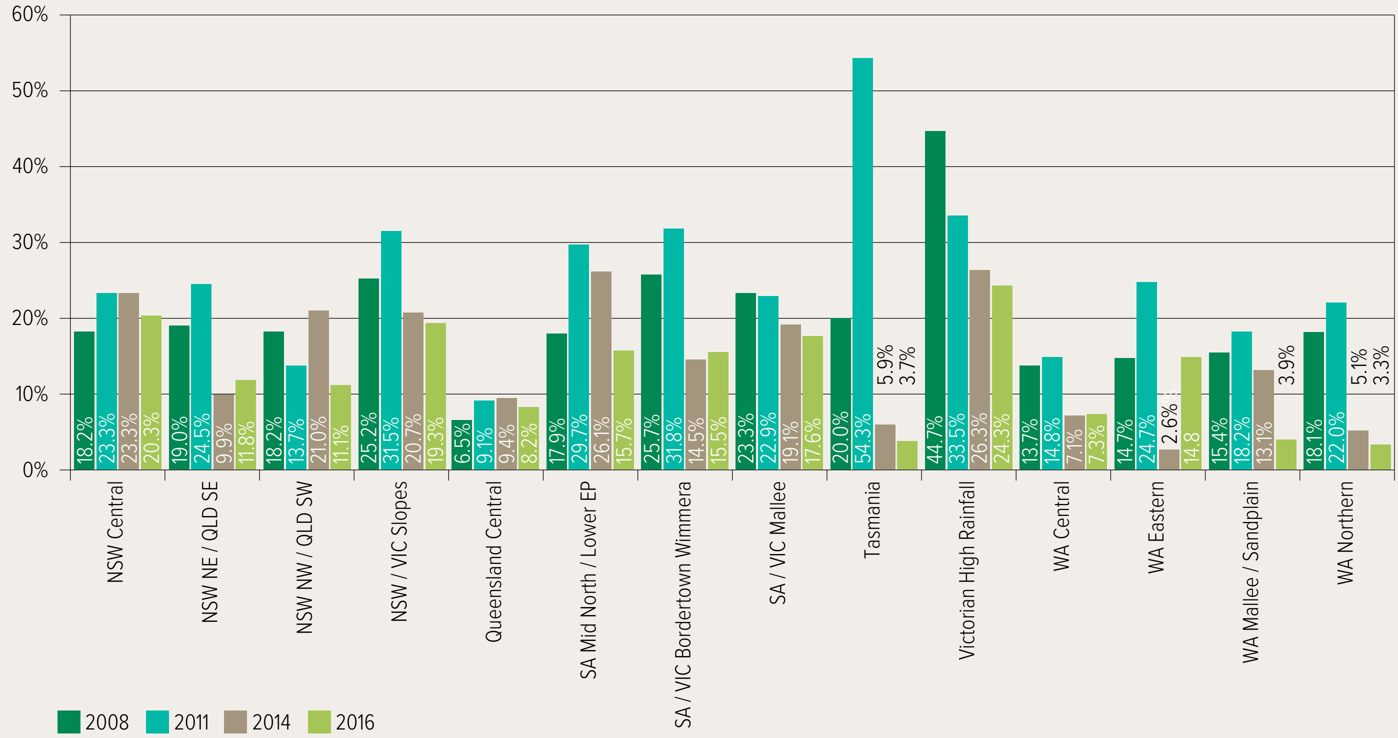
As with zero and no-tillage this is a 'one-pass' planting operation, however, frequently more 'conventional' (traditional) or modified conventional machines are used.

TABLE 26 Average percentage of cropped area planted using direct drill.

Agro-ecological zone	Average cropped area planted using direct-drill (%)				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	18.2	23.3	23.3	20.3		
NSW NE / QLD SE	19.0	24.5	9.9	11.8		***
NSW NW / QLD SW	18.2	13.7	21.0	11.1		
NSW / VIC Slopes	25.2	31.5	20.7	19.3		***
QLD Central	6.5	9.1	9.4	8.2		
SA Mid North / Lower EP	17.9	29.7	26.1	15.7	**	***
SA / VIC Bordertown, Wimmera	25.7	31.8	14.5	15.5		***
SA / VIC Mallee	23.3	22.9	19.1	17.6		
TAS	20.0	54.3	5.9	3.7		***
VIC High Rainfall	44.7	33.5	26.3	24.3		
WA Central	13.7	14.8	7.1	7.3		**
WA Eastern	14.7	24.7	2.6	14.8		
WA Mallee/Sandplain	15.4	18.2	13.1	3.9		**
WA Northern	18.1	22.0	5.1	3.3		***
NATIONAL AVERAGES	20.0	25.3	14.6	12.6		

GRDC

FIGURE 28 Average percentage of cropped area planted using direct drill.



When direct-drilling, soil engaging points are wide enough to loosen the soil across the whole planting width, providing a 'full cut' or more complete disturbance of the soil across the width of the planting machine, with no area left undisturbed between crop rows. Covering or soil-levelling devices may consist of a range of options, from press wheels to more conventional harrows in various forms.

Nationally the proportion of total crop area planted with direct-drill in 2016 was slightly lower than it was in 2014, continuing a decline in the use of this technique since 2011. There are a number of AEZs where the use of direct-drilling has shown an increase since 2014, these include NSW NE/Queensland SE, SA/Victoria Bordertown–Wimmera and WA Eastern. The levels of use of this planting technique are generally less than 20 per cent in individual AEZs and nationally average 12.6 per cent. At these levels some fluctuation is expected between surveys due to sampling or other error.

It is possible that there are seasonal, weed management or other reasons for these fluctuations in the levels of direct-drilling that are unable to be determined without follow up qualitative survey work.

TABLE 27 Average percentage of cropped area planted using one pass planting (zero-tillage, no-tillage or direct-drill).

Agro-ecological zone	Average cropped area planted using 'one-pass' planting (%)				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	75.0	65.7	77.8	73.7		
NSW NE / QLD SE	85.3	83.6	77.9	78.8		
NSW NW / QLD SW	87.2	84.3	88.2	80.0		
NSW / VIC Slopes	93.5	90.2	84.6	88.1		
QLD Central	91.3	79.1	79.3	90.9		
SA Mid North / Lower EP	90.2	90.2	91.2	94.7		
SA / VIC Bordertown, Wimmera	88.4	85.1	83.8	88.1		
SA / VIC Mallee	79.4	77.8	77.5	88.0	***	***
TAS	95.0	71.4	15.0	58.5	**	
VIC High Rainfall	99.0	91.0	82.5	86.3		
WA Central	97.3	96.5	96.8	97.2		
WA Eastern	92.0	92.9	90.3	93.1		
WA Mallee/Sandplain	96.4	93.1	96.6	96.8		
WA Northern	91.4	92.5	91.4	95.3		
NATIONAL AVERAGES	90.1	85.2	80.9	86.4		

FIGURE 29 Percentage of cropped area planted using direct-drill in 2016.

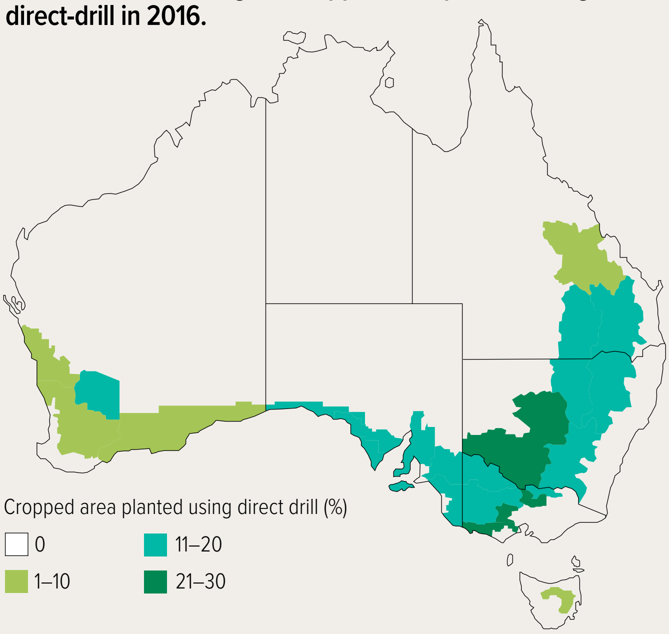
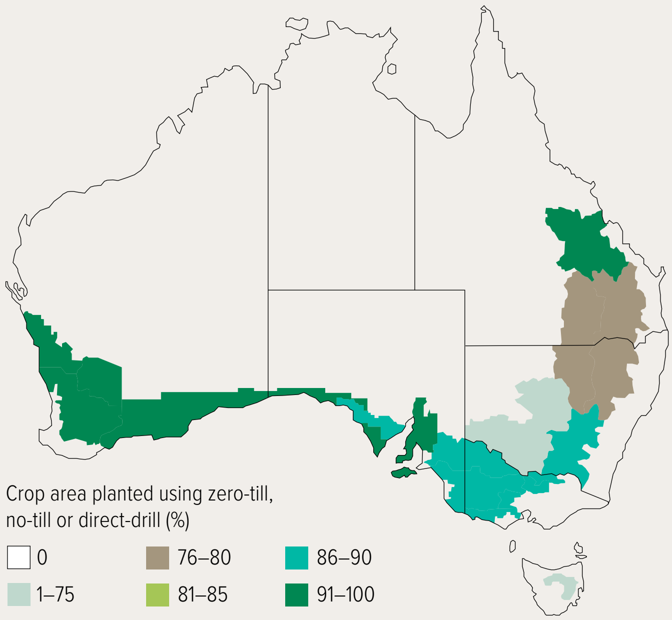


FIGURE 31 Proportion of crop area planted using zero or no-tillage or direct-drill in 2016.



Zero-tillage, no-tillage and direct-drill combined ('one-pass' planting)

Given the potential for some confusion about conservation tillage system terminology among survey respondents and the potential impacts of this on how they may have reported the usage of different tillage practices, the data for the combination of these three practices is also presented in amalgamated form (see Table 27, Figure 30 and Figure 31). This allows some consideration to be made between the levels of adoption of the combined zero-tillage, no-tillage and direct-drilling (that is, any practice where only one pass through the soil occurs at planting) and how these 'one-pass' practices may have changed in relation to the use of minimum, reduced and multiple tillage practices that are described below.

The three one-pass planting practices (zero-tillage, no-tillage and direct-drill) represent the majority of methods used for cropping in most AEZs, generally representing well over 80 per cent of the total crop area planted.

While there was some decline in their use in a general sense as reported in 2014, since then there has been a general increase in the use of these one-pass planting techniques.

TABLE 28 Average percentage of cropped area planted using minimum tillage techniques.

Agro-ecological zone	Average cropped area planted using minimum-tillage (%)				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	16.1	22.6	9.0	10.7		***
NSW NE / QLD SE	6.8	7.9	9.4	12.6		
NSW NW / QLD SW	9.2	10.1	4.7	8.2		
NSW / VIC Slopes	4.1	6.4	10.0	6.7		
QLD Central	4.3	12.3	5.8	3.6		
SA Mid North / Lower EP	4.4	6.6	5.2	4.3		
SA / VIC Bordertown, Wimmera	9.3	9.8	8.6	9.0		
SA / VIC Mallee	14.4	14.2	15.4	7.3	***	**
TAS	5.0	22.1	30.8	4.6		
VIC High Rainfall	0.4	5.2	12.3	4.4	**	
WA Central	2.0	2.3	2.6	1.9		
WA Eastern	5.9	3.9	6.7	6.9		
WA Mallee/Sandplain	1.1	3.9	1.1	0.0		
WA Northern	7.1	3.0	5.7	4.4		
NATIONAL AVERAGES	6.4	9.3	9.1	6.0		

GRDC

FIGURE 30 Average percentage of cropped area planted using zero-tillage, no-tillage or direct-drill in 2008, 2011, 2014 and 2016.

FIGURE 32 Average percentage of cropped area planted using minimum tillage techniques.

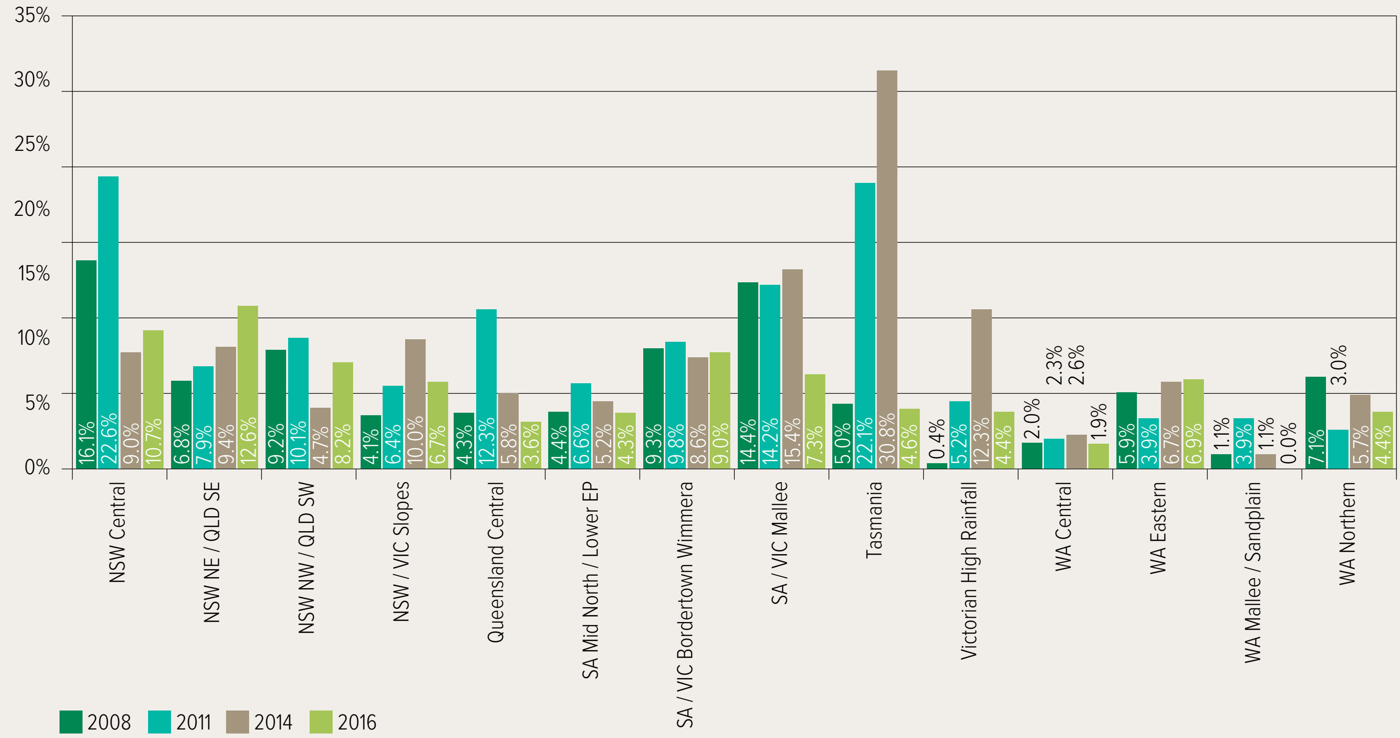


FIGURE 33 Proportion of crop area planted using minimum-tillage techniques in 2016.

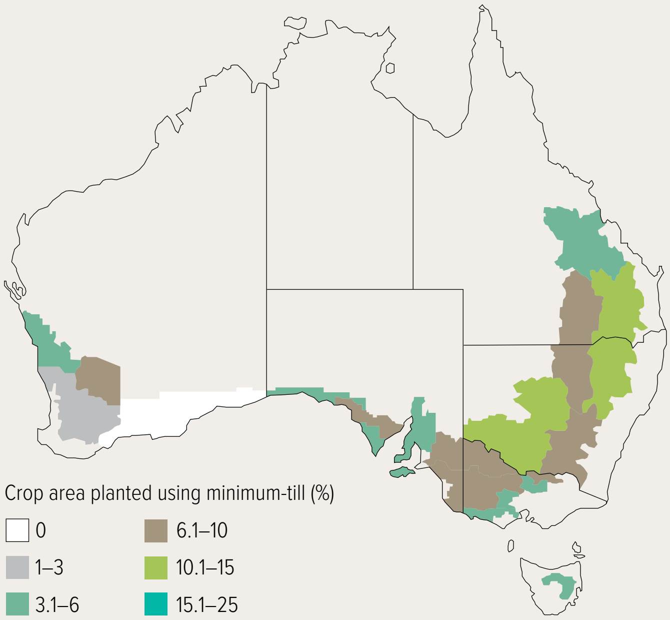


FIGURE 35 Percentage of crop area planted using multiple-tillage techniques in 2016.

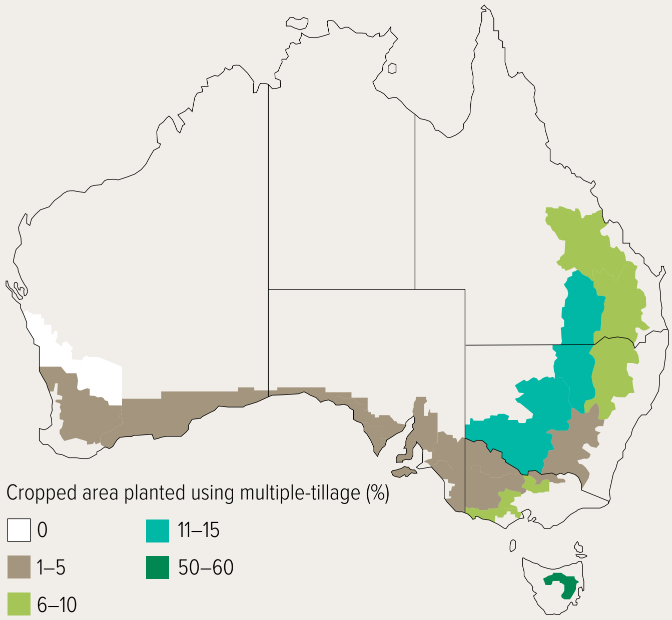


TABLE 29 Average percentage of cropped area planted using multiple-tillage techniques.

Agro-ecological zone	Average cropped area planted using multiple-tillage (%)				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	3.4	6.4	11.7	13.8		**
NSW NE / QLD SE	1.7	1.7	12.5	7.5		***
NSW NW / QLD SW	0.4	0.4	7.0	11.7		***
NSW / VIC Slopes	0.0	1.3	5.6	4.3		
QLD Central	0.0	0.0	14.8	5.2		
SA Mid North / Lower EP	0.0	0.3	3.9	0.2	**	
SA / VIC Bordertown, Wimmera	0.8	2.5	7.6	2.5	**	
SA / VIC Mallee	2.1	1.9	7.6	3.1	**	
TAS	0.0	3.6	54.1	34.0		
VIC High Rainfall	0.3	0.0	6.7	8.7		***
WA Central	0.0	0.0	0.7	0.8		
WA Eastern	0.0	1.6	2.9	0.0		
WA Mallee/Sandplain	0.0	0.0	2.3	3.6		
WA Northern	0.0	0.0	3.1	0.0		
NATIONAL AVERAGES	0.6	1.4	10.0	6.8		

Minimum-tillage

Minimum-tillage generally involves only one cultivation, with full soil disturbance, prior to the planting operation. That is, less disturbance/fewer cultivations than the 'multiple tillage' system, but more than any of the direct-drill, no-tillage or zero-tillage systems.

Such cultivations are often used for weed control or to place previous crop residues into the soil so that planting operations, often with conventional machinery, are not impeded by such residues.

As shown in Table 28, Figure 32 and Figure 33, minimum-tillage techniques are seen to be slightly higher in some AEZs (for example, in NSW), although there is generally lower use of this practice nationally compared to one-pass planting techniques.

Multiple tillage (conventional cultivation)

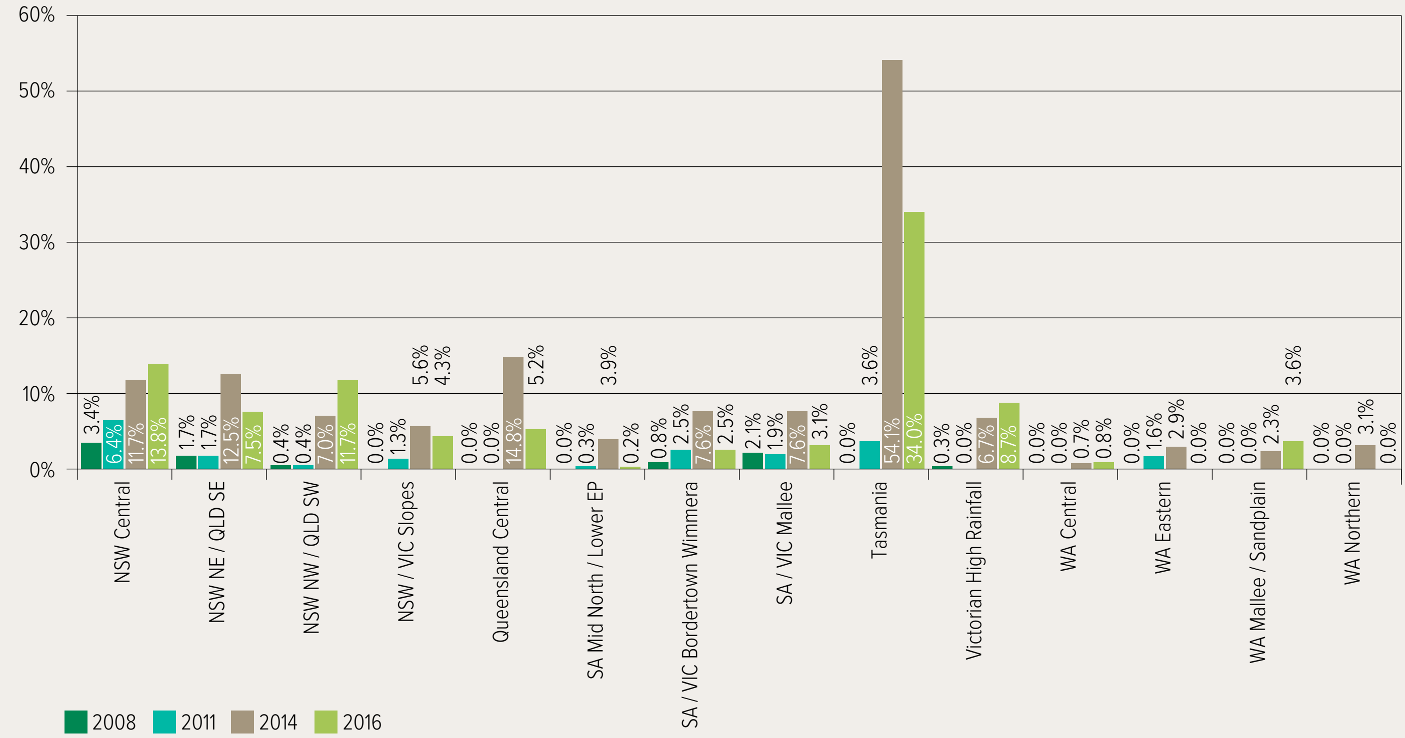
This system often includes a long fallow (no crop) period where tillage is the dominant method of weed control and soil preparation prior to planting.

This category, previously known as 'conventional cultivation' in early surveys, is used to ensure low crop residue and loose soil at planting.

The use of a multiple-tillage-based system had been reported as being at very low levels in the 2008 and 2011 surveys (both less than 1.5 per cent of total crop area). However, in 2014 (see Table 29, Figure 34 and Figure 35) survey results showed an increased use of cultivation prior to sowing nationally and in most individual AEZs. Reasons for these increases are speculative, but are thought to be likely a result of seasonal conditions, or weed or disease management requirements.

Nationally in 2016 the use of this technique declined modestly compared to 2014, although the trend in individual AEZs varied. Given the generally low levels of the use of this technique it is possible that the variation in levels between surveys is due to sampling or other errors, or other seasonal or specific local conditions.

FIGURE 34 Average percentage of cropped area planted using multiple-tillage techniques.



Precision agriculture in 2016

The use of various precision agriculture practices, including controlled traffic, autosteer (GPS machine guidance), yield mapping and variable rate fertiliser application were included in the 2016 survey.

Questions were:

- On what area of your crops are the following techniques used:
  - autosteer or GPS guidance;
  - controlled traffic;
  - remote sensing using EM38 or NDVI;
  - yield mapping;
  - variable rate technology for seeding; and
  - variable rate for fertiliser application.

Controlled traffic

Controlled traffic (CT) is where the drive and other wheels on all implements and tractors, headers etc., follow the same path with each pass over the paddock. This means that wheels always travel on defined paths, leaving the soil area elsewhere un-trafficked.

The adoption of CT has continued to increase as reported by growers in the 2016 survey. It appears that, in general, CT is widely used on larger farms with larger crop areas in the northern region AEZs, notably northern NSW and southern and central Queensland, with some use in several AEZs in WA.

CT is understood to have benefits for soil compaction, which can be a problem in heavier clay soils (for example, in much of northern NSW, and southern and central Queensland). This is thought to explain the relatively high adoption of CT in these zones.

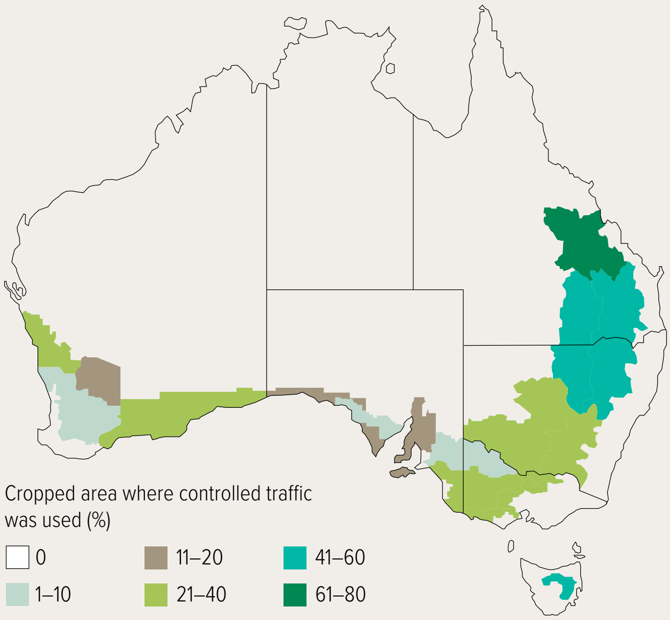
As shown in Table 30, Figure 36 and Figure 37, nationally the use of CT has increased steadily since 2008 to reach 29.3 per cent of the total crop area in 2016.

Autosteer

Autosteer uses GPS-based guidance to assist with guiding the machinery across the cropped or pasture area. Autosteer automatically steers the machine for the driver.

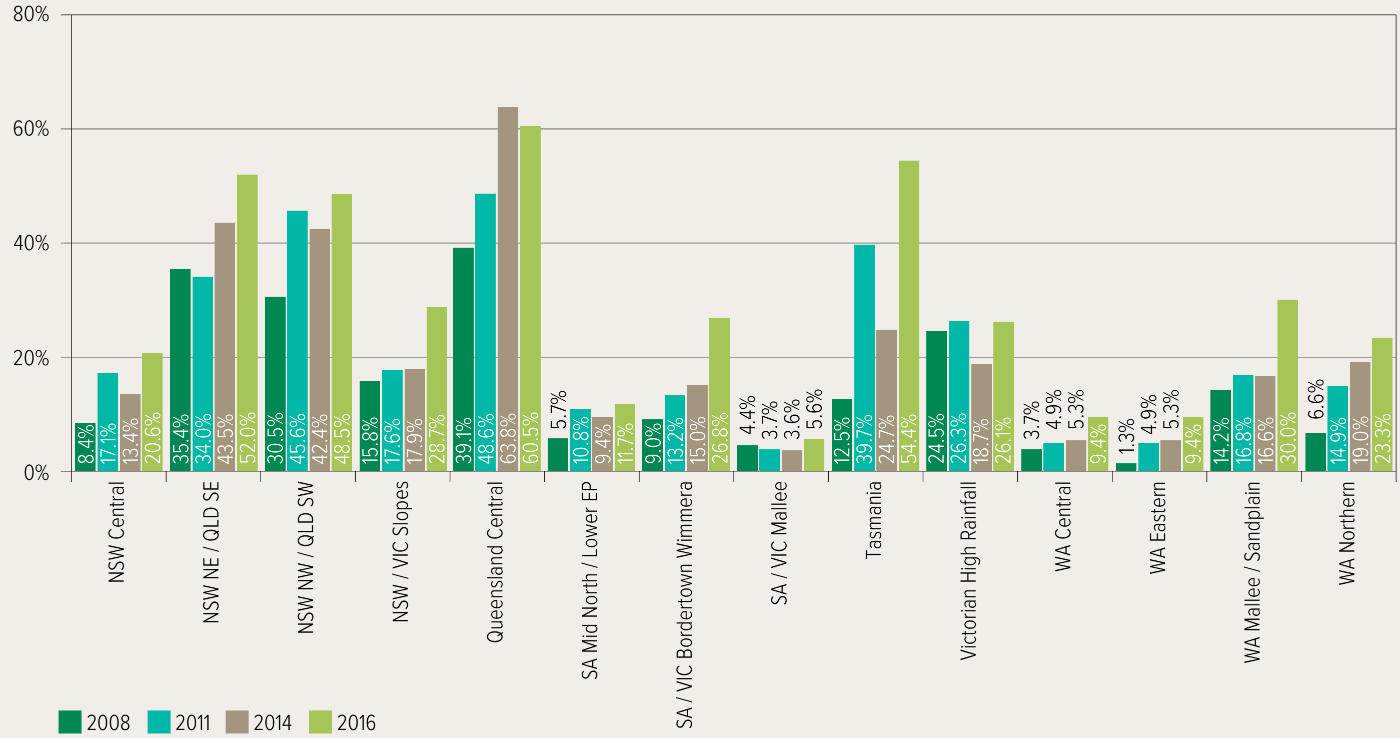
Autosteer can now be used to guide machinery to within two centimetres (or less) of the desired location and can be a form of controlled traffic, although this is not always the case. Autosteer can be used with any implement to provide accurate steering and to avoid overlapping or missed areas.

FIGURE 37 Percentage of crop area using controlled traffic by agro-ecological zone in 2016.



GRDC

FIGURE 36 Average percentage of cropped area where controlled traffic was used.



There has been a significant uptake in the adoption of autosteer in recent years. Usage as reported in the 2016 survey is now at very high levels, being over 90 per cent of the crop area in many AEZs (Table 31, Figure 38 and Figure 39 (page 47)).

Variable rate technology

One aspect of precision agriculture (PA) is to use data about crop performance, soil tests and paddock history, along with other remote sensing data, to determine the characteristics of various areas within a paddock and then use the information to guide site-specific crop management. One application of this integrated approach is to use PA data to apply variable rates of seed and/or fertiliser (or other inputs) to different areas of paddocks using GPS. This technology is relatively sophisticated and complex, and requires expert PA technical input. The technology is often linked to yield maps or other data about paddock performance or characteristics where these vary across the crop area.

In the 2016 survey growers were asked about their use of variable rate technology (VRT) for both seed and fertiliser applications. The resulting data are shown in Table 32, Table 33, Figure 40, Figure 41 and Figure 42.

The uptake of VRT is lower than other forms of PA technologies studied in the 2016 survey, although is reported by growers in the

TABLE 30 Average percentage of cropped area where controlled traffic (CT) was used.

Agro-ecological zone	Average cropped area where CT was used (%)				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	8.4	17.1	13.4	20.6		
NSW NE / QLD SE	35.4	34.0	43.5	52.0		***
NSW NW / QLD SW	30.5	45.6	42.4	48.5		
NSW / VIC Slopes	15.8	17.6	17.9	28.7	**	**
QLD Central	39.1	48.6	63.8	60.5		
SA Mid North / Lower EP	5.7	10.8	9.4	11.7		
SA / VIC Bordertown, Wimmera	9.0	13.2	15.0	26.8	**	**
SA / VIC Mallee	4.4	3.7	3.6	5.6		
TAS	12.5	39.7	24.7	54.4		
VIC High Rainfall	24.5	26.3	18.7	26.1		
WA Central	3.7	4.9	5.3	9.4		
WA Eastern	1.3	1.6	6.2	13.1		
WA Mallee/Sandplain	14.2	16.8	16.6	30.0		
WA Northern	6.6	14.9	19.0	23.3		
NATIONAL AVERAGES	15.1	21.1	21.4	29.3		

TABLE 31 Average percentage of cropped area where autosteer was used.

Agro-ecological zone	Average cropped area where autosteer was used (%)				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	46.9	67.5	76.4	82.1		**
NSW NE / QLD SE	53.5	57.1	70.7	79.9		***
NSW NW / QLD SW	53.3	75.9	86.0	84.4		
NSW / VIC Slopes	48.3	69.4	77.9	80.6		**
QLD Central	69.6	76.1	84.4	84.9		
SA Mid North / Lower EP	46.7	69.0	79.1	93.8	***	***
SA / VIC Bordertown, Wimmera	43.1	62.6	74.6	81.1		***
SA / VIC Mallee	44.5	71.2	83.9	87.8		***
TAS	25.0	39.3	67.6	85.7		
VIC High Rainfall	47.8	74.3	67.0	71.3		
WA Central	38.1	65.7	78.3	84.7		***
WA Eastern	40.8	60.0	89.3	96.5		***
WA Mallee/Sandplain	58.1	73.0	96.9	99.4		***
WA Northern	38.5	72.0	89.3	92.0		***
NATIONAL AVERAGES	46.7	66.7	80.1	86.0		

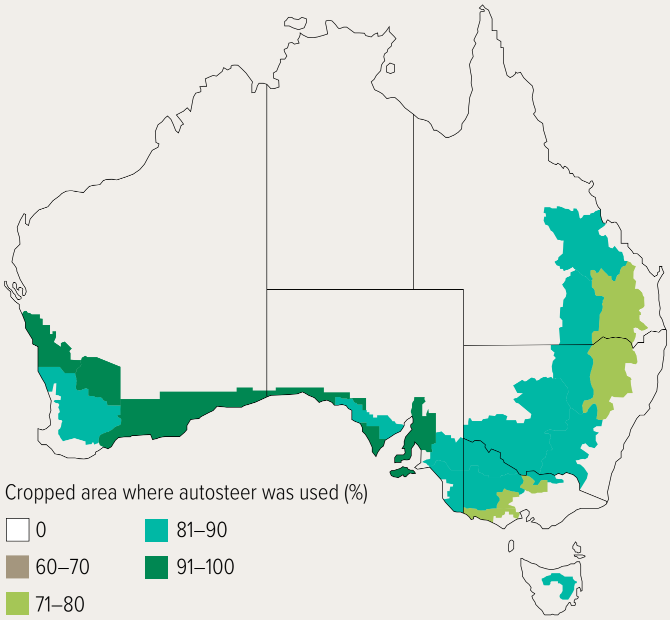
SA/Victorian Mallee to be used on approximately 23 per cent of the total crop area, and more than 15 per cent of the WA eastern areas and more than 5 per cent of of other AEZs in WA.

The high uptake in the SA/Victorian Mallee may be due to the development of applying different fertiliser regimes to dunes and swale areas that are common in this AEZ.

It is also possible that as the value of using VRT, for both seed and fertiliser use, becomes more evident and understood by growers and advisers that the adoption of the technique will increase. This may explain the recent growth in adoption in WA and some AEZs in eastern and northern Australia.

FIGURE 38 Average percentage of cropped area where autosteer was used as reported in surveys of 2008, 2011, 2014 and 2016.

FIGURE 39 Average percentage of cropped area where autosteer was used in 2016.



Variable rate seed technology

Variable rate seed technology is where the seed rate (i.e. amount of seed per hectare) is varied across the paddock, in response to guidance from previous measurements, remote-sensed or historic crop data. This practice is relatively recent and is used on less than 7 per cent of the cropped area nationally, a proportion that has not changed on average since 2014.

However, this technology is more popular in the SA/Victorian Mallee and in WA (see Table 32 and Figure 40). It is also notable that the rate of adoption in some AEZs has fluctuated since 2014, declining modestly (but not significantly) in several AEZs. This suggests that growers and advisers are still testing this technology and may not have yet determined the value in its use.

One feature of some Mallee crop areas is the presence of dune-and-swale land systems. Growers have traditionally often chosen to sow different crop types on these areas (for example, alternating wheat with barley on dune and swale areas respectively) and/or varying fertiliser use. It is possible that some growers have reported this practice as a form of variable rate application, potentially inflating VRT data in AEZs where Mallee soils are prevalent.

Variable rate fertiliser technology

Similarly to variable rate seed technology, variable rate fertiliser technology involves the varying of fertiliser rates on different areas of a paddock, guided by previous crop results, soil-test data or remote-sensed information, or analysis and calculations of these. Data for 2016 is shown in Table 33, Figure 41 and Figure 42.

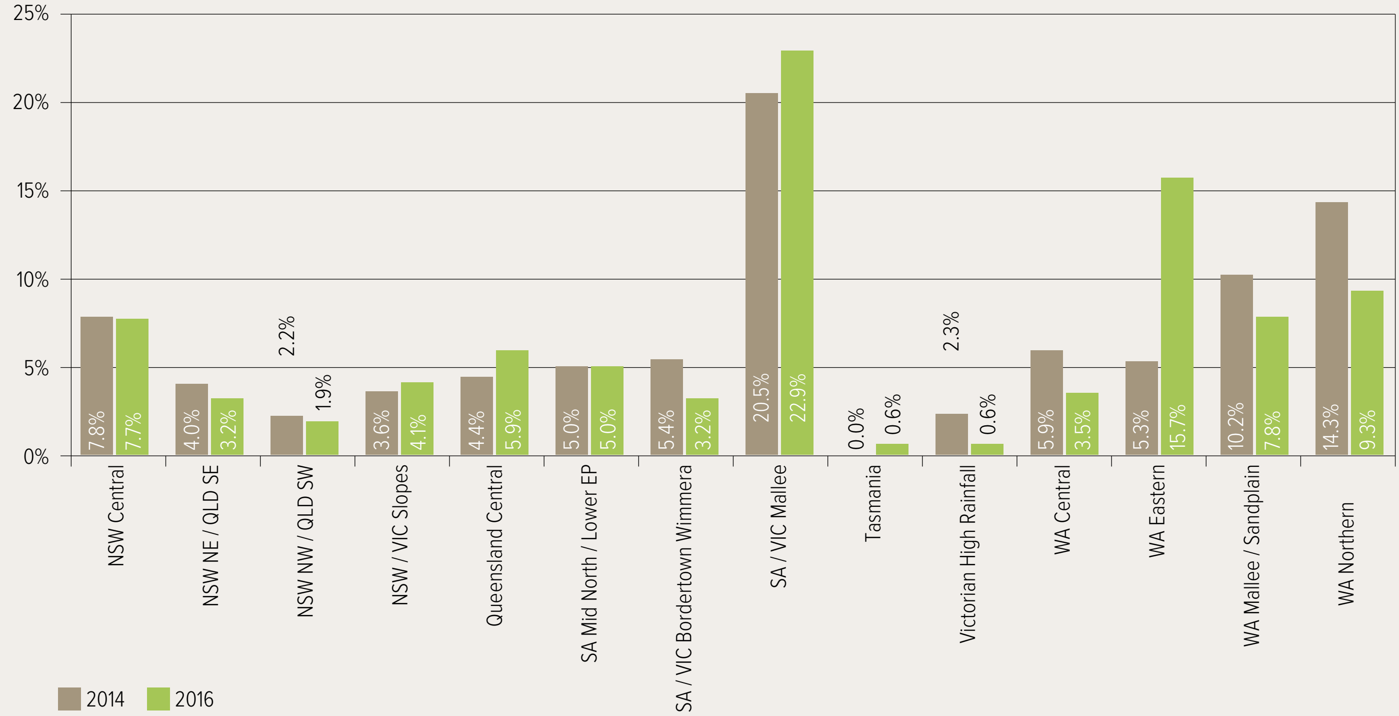
TABLE 32 Average percentage of cropped area where variable rate seed technology was used.

Agro-ecological zone	Average cropped area where variable rate seed technology was used (%)		Significant difference between agro-ecological zones	
	2014	2016	2014 to 2016	2011 to 2016
NSW Central	7.8	7.7		
NSW NE / QLD SE	4.0	3.2		
NSW NW / QLD SW*	2.2	1.9		
NSW / VIC Slopes	3.6	4.1		
QLD Central*	4.4	5.9		
SA Mid North / Lower EP	5.0	5.0		
SA / VIC Bordertown, Wimmera	5.4	3.2		
SA / VIC Mallee	20.5	22.9	No significant differences	
TAS*	0.0	0.6		
VIC High Rainfall	2.3	0.6		
WA Central	5.9	3.5		
WA Eastern*	5.3	15.7		
WA Mallee/Sandplain*	10.2	7.8		
WA Northern*	14.3	9.3		
NATIONAL AVERAGES	6.5	6.5		

TABLE 33 Average percentage of cropped area where variable rate fertiliser technology was used.

Agro-ecological zone	Average cropped area where variable rate fertiliser technology was used (%)		Significant difference between agro-ecological zones	
	2014	2016	2014 to 2016	2011 to 2016
NSW Central	12.7	8.1		
NSW NE / QLD SE	6.9	4.1		
NSW NW / QLD SW	0.5	0.0		
NSW / VIC Slopes	6.9	7.6		
QLD Central	3.1	0.0		
SA Mid North / Lower EP	9.8	7.5		
SA / VIC Bordertown, Wimmera	7.2	3.6		
SA / VIC Mallee	22.3	21.0		
TAS	0.0	0.0		
VIC High Rainfall	4.0	0.6		
WA Central	9.0	6.7		
WA Eastern	5.4	24.0	**	
WA Mallee/Sandplain	17.3	7.0		
WA Northern	21.3	13.6		
NATIONAL AVERAGES	9.0	7.4		

FIGURE 40 Average percentage of cropped area where variable rate seed technology was used in 2014 and 2016.



The survey results show that adoption of variable rate fertiliser use is slightly higher than variable rate seed, being again higher in the Mallee, and also in Central NSW, WA Eastern and WA Northern.

However, as noted in comments about variable rate seed technology, the adoption is variable and fluctuates, declining in some AEZs since 2014. Again, this may suggest growers/advisers are still determining the best application for this technology and have yet to determine the value for its use.

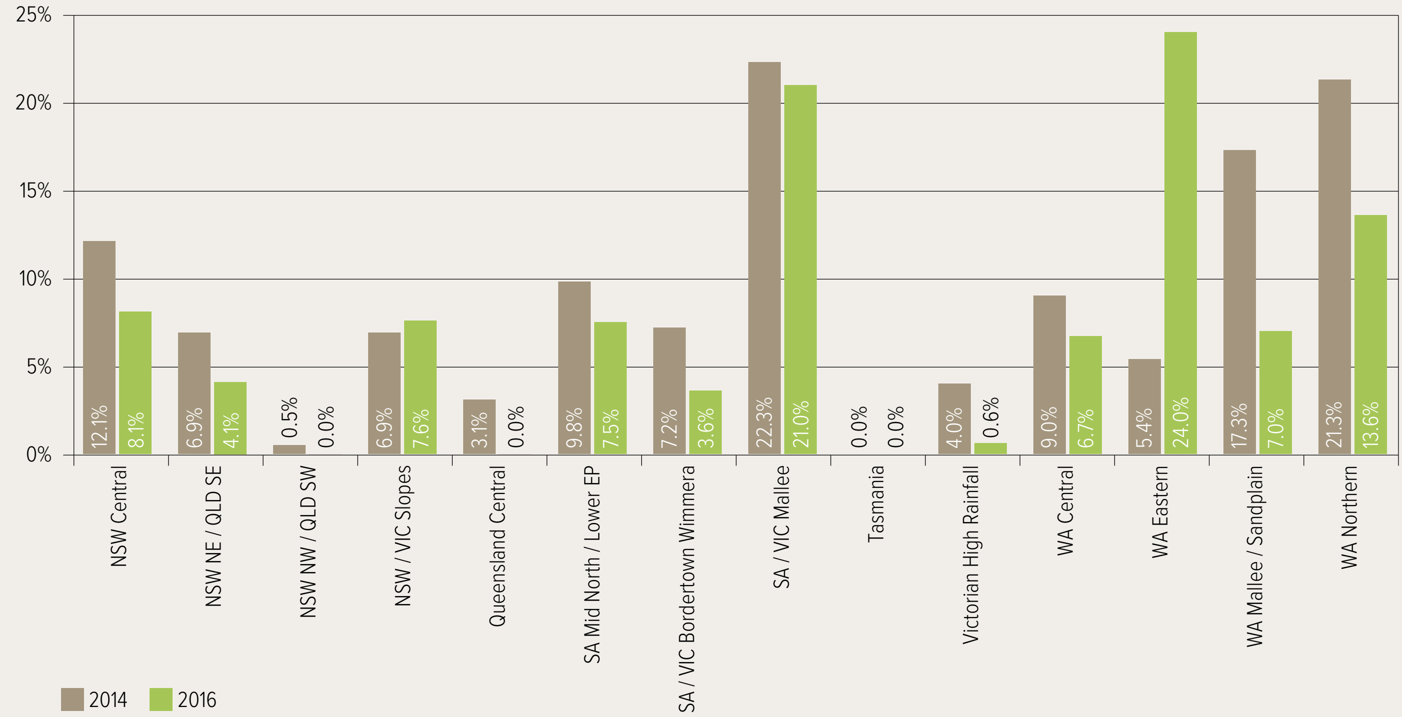
Yield mapping

Yield mapping can be used for general monitoring of crop performance, for making decisions about inputs, or even to choose the type of crop for various paddocks. It can be used to provide guidance to growers and advisers as to further investigations that should be undertaken, for example, zoned soil tests, for investigating the presence of diseases or impediments in soil, or other factors across a paddock.

TABLE 34 Average percentage of cropped area where yield mapping was used in 2008, 2011, 2014 and 2016.

Agro-ecological zone	Average cropped area where yield mapping was used (%)				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	15.5	12.7	27.3	26.6		***
NSW NE / QLD SE	11.5	10.9	26.4	33.1		***
NSW NW / QLD SW	10.0	16.9	20.7	20.5		
NSW / VIC Slopes	15.0	21.6	24.1	32.4		**
QLD Central	13.0	17.1	34.7	32.7		
SA Mid North / Lower EP	17.3	32.0	33.9	43.9		
SA / VIC Bordertown, Wimmera	10.5	17.2	22.9	31.3		**
SA / VIC Mallee	8.3	21.4	28.1	37.4		***
TAS	0.0	11.4	0.0	33.7		
VIC High Rainfall	8.8	20.0	18.3	18.9		
WA Central	16.5	20.6	28.5	34.6		***
WA Eastern	18.1	21.5	37.9	41.5		
WA Mallee/Sandplain	22.4	40.4	47.0	49.4		
WA Northern	22.7	41.0	56.8	53.3		
NATIONAL AVERAGES	13.5	21.8	29.0	34.9		

FIGURE 41 Average percentage of cropped area where variable rate fertiliser technology was used in 2014 and 2016.



Yield mapping is also an important input for use when partnered with variable rate seed or fertiliser technology, in assisting with determining where the variable rates of these are best applied.

There has been an increase in the proportion of the cropped area where yield mapping is used in 2016 compared with the previous surveys (Table 34, Figure 43 and Figure 44). It is considered that this reflects that most new harvesters bought by growers have this technology in-built as standard, and that where contract harvesters are used, many provide yield mapping as an additional service.

FIGURE 42 Average percentage of cropped area where variable rate fertiliser technology was used in 2016.

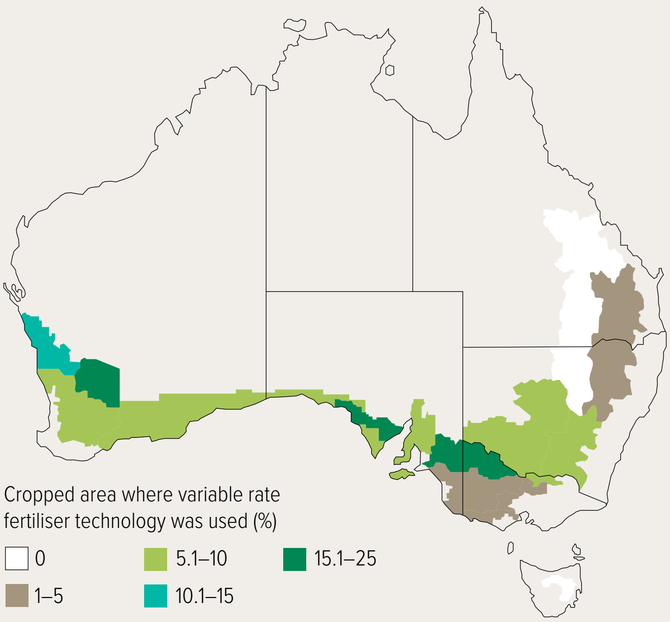


TABLE 35 Average percentage of cropped area where remote sensing (using EM38 or NDVI) was used in 2014 and 2016.

Agro-ecological zone	Average cropped area where remote sensing was used (%)		Significant difference between agro-ecological zones	
	2014	2016	2014 to 2016	2011 to 2016
NSW Central	4.2	10.8		
NSW NE / QLD SE	0.4	6.6	***	
NSW NW / QLD SW	0.8	0.0		
NSW / VIC Slopes	1.7	5.3		
QLD Central	0.1	2.9		
SA Mid North / Lower EP	0.2	4.1	**	
SA / VIC Bordertown, Wimmera	3.5	4.9		
SA / VIC Mallee	2.9	9.4	**	
TAS	0.0	10.4	**	
VIC High Rainfall	1.2	2.9		
WA Central	1.6	2.4		
WA Eastern	0.0	0.1		
WA Mallee/Sandplain	6.3	8.7		
WA Northern	1.8	3.6		
NATIONAL AVERAGES	1.8	5.1		

Use of other remote-sensing technologies.

Some grain growers use technologies to provide knowledge about their soil or other resources to assist with their crop management. Two candidate technologies are remote sensing using electromagnetic sensing (most commonly conducted using an EM38 device), and normalised difference vegetation index (NDVI).

Soil mapping using an EM38 is a relatively quick method of measuring relative levels and depths of clay and lighter-textured soil and can assist with indicating soil areas with different moisture-holding content, salt levels and soil texture (clay). EM38 mapping is generally carried out using portable measuring equipment (for example towed behind quadbikes, or other vehicles).

NDVI data can be used to determine relative crop biomass levels across a crop area, which correlate with potential crop yield. NDVI data can assist with defining areas in terms of yield potential, and as potential data sources for fertiliser or other input application, potentially using variable rate technologies.

Survey respondents in 2016 were asked about their use of EM38 and NDVI technologies. The data show (Table 35, Figure 45) that the adoption of these technologies as reported by survey respondents is relatively low, but is growing, now averaging just over 5 per cent of the cropped area nationally. Higher use of these technologies was noted in AEZs in the SA and Victoria Mallee, NSW Central, and WA Southern.

FIGURE 44 Average percentage of cropped area where yield mapping was used in 2016.

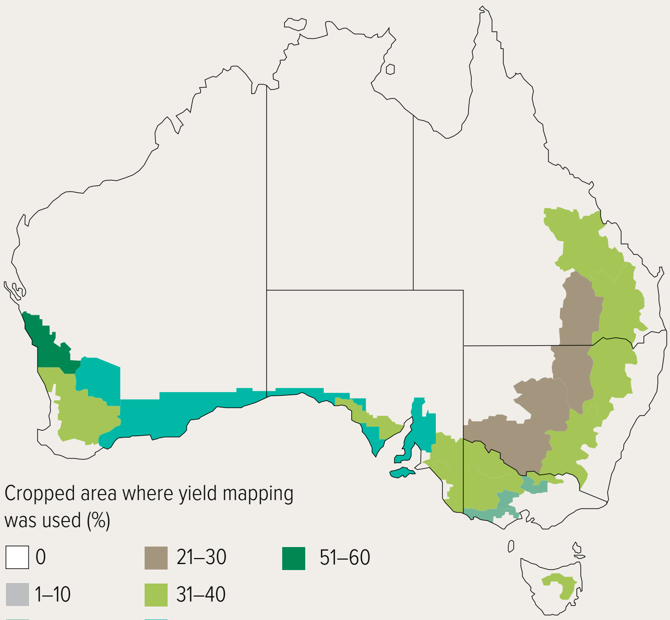


FIGURE 43 Average percentage of cropped area where yield mapping was used in 2008, 2011, 2014 and 2016.

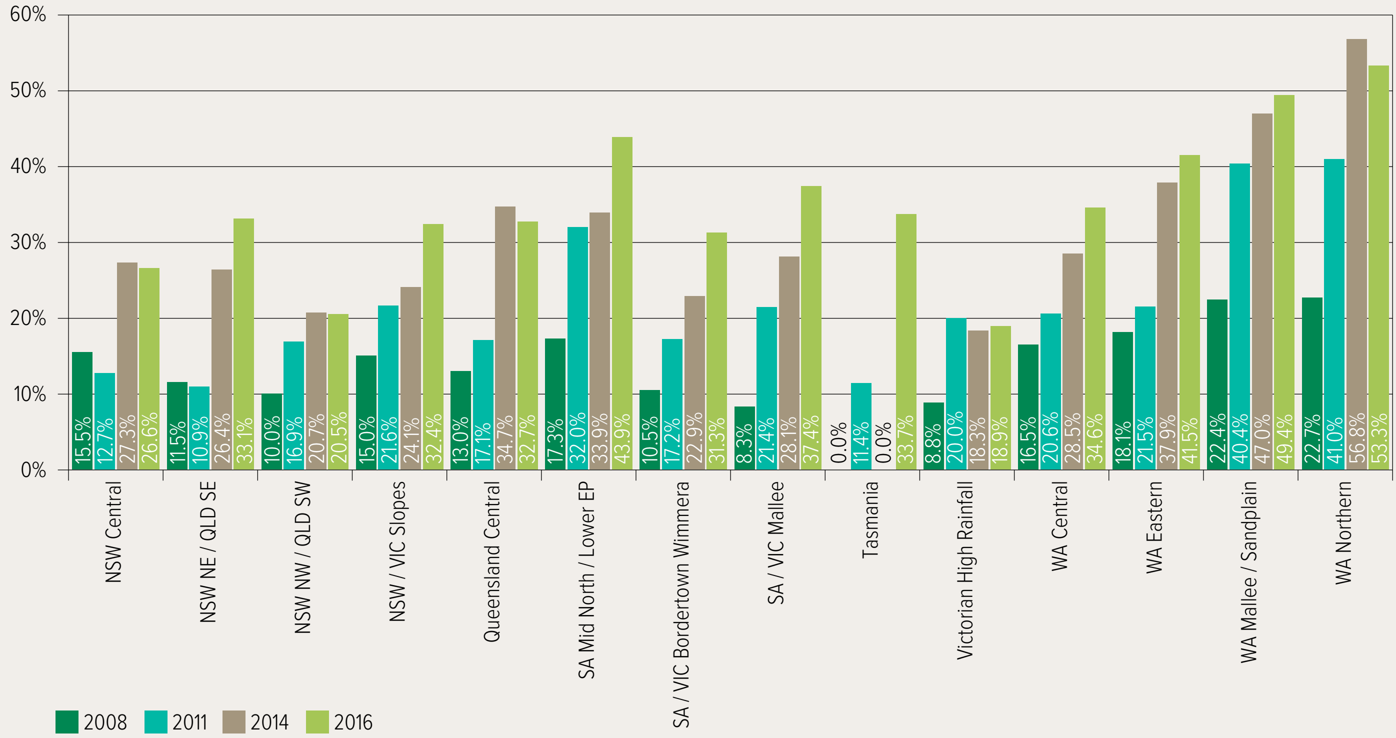
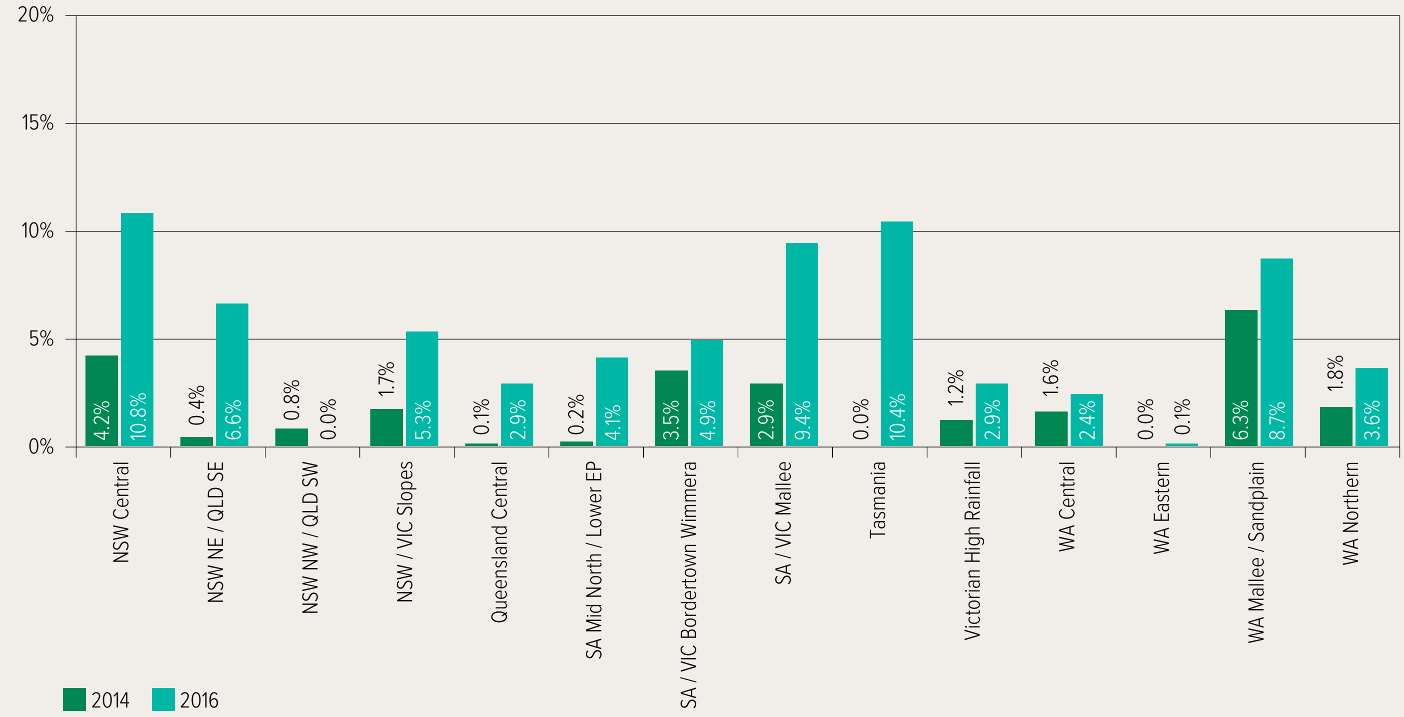


FIGURE 45 Average percentage of cropped area where remote sensing using EM38 or NDVI was used in 2016.



Fallow management in 2016

Questions included in 2016 were:

- How much area of your farm has been fallowed in the past 12 months?
- What area of the fallows has been managed:
  - without any tillage;
  - only with herbicides;
  - grazed by livestock; and
  - cultivated.

In the context of this survey, a period of fallow was described as: "The period between a pasture phase and beginning a cropping phase in a paddock, or the period between one crop and a following crop where management of weeds and moisture is practiced to benefit the following crop. The length of fallow may vary from a few weeks to several months."

A short fallow can be very short – as short as weeks (for a summer crop following a winter crop harvest in the more northern regions) to some months (between three and seven months in the GRDC southern and western regions from a November/December harvest to a April/May/June planting).

Long fallows can last up to 18 months.

Fallow periods have traditionally been seen as useful for storing soil moisture, weed control, promoting the mineralisation of organic nitrogen and providing a disease break, predominantly for soil-borne diseases. The length of the fallow period and how it is managed can have an influence on the available soil moisture and ultimate water use efficiency of the crop. Not all growers would identify as using a fallow period, although in most cases the period between crops could be considered a 'fallow'.

In some grain-growing areas, soil types and seasonal conditions are such that the generally recognised benefits from a fallow are less apparent. The key factor that would lead to this period being identified as a 'fallow period' would be whether the grower actively manages the area in the period between crops (or in the period leading up to the sowing of the crop). Controlling plant growth (weeds/volunteer crop plants that emerge) is the key consideration in fallow management, and is the reason that fallows can assist with building soil moisture, providing weed and disease control, and conserving/promoting nitrogen mineralisation.

TABLE 36 Average percentage of farms using a fallow period.

Agro-ecological zone	Average number of farms using a fallow (%)		Significant difference between agro-ecological zones
	2014	2016	2014 to 2016
NSW Central	73	72	
NSW NE / QLD SE	76	88	***
NSW NW / QLD SW	77	94	**
NSW / VIC Slopes	77	70	
QLD Central	72	71	
SA Mid North / Lower EP	30	34	
SA / VIC Bordertown, Wimmera	47	53	
SA / VIC Mallee	53	61	
TAS	71	86	
VIC High Rainfall	45	42	
WA Central	26	36	**
WA Eastern	64	65	
WA Mallee/Sandplain	32	50	
WA Northern	55	70	
NATIONAL AVERAGES	57	64	

In the 2016 survey, respondents were asked if they managed a fallow period over the past 12 months, prior to sowing their crops in 2016, with the definition (if needed) following the dot points above.

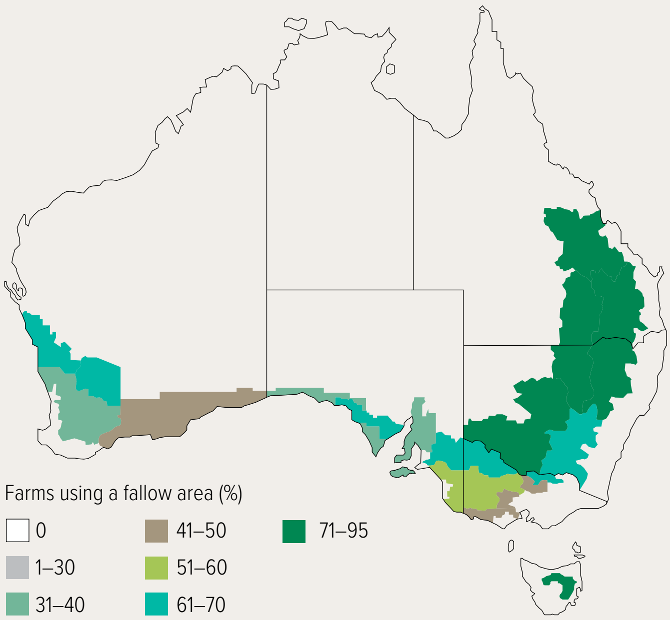
Proportion of grain farms where a fallow was a feature of the 2014 crop

The data in Table 36, Figure 46 and Figure 47 details the number of respondents reporting the use of some area of fallow in their cropping system. More growers use a fallow period in the AEZs of NSW and Queensland than elsewhere, although some fallow occurs in most AEZs nationally.

Fallows are much less common in southern and central WA and parts of SA, although fallows are more utilised in eastern and northern WA, suggesting some soil types in these AEZs have the ability to hold more moisture compared with the more sandy-textured soils in central and southern WA grain areas. In the northern region AEZs the combination of clay-textured soils with moisture-holding capacity, the presence of summer and winter crop options, and a farming system that includes a significant emphasis on soil moisture management led to fallows being a common feature.

The number of growers reporting the use of some fallow has increased since the survey of 2014 in most AEZs, notably in northern NSW and southern Queensland. In 2016 64 per cent of growers reported using some fallow.

FIGURE 47 Percentage of respondents reporting a fallow period being used in the past 12 months, in 2016.



Fallow management technique

One of the main priorities in managing the fallow period is controlling plant growth (weeds and volunteer crop plants) to maintain the area as free as possible from plant growth. Keeping a fallow weed-free minimises moisture loss from plant growth and promotes/conserves nitrogen mineralisation, and can help break the fungal disease life cycle (as removing volunteer crop plants through this period can prevent fungal diseases persisting through the intercrop period and providing inoculum for the subsequent crop).

There are several options and combinations of options for weed control available to growers, including the use of herbicides, cultivation or grazing.

FIGURE 46 Percentage of farms using a fallow period over the past 12 months in 2016.

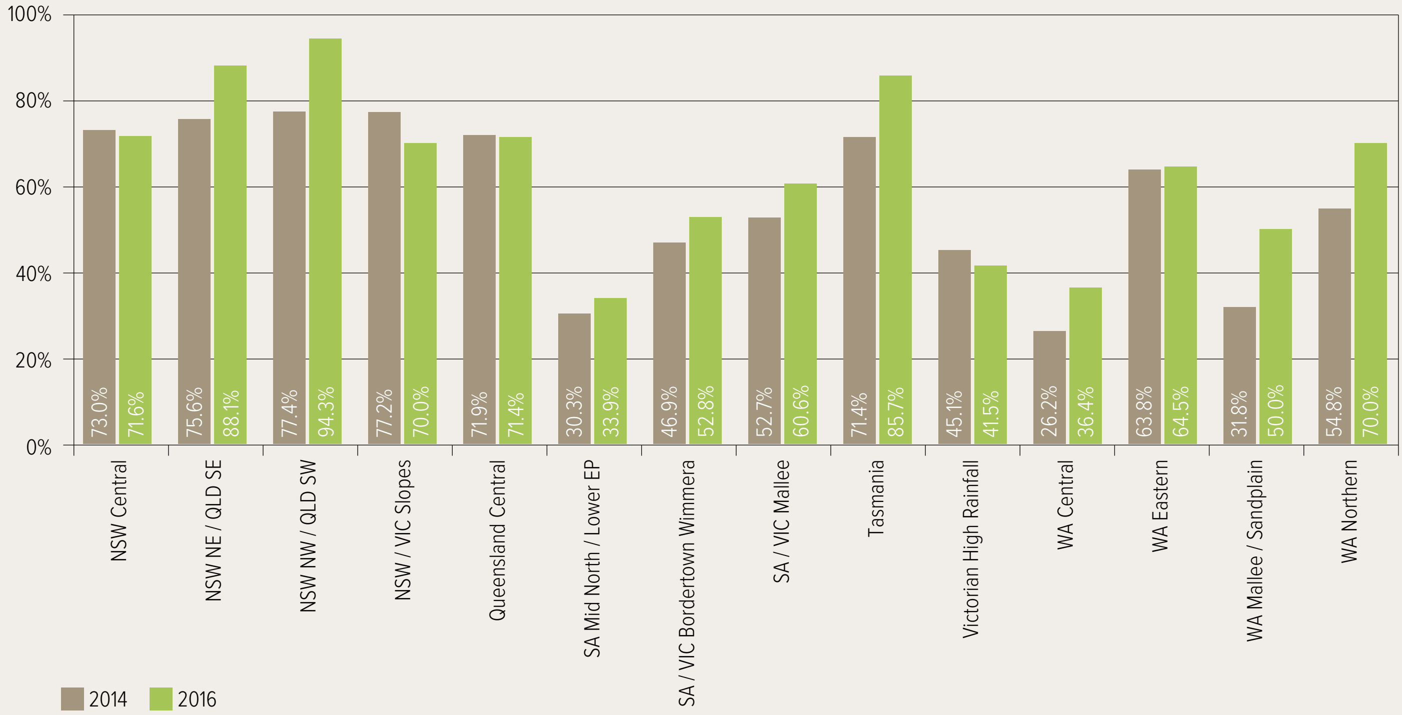
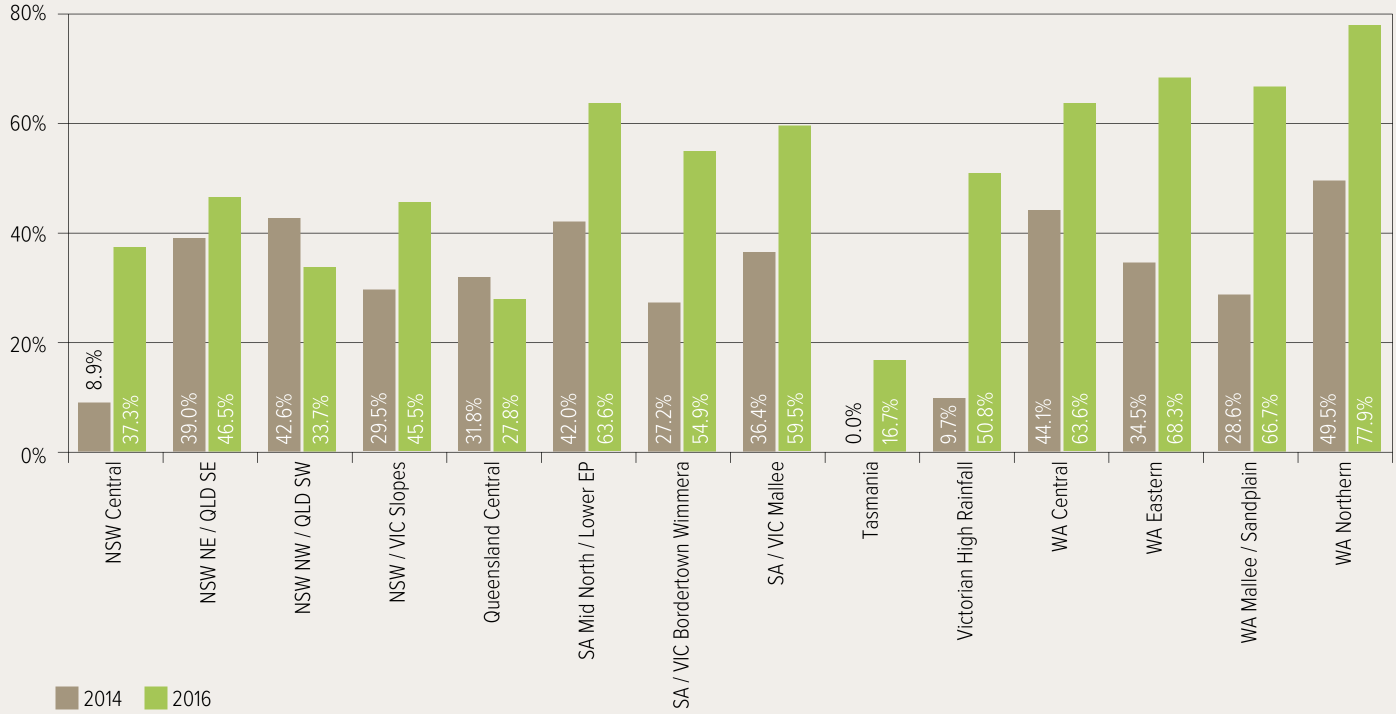


FIGURE 48 Percentage of fallow maintained without tillage in 2014 and 2016.



Fallow managed without tillage through the fallow period

Tillage is the traditional method of weed control used in the period prior to a crop being sown. Tillage is now one means of controlling weeds, with herbicides and strategic grazing other options.

The survey respondents were asked how much of the fallow was used and maintained without using tillage through the fallow period. The resulting data is presented in Table 37 and Figure 48.

The data show a strong increase in the proportion of fallow managed without any tillage in many AEZs, notably in WA, SA/

TABLE 37 Average percentage of fallow area managed without tillage.

Agro-ecological zone	Average area of fallow managed without tillage (%)		Significant difference between agro-ecological zones
	2014	2016	2014 to 2016
NSW Central	8.9	37.3	***
NSW NE / QLD SE	39.0	46.5	
NSW NW / QLD SW	42.6	33.7	
NSW / VIC Slopes	29.5	45.5	***
QLD Central	31.8	27.8	
SA Mid North / Lower EP	42.0	63.6	
SA / VIC Bordertown, Wimmera	27.2	54.9	***
SA / VIC Mallee	36.4	59.5	***
TAS	0.0	16.7	
VIC High Rainfall	9.7	50.8	***
WA Central	44.1	63.6	**
WA Eastern	34.5	68.3	**
WA Mallee/Sandplain	28.6	66.7	**
WA Northern	49.5	77.9	**
NATIONAL AVERAGES	30.3	50.9	

TABLE 38 Average percentage of fallow area managed only with herbicides.

Agro-ecological zone	Average area of fallow managed only with herbicides (%)		Significant difference between agro-ecological zones
	2014	2016	2014 to 2016
NSW Central	51.4	34.1	**
NSW NE / QLD SE	58.2	54.7	
NSW NW / QLD SW	62.5	47.0	
NSW / VIC Slopes	62.6	25.3	***
QLD Central	69.3	53.5	
SA Mid North / Lower EP	62.9	33.7	***
SA / VIC Bordertown, Wimmera	66.0	37.1	***
SA / VIC Mallee	74.4	33.6	***
TAS	40.0	8.3	
VIC High Rainfall	31.2	36.5	
WA Central	62.3	28.7	***
WA Eastern	73.2	34.5	***
WA Mallee/Sandplain	61.0	45.4	
WA Northern	67.2	46.2	
NATIONAL AVERAGES	60.2	37.0	

FIGURE 49 Average percentage of fallow area managed by herbicides only in 2016.

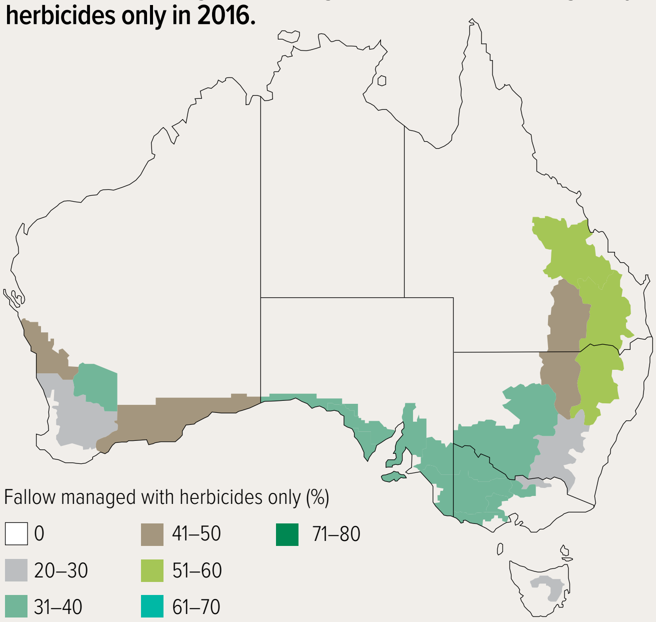
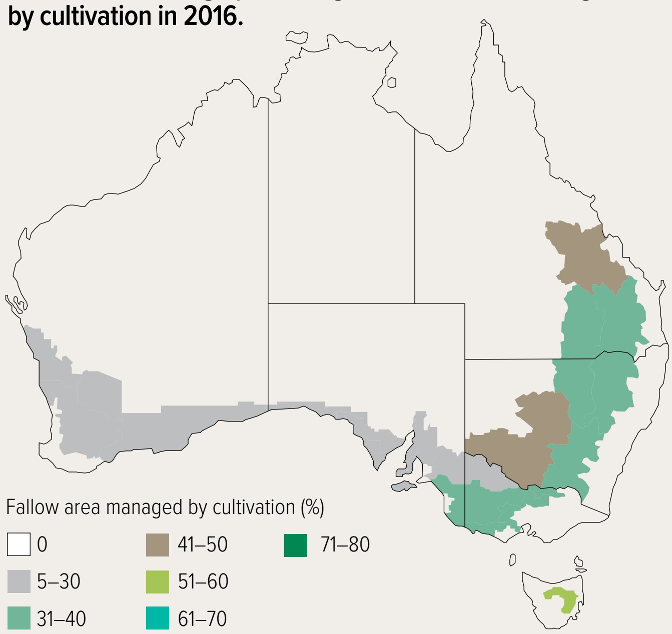


FIGURE 50 Average percentage of fallow area managed by cultivation in 2016.



Victoria, central NSW and the Mallee. Nationally, the proportion of fallow (where used) maintained without tillage increased from 30.3 per cent to 50.9 per cent since 2014.

This possibly reflects the increase in use of fallow per se (see above data), seasonal conditions in early 2016 that made having some fallow worthwhile, and the popularity of herbicides for fallow maintenance.

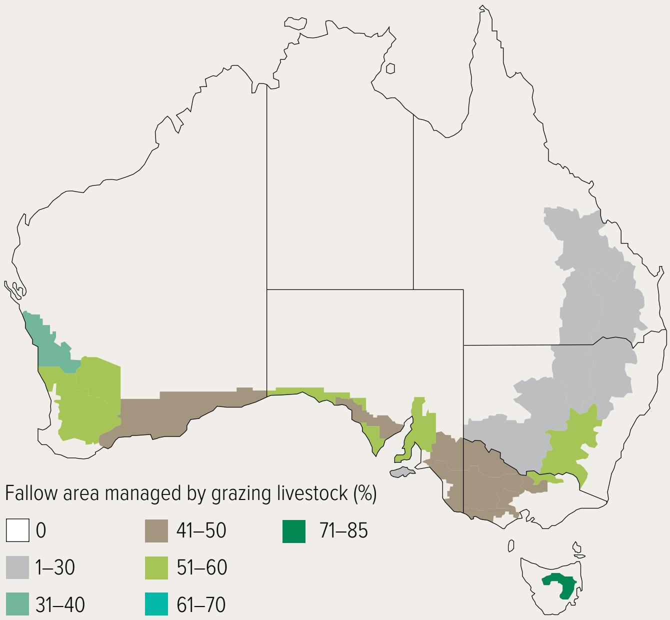
TABLE 39 Average percentage of fallow area managed by cultivation (base: used fallow period).

Agro-ecological zone	Average area of fallow managed with cultivation (%)		Significant difference between agro-ecological zones
	2014	2016	2014 to 2016
NSW Central	56.2	47.1	No significant differences
NSW NE / QLD SE	38.1	34.4	
NSW NW / QLD SW	32.6	37.4	
NSW / VIC Slopes	44.2	38.8	
QLD Central	26.5	41.8	
SA Mid North / Lower EP	25.0	23.0	
SA / VIC Bordertown, Wimmera	42.6	31.7	
SA / VIC Mallee	31.6	29.3	
TAS	60.0	57.9	
VIC High Rainfall	56.5	38.0	
WA Central	18.2	25.2	
WA Eastern	27.1	21.3	
WA Mallee/Sandplain	22.6	27.0	
WA Northern	25.5	6.6	
NATIONAL AVERAGES	36.2	32.8	

TABLE 40 Average percentage of fallow area managed by grazing with livestock (base: used fallow period).

Agro-ecological zone	Average area of fallow managed with livestock grazing (%)		Significant difference between agro-ecological zones
	2014	2016	2014 to 2016
NSW Central	40.7	23.6	**
NSW NE / QLD SE	22.5	14.9	
NSW NW / QLD SW	31.3	16.0	
NSW / VIC Slopes	56.8	53.7	
QLD Central	22.6	4.0	
SA Mid North / Lower EP	78.2	51.7	***
SA / VIC Bordertown, Wimmera	51.5	46.8	
SA / VIC Mallee	60.0	49.4	
TAS	50.0	83.8	
VIC High Rainfall	39.2	43.0	
WA Central	65.1	53.9	
WA Eastern	64.9	55.8	
WA Mallee/Sandplain	59.2	40.9	
WA Northern	45.2	39.9	
NATIONAL AVERAGES	49.1	41.2	

FIGURE 51 Proportion of crop area in 2016 where grazing occurred in the inter-crop period.



Fallow managed by herbicide only

Where tillage is not used, weed control is mainly by herbicide or grazing. The survey respondents in 2016 were asked about the proportion of fallow where herbicides were the only means of weed control used through the fallow period.

These data for 2016 (Table 38, Figure 49) suggest that herbicides were responsible for the majority (although not all) of the weed management on fallow areas in 2014. However, this declined markedly in 2016. This decline is most marked in AEZs in SA, Victoria, and WA, but has occurred in almost all AEZs.

This decline is possibly related to the seasonal conditions experienced through the fallow period, or the choices that were available to growers for the use of alternative means of managing weeds on fallows in early 2016.

Fallow managed by cultivation

The data from survey respondents (based on those who reported using a fallow period) suggests that there remains a substantial area of fallow where cultivation is used, generally for weed control, nationally averaging 32.8 per cent of the fallow area in 2016 (down slightly from 2014, see Table 39 and Figure 50).

When considered with the data for fallows managed with herbicides and fallows where grazing is used, it is apparent that where there is a lower usage of herbicides only, this is not necessarily correlated with a consequent increase in the use of cultivation or grazing.

It is possible that growers are using a combination of methods of fallow maintenance, being more flexible in their use of a combination of herbicides, grazing and cultivation. This may reflect seasonal conditions, the need or availability of livestock for grazing, or concerns about herbicide-resistant weeds.

Livestock grazing of the fallow

The data from survey respondents in 2016 shows some changes in the proportion of the fallow and inter-crop period where some grazing is used through the inter-crop or summer/short fallow period (Table 40, Figure 51). Nationally there has been a decrease in the proportion of fallow where grazing was reported as being used in 2016; this is relatively uniformly across all AEZs.

As previously discussed in relation to changes in proportion of fallow maintained with herbicides and/or cultivation, the changes in how the area of fallow is reported to be managed are difficult to interpret. It is possibly a more complex situation where a range of fallow management practices are used, that is not able to be determined by examining the data without being able to interview the respondents for their reasons and situations.

Stubble management in 2016

There were several questions included in the 2014 survey in the interests of assisting with gathering baseline data for use in the GRDC Stubble Initiative (a suite of grower-group-led farming systems projects in the former GRDC southern region, with CSIRO research support). This data was presented in the report for that survey in 2015.

In the survey of 2016, fewer questions were included to monitor the use of the major stubble management techniques in line with previous questions used in earlier (pre-2014) surveys. The full set of questions raised in the 2014 survey may be used in later GRDC Farming Practice surveys to monitor the impacts of the GRDC Stubble Initiative suite of projects.

The following questions about stubble management and the area of the crop managed in 2016 were asked:

- Proportion of the cropped area planted with the stubble left intact (i.e. standing, undisturbed)?
- Proportion of the cropped area planted with the stubble from the previous crop retained, but treated to help with managing the stubble at planting (slashed, baled, raked, harrowed, chained otherwise), such that the stubble was not standing at planting?
- Proportion where stubble was burnt late (within a few weeks of sowing – a cool burn)?
- Proportion where stubble was burnt early (some months prior to sowing – a hot burn)?
- Proportion where stubble was incorporated into the soil using tillage with tynes or discs?

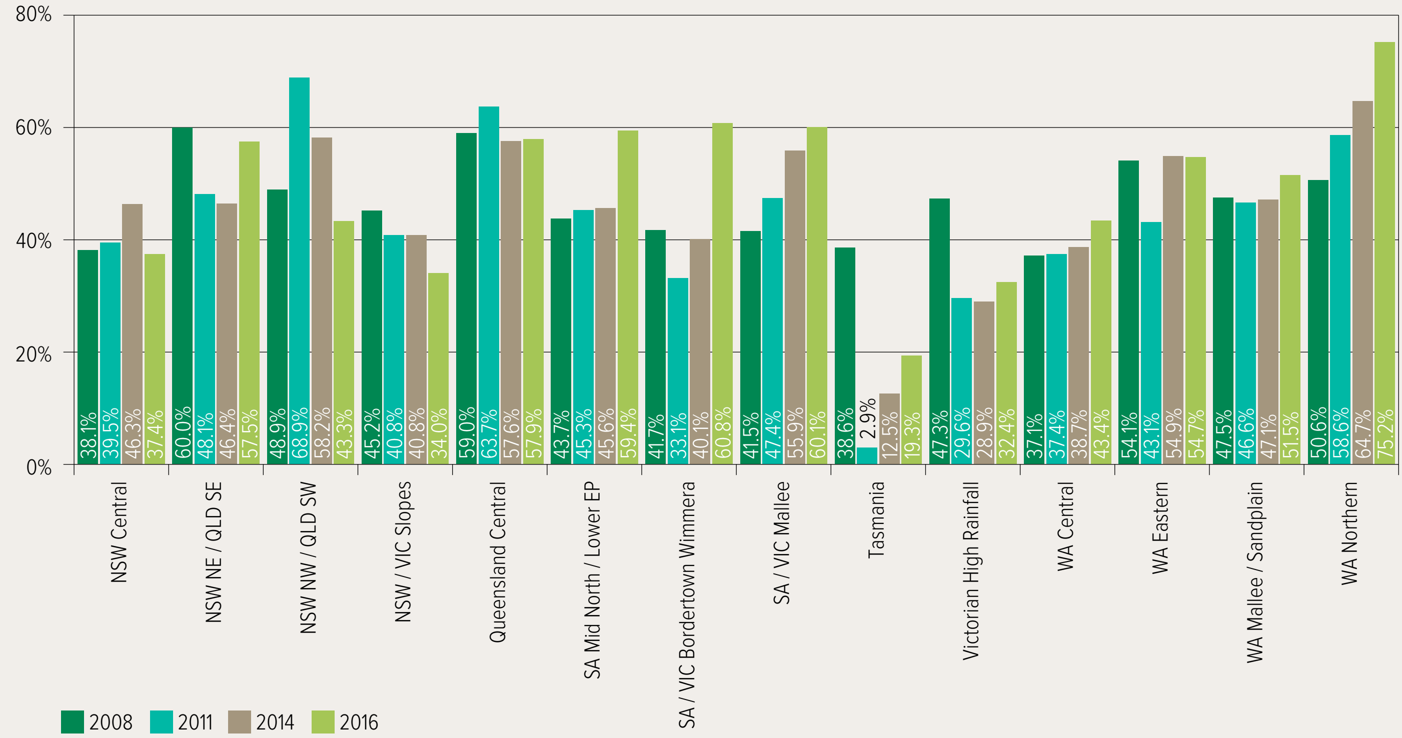
Stubble retained through to planting

The data from 2014 (Table 41) suggested that growers chose to retain stubble cover, through to planting the next crop on approximately 60 per cent of their total cropped area. The proportion as reported in 2014 varied between 47 per cent and over 80 per cent of the cropped area.

TABLE 41 Average percentage of cropped area where stubble was retained through to planting as reported in the surveys of 2011 and 2014.

Agro-ecological zone	Average area cropped where stubble was retained (%)		Significant difference between years
	2011	2014	
NSW Central	44.2	58.3	**
NSW NE / QLD SE	69.7	67.3	
NSW NW / QLD SW	76.9	68.8	
NSW / VIC Slopes	60.6	55.9	
QLD Central	68.3	84.3	
SA Mid North / Lower EP	66.1	70.7	
SA / VIC Bordertown, Wimmera	54.3	59.8	
SA / VIC Mallee	67.9	65.6	
TAS	41.4	16.4	
VIC High Rainfall	37.0	47.1	
WA Central	54.5	49.7	
WA Eastern	66.0	57.2	
WA Mallee/Sandplain	67.6	66.3	
WA Northern	72.8	73.2	
NATIONAL AVERAGES	60.5	60.0	

FIGURE 52 Average percentage of cropped area where stubble was retained intact through to planting.



In 2016, this question was not asked in this form, and data are presented for two contributory questions: stubble retained to planting either standing or not standing at planting (Table 42 and Table 43).

Stubble retained intact (standing) through to planting

Stubble retained intact is defined as stubble that has not been grazed, slashed or otherwise managed to remove or reduce it.

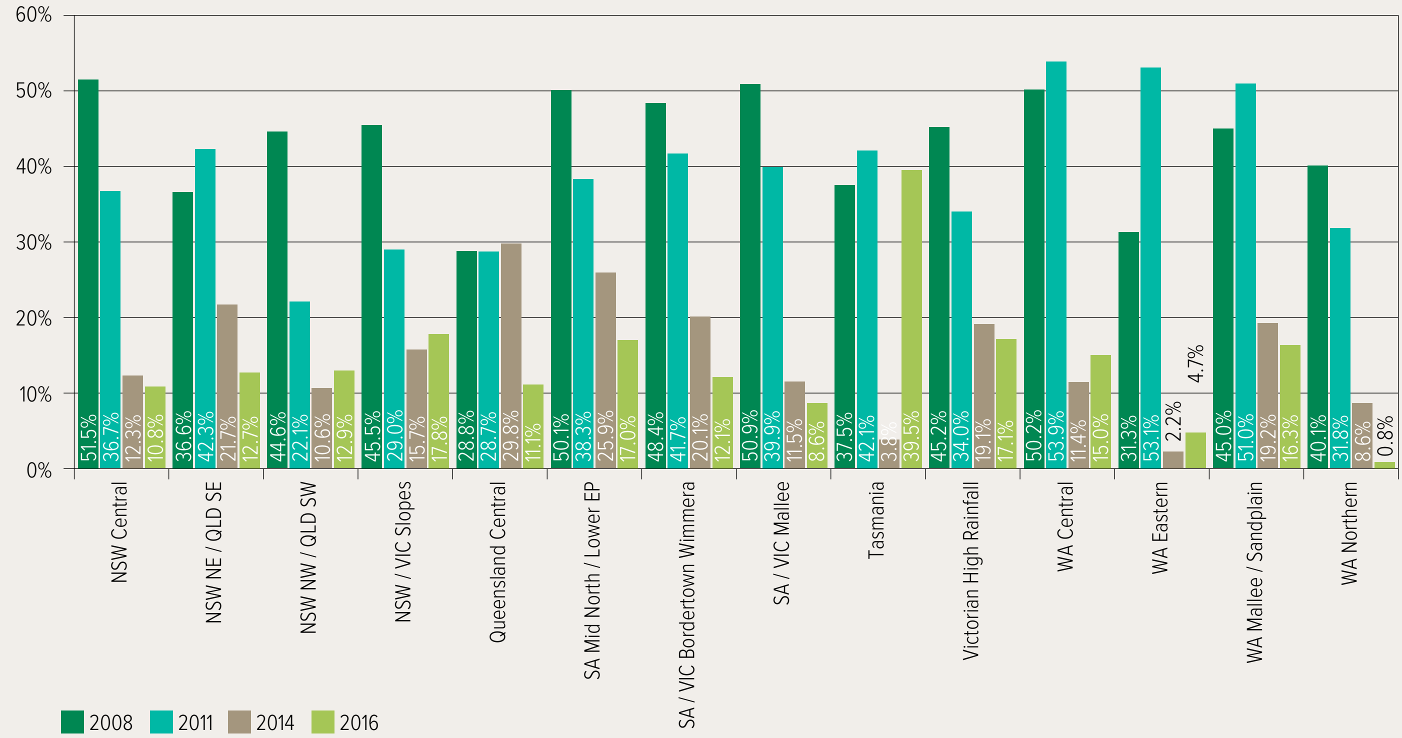
The proportion of the cropped area where stubble has been retained intact through until sowing had remained relatively stable across the three previous surveys (2008, 2011 and 2014), at approximately 45 per cent of the cropped area nationally.

The data from respondents in the 2016 survey (Table 42, Figure 52) shows a general increase in the proportion of the cropped area where stubble has been retained intact through until sowing, now at 49.1 per cent of the total crop area. Nearly all AEZs showed a significant increase in the proportion of cropped area where stubble was retained intact over the period 2011 to 2016, with some in SA, Victoria and NSW/Queensland continuing to increase this practice over the period 2014–2016. In 2016 there were

TABLE 42 Average percentage of cropped area where stubble was retained intact through to planting 2011 to 2016.

Agro-ecological zone	Average area cropped where stubble was retained intact (%)				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	38.1	39.5	46.3	37.4		***
NSW NE / QLD SE	60.0	48.1	46.4	57.5	**	***
NSW NW / QLD SW	48.9	68.9	58.2	43.3		***
NSW / VIC Slopes	45.2	40.8	40.8	34.0		***
QLD Central	59.0	63.7	57.6	57.9		***
SA Mid North / Lower EP	43.7	45.3	45.6	59.4	**	***
SA / VIC Bordertown, Wimmera	41.7	33.1	40.1	60.8	**	***
SA / VIC Mallee	41.5	47.4	55.9	60.1		***
TAS	38.6	2.9	12.5	19.3		
VIC High Rainfall	47.3	29.6	28.9	32.4		**
WA Central	37.1	37.4	38.7	43.4		***
WA Eastern	54.1	43.1	54.9	54.7		***
WA Mallee/Sandplain	47.5	46.6	47.1	51.5		***
WA Northern	50.6	58.6	64.7	75.2		***
NATIONAL AVERAGES	46.7	43.2	45.6	49.1		

FIGURE 53 Average percentage of cropped area where stubble was retained (not standing) through to planting.



several AEZs where retaining stubble intact accounted for more than 60 per cent of the cropped area, and more than 75 per cent in northern WA.

This suggests that stubble loads from the 2015 crop harvest were at levels where growers believed that they could manage these loads as standing stubble, or that sowing machinery has continued to improve with growers changing to configurations (e.g. disc-based machines) where management of standing stubbles is achievable.

Stubble retained (not necessarily standing)

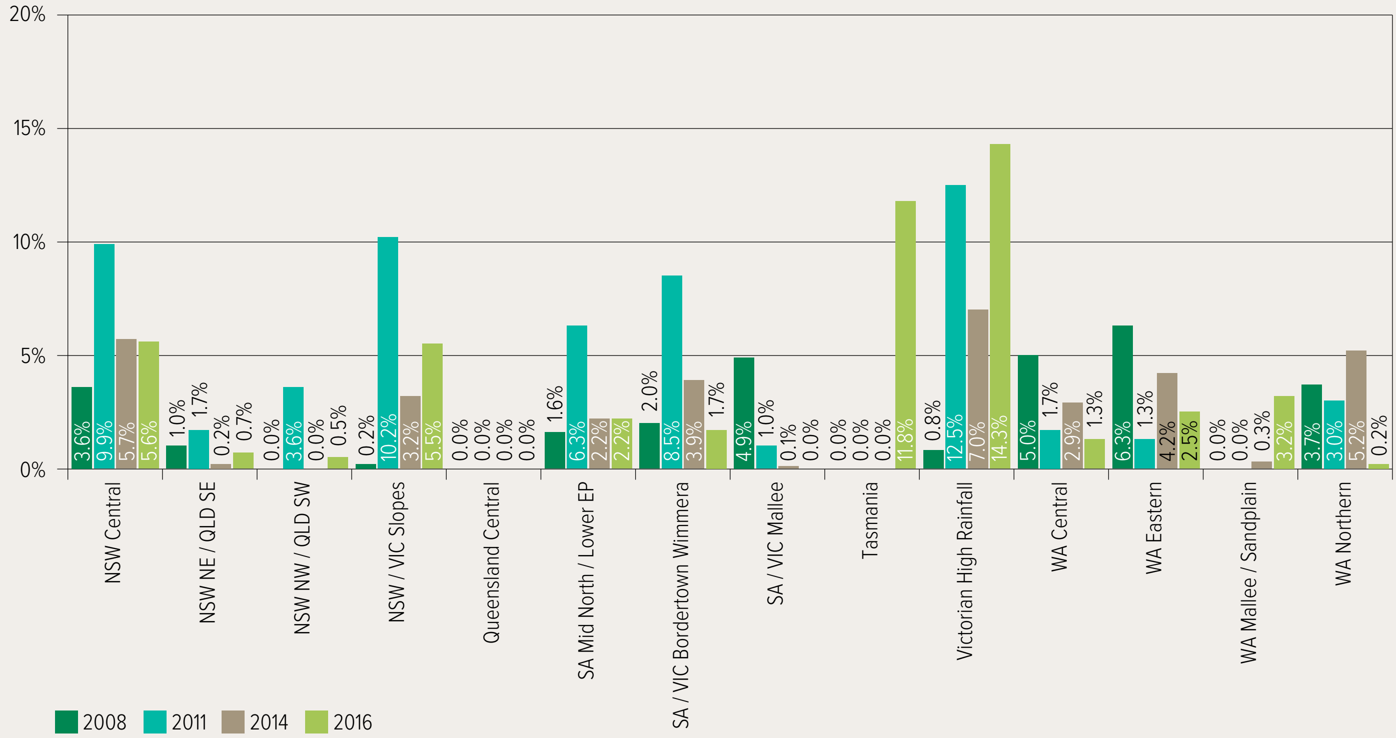
Stubble retained (not standing) can include stubble grazed, slashed or otherwise managed such that it remains present on the soil surface. Where livestock are used on stubbles they are likely to knock stubble down, such that what was 'standing' becomes 'not standing' due to this grazing.

The proportion of stubble retained (not standing) as reported in 2014 decreased significantly as compared with the previous surveys, and the proportion of the cropped area managed this way has remained at similar levels in 2016 (see Table 43 and Figure 53).

TABLE 43 Average percentage of cropped area where stubble was retained (not standing) through to planting.

Agro-ecological zone	Average area cropped where stubble was retained (not standing) (%)				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	51.5	36.7	12.3	10.8		***
NSW NE / QLD SE	36.6	42.3	21.7	12.7	**	***
NSW NW / QLD SW	44.6	22.1	10.6	12.9		
NSW / VIC Slopes	45.5	29.0	15.7	17.8		***
QLD Central	28.8	28.7	29.8	11.1	**	**
SA Mid North / Lower EP	50.1	38.3	25.9	17.0	**	***
SA / VIC Bordertown, Wimmera	48.4	41.7	20.1	12.1	**	***
SA / VIC Mallee	50.9	39.9	11.5	8.6		***
TAS	37.5	42.1	3.8	39.5	***	
VIC High Rainfall	45.2	34.0	19.1	17.1		
WA Central	50.2	53.9	11.4	15.0		***
WA Eastern	31.3	53.1	2.2	4.7		***
WA Mallee/Sandplain	45.0	51.0	19.2	16.3		***
WA Northern	40.1	31.8	8.6	0.8	**	***
NATIONAL AVERAGES	43.3	38.9	15.1	14.0		

FIGURE 54 Average percentage of cropped area where stubble was burnt early (hot burn).



When the proportions of retained stubble standing and not-standing are added, it totals over 60 per cent of the total cropped area in 2016. This is an increase more than the levels reported in 2014. However, it is also notable that a marked decrease in the proportion of cropped area where stubble was retained (not standing) was found in the survey of 2014, with the lower levels being maintained through to 2016. Some AEZs that did not report this decrease in 2014, did have a decrease in 2016 (e.g. NSW NE/ Queensland SE, central Queensland).

Stubble burnt

Crop areas where stubble is burnt represent a minority of the total crop area, less than 10 per cent as reported in 2016 survey results. Stubble burning can be carried out anytime following harvest of the previous crop, although growers often opt to keep stubble in place to assist with protecting soil from erosion, and to assist with capturing rainfall and holding soil moisture.

The stubble load from the previous crop and height of stubble, coupled with a consideration of the stubble-handling ability of the

TABLE 44 Average percentage of cropped area where stubble was burnt early (hot burn).

Agro-ecological zone	Average area cropped where stubble was burnt early (hot burn) (%)				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	3.6	9.9	5.7	5.6		
NSW NE / QLD SE	1.0	1.7	0.2	0.7		
NSW NW / QLD SW	0.0	3.6	0.0	0.5		**
NSW / VIC Slopes	0.2	10.2	3.2	5.5		
QLD Central	0.0	0.0	0.0	0.0		
SA Mid North / Lower EP	1.6	6.3	2.2	2.2		**
SA / VIC Bordertown, Wimmera	2.0	8.5	3.9	1.7		***
SA / VIC Mallee	0.0	4.9	1.0	0.1		***
TAS	0.0	0.0	0.0	11.8		
VIC High Rainfall	0.8	12.5	7.0	14.3		
WA Central	5.0	1.7	2.9	1.3		
WA Eastern	6.3	1.3	4.2	2.5		
WA Mallee/Sandplain	0.0	0.0	0.3	3.2		
WA Northern	3.7	3.0	5.2	0.2	**	
NATIONAL AVERAGES	1.7	4.5	2.6	3.6		

FIGURE 55 Percentage of cropped are where stubble was burnt early (hot burn) in 2016.

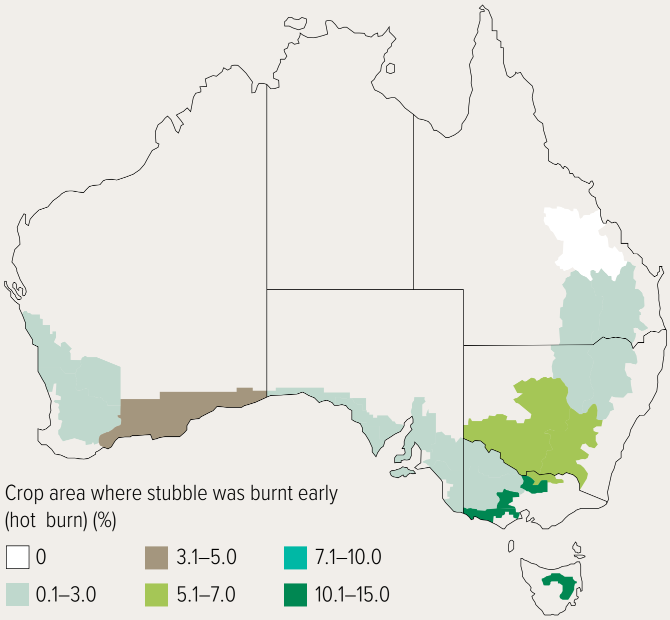
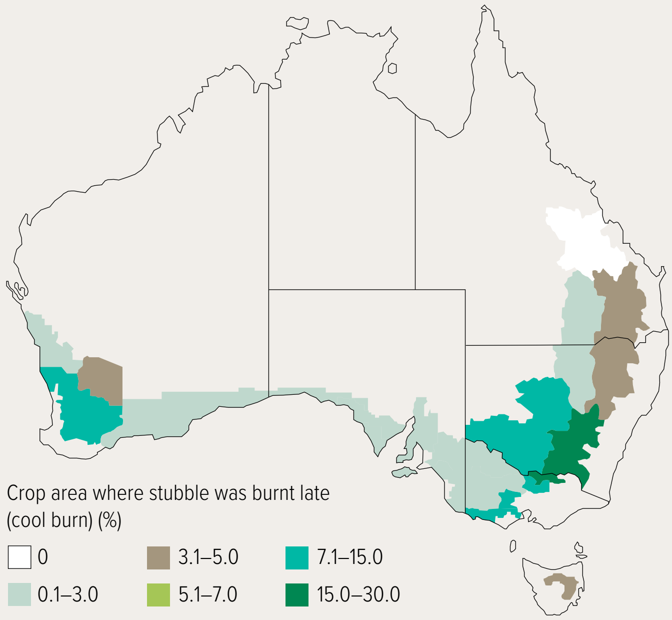


FIGURE 57 Percentage of cropped area where stubble was burnt late (cool burn) in 2016.



planting machinery generally determines whether stubble is burnt.

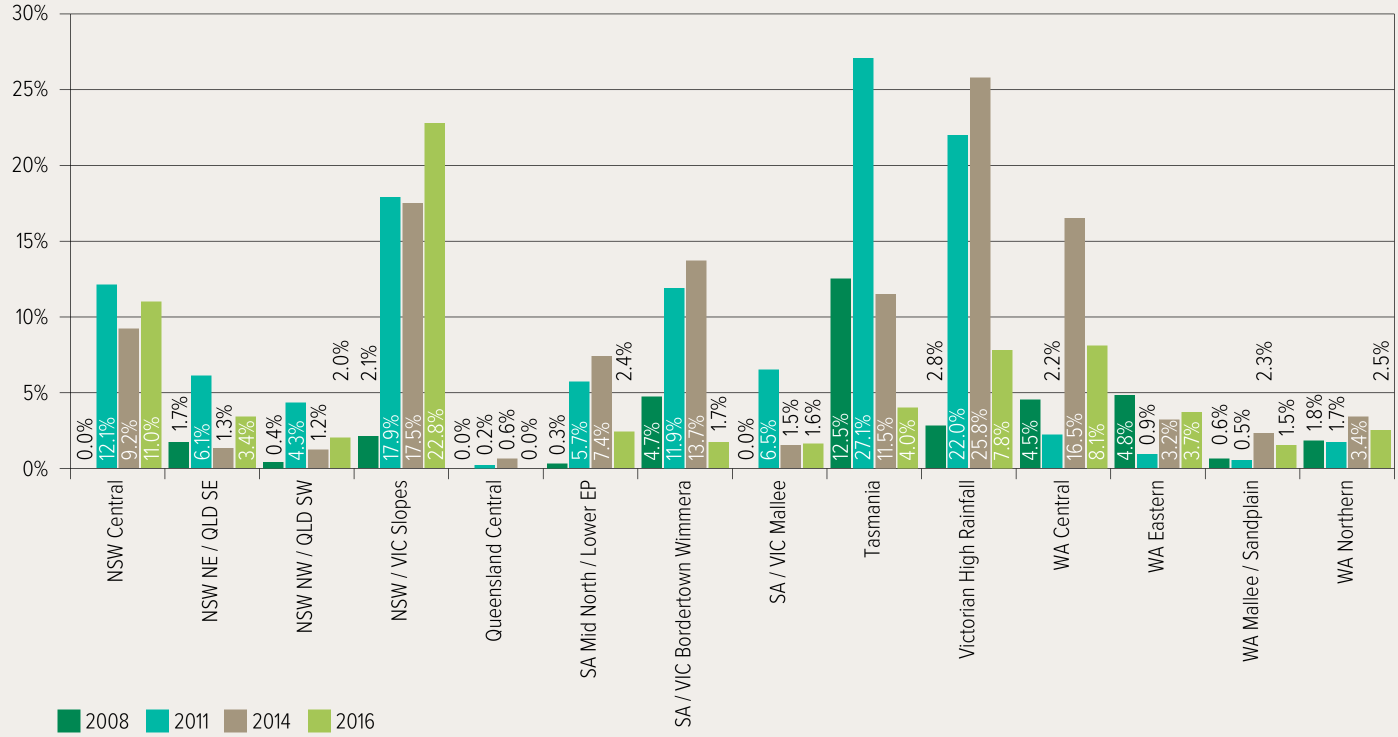
Narrow windrow burning (NWB) is a relatively new weed-management practice, where, at harvest crops are cut relatively short (e.g. 15cm above ground) and the straw and chaff or chaff only is placed in narrow windrows (e.g. less than one metre wide). The objective is to capture weed seeds by ensuring that they enter the harvester and then to deposit the weed seeds in the windrows, which are burnt in the lead up to sowing of the following crops, thereby destroying the seeds. The aim is to burn only the windrow rather than the whole paddock. As such NWB is primarily a weed-management technique rather than a technique for stubble management. However, by the nature of the harvest height and removal of some crop residue by burning, growers also find that stubble flow in sowing machinery is greatly improved and so this practice has both weed-control and stubble-management benefits.

Some data for this practice was gathered in 2016 and is reported further below.

TABLE 45 Average percentage of cropped area where stubble was burnt late (cool burn).

Agro-ecological zone	Average area cropped where stubble was burnt late (cool burn) (%)				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	0.0	12.1	9.2	11.0		
NSW NE / QLD SE	1.7	6.1	1.3	3.4	**	
NSW NW / QLD SW	0.4	4.3	1.2	2.0		
NSW / VIC Slopes	2.1	17.9	17.5	22.8		
QLD Central	0.0	2.0	0.6	0.0		
SA Mid North / Lower EP	0.3	5.7	7.4	2.4	**	**
SA / VIC Bordertown, Wimmera	4.7	11.9	13.7	1.7	***	***
SA / VIC Mallee	0.0	6.5	1.5	1.6		***
TAS	12.5	27.1	11.5	4.0		
VIC High Rainfall	2.8	22.0	25.8	7.8	***	***
WA Central	4.5	2.2	16.5	8.1	***	***
WA Eastern	4.8	0.9	3.2	3.7		
WA Mallee/Sandplain	0.6	0.5	2.3	1.5		
WA Northern	1.8	1.7	3.4	2.5		
NATIONAL AVERAGES	2.6	8.6	8.2	5.2		

FIGURE 56 Average percentage of cropped area where stubble was burnt late (cool burn).



Stubble burnt early ('hot' burn)

A hot burn occurs when stubble (residue from the previous crop(s)) is burnt relatively soon (early) after harvest, for example, in summer or early autumn following harvest of the recent winter crop. Dry and hot conditions, common at this time, lead to hot burns, where all above ground crop residue is burnt.

The proportion of stubble burnt soon after the previous harvest is generally quite low, considerably less than 5 per cent of the cropped area in many AEZs (see Table 44, Figure 54 and Figure 55).

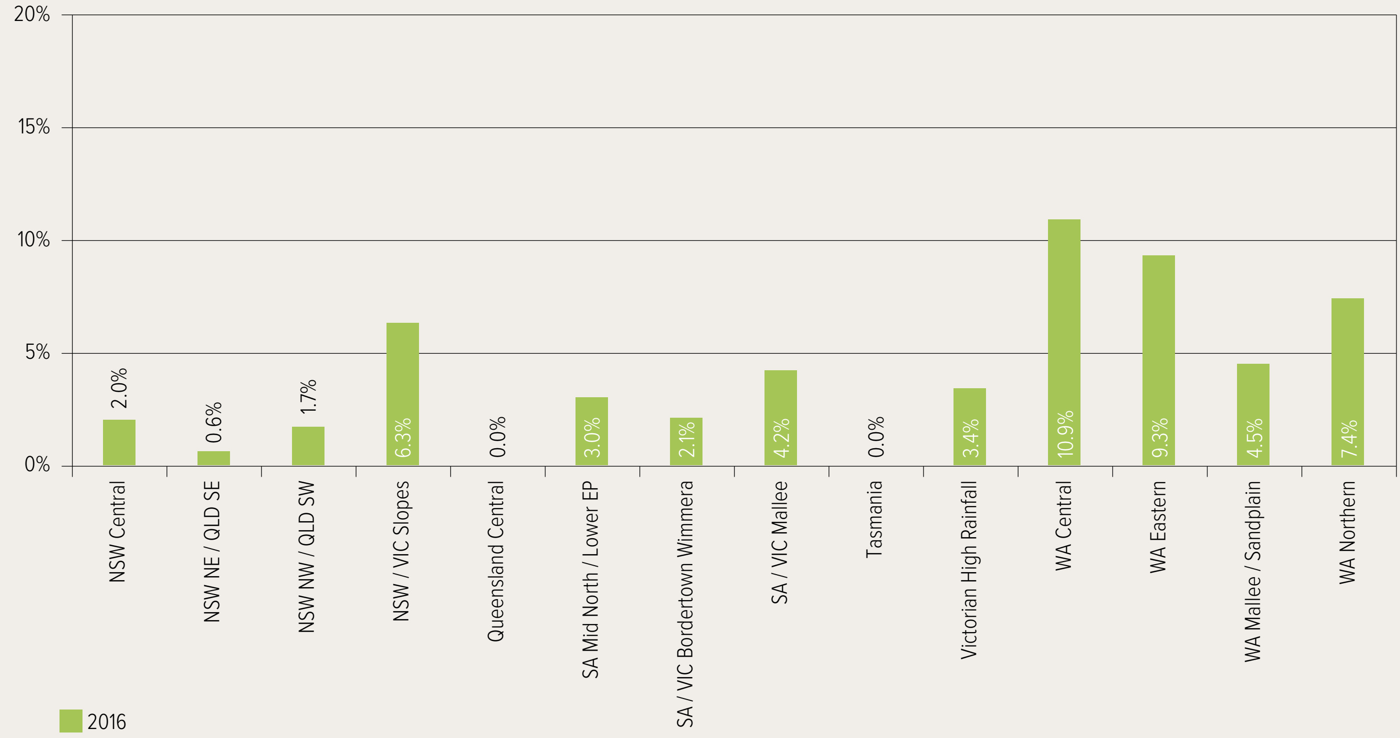
TABLE 46 Average percentage of cropped area where stubble was harvested to produce windrows, then burnt later.

Agro-ecological zone	2016
NSW Central	2.0
NSW NE / QLD SE	0.6
NSW NW / QLD SW	1.7
NSW / VIC Slopes	6.3
QLD Central	0.0
SA Mid North / Lower EP	3.0
SA / VIC Bordertown, Wimmera	2.1
SA / VIC Mallee	4.2
TAS	0.0
VIC High Rainfall	3.4
WA Central	10.9
WA Eastern	9.3
WA Mallee/Sandplain	4.5
WA Northern	7.4
NATIONAL AVERAGES	3.9

TABLE 47 Average percentage of cropped area where stubble was incorporated into soil using tillage.

Agro-ecological zone	Average area cropped where stubble was incorporated using tillage (%)		Significant difference between years
	2014	2016	
NSW Central	16.8	16.5	
NSW NE / QLD SE	20.0	16.0	
NSW NW / QLD SW	15.9	20.2	
NSW / VIC Slopes	10.1	5.9	
QLD Central	12.2	21.3	
SA Mid North / Lower EP	6.6	2.3	
SA / VIC Bordertown, Wimmera	6.6	8.2	
SA / VIC Mallee	10.7	4.0	***
TAS	63.5	5.7	***
VIC High Rainfall	16.1	13.3	
WA Central	3.4	2.9	
WA Eastern	6.2	3.0	
WA Mallee/Sandplain	4.6	1.9	
WA Northern	10.8	6.1	
NATIONAL AVERAGES	14.5	9.1	

FIGURE 58 Average percentage of cropped area where stubble was windrowed then burnt.

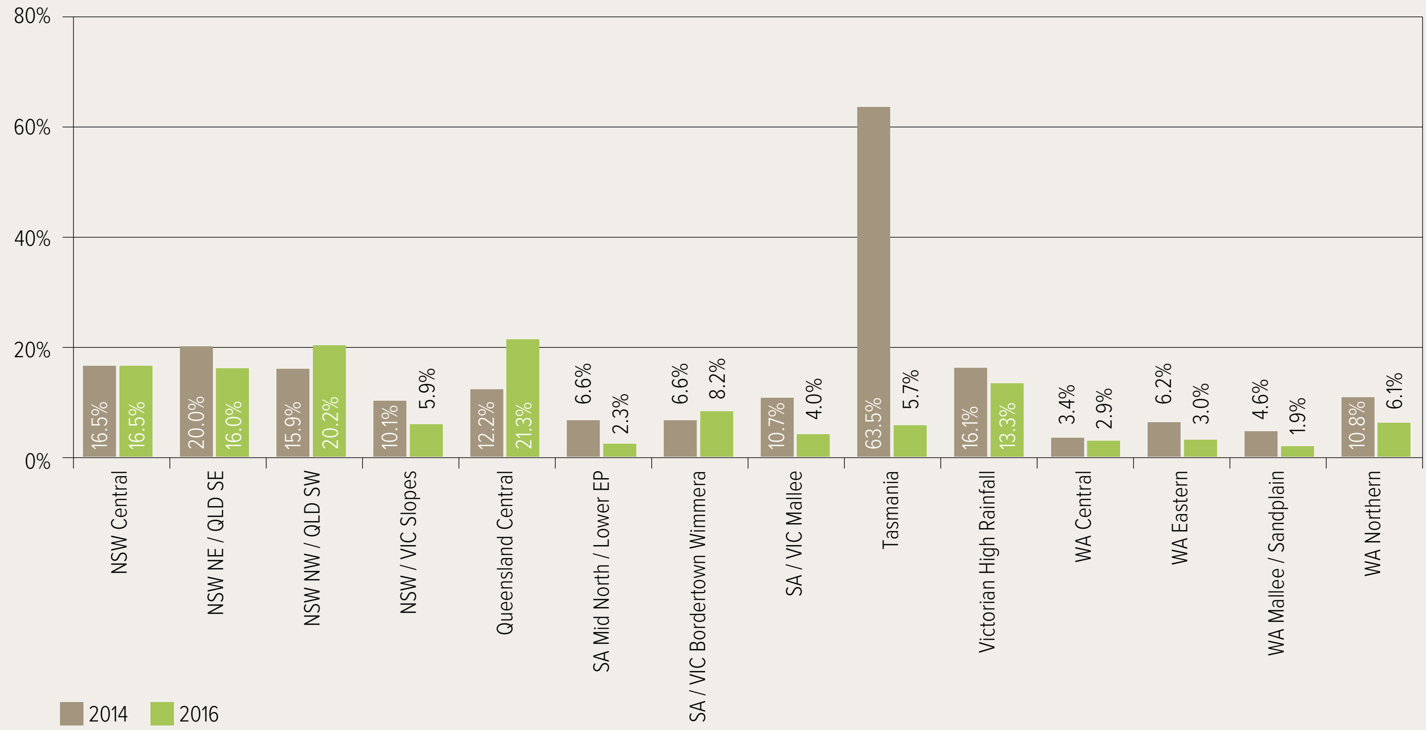


Stubble burnt late prior to planting ('cool' burn)

A 'cool burn' is defined as burning late in the season (late summer or early autumn), often just before or at the point of planting. With such stubble burns (residue from the previous crop(s)) is often incomplete due to cool and/or wet conditions. This leaves a proportion of the crop residue remaining on or attached to the soil, while sufficient residue is removed to allow most planting machinery, including conventional, to get through.

Use of late burning remains at levels similar to that reported in the previous surveys, nationally accounting for 5.2 per cent of the total crop area (Table 45, Figure 56 and Figure 57).

FIGURE 59 Average percentage of cropped area where stubble was incorporated into soil using tillage in 2014 and 2016.



Windrow burning

The recently developed practice of narrow windrow burning (NWB), discussed earlier, is of interest since it has a role in both weed control and stubble management.

The question in the survey of 2016 may not have described NWB clearly enough. It is considered that growers may have understood the question to be about raking stubble into windrows at some stage after the harvest operation, rather than NWB. Raking of stubble into windrows has been asked as part of a question in previous surveys, and has generally been reported as a practice used at very low levels.

The data for 2016 (Table 46, Figure 58) suggests that 'stubble harvested to produce windrows then burnt later' is not a widely used practice, with less than 5 per cent of the cropped area reporting this activity. It is suggested that this practice should be evaluated using further investigation, where the practice and associated questions to growers are more specific.

Stubble incorporated by cultivation

Some growers manage stubble by incorporating it into the soil using a tillage, commonly using an offset disc, one-way disc plough, a 'speed tiller' or a tyned implement, such as a scarifier. Disc machines also tend to cut stubble into shorter lengths as well as mixing it into the soil, whereas tyned machines tend to leave a greater proportion of stubble on the soil surface, while mixing some into the soil.

The data from the survey of 2016 shows a general decline in the use of this practice, although it is still used at levels of over 15 per cent of the cropped area in much of NSW and Queensland (Table 47, Figure 59). Reasons for this are likely to do with seasonal conditions, stubble loads, the ability of stubble incorporated into soil in warm and moist conditions to decompose relatively quickly, and the presence of double cropping, where this practice can assist.

GRDC

Crop sequencing in 2016

Respondents were asked:

- What proportion of your cereal crop in 2016 was planted following:
  - a long fallow;
  - a pulse crop;
  - a canola crop;
  - a legume-dominant pasture phase; and/or
  - the same crop (i.e. wheat-wheat)?
- What proportion of the 2016 crop was planted with a break crop specifically for weed, disease or nutrient benefit purposes?

Similar questions were asked in previous surveys in 2011 and 2014, allowing a comparison to be made over the period 2011 to 2016.

Previous crop type where a cereal was planted in 2016 (or other survey year)

Survey respondents were asked about what the previous crop was in the areas where they had sown cereal crops in the survey year (see the question list above). The data are presented below.

Summary

a) Previous crop as reported in survey of 2011

The survey data (Table 48) shows the previous crop type as reported by survey respondents where a cereal crop was planted in 2011.

b) Previous crop as reported in survey of 2014

The same questions were used in the survey of 2014, with the data reported in Table 49. The data is described for the individual previous crop types in the follow sections.

Based on the data presented in Table 48 and Table 49, nationally the proportion of cereals sown following 'break crops' (canola, pulses or a legume-dominant pasture) decreased between 2011 and 2014 (36.2 per cent compared with 28.3 per cent).

c) Previous crop as reported in survey of 2016

The same questions were asked in the survey of 2016, with the data reported in Table 50. The data are described for the individual previous crop types in the following sections.

Based on the the data presented in Table 48, Table 49 and Table 50, the proportion of cereals sown following 'break crops' has increased since the survey of 2014, which showed a decline since 2011. The data for 2016 suggest a 'rebound' in cereals sown after break crops. It appears that sowing cereals following pulses or legume-based pasture has been responsible for much of this change, although following canola remains strong in many southern and western AEZs. A move to sowing cereals following pulses or legume pasture is evident in parts of WA and most of the rest of the cropping belt, suggesting growers are increasing the proportion of pulses in their crop sequence.

The proportion of cereals sown following canola and legume pasture appears to show more stability than that following pulses, suggesting that the variability is in the amount of pulses sown rather than their planning of cereal following pasture or canola.

As shown in Table 51, the proportion of cereal sown following canola, a pulse crop or legume pasture (taken as a total of these) shows some increase in 2016 following a strong decrease in 2014 from the levels reported in 2011. Discussion regarding the proportion of cereal following the individual preceding crop/pasture is provided in the follow sections.

TABLE 48 Average percentage of cereal crop area planted in 2011 following canola, pulses or legume-based pasture.

Agro-ecological zone	Following canola crop	Following pulse crop	Following legume pasture	Net: following canola/ pulse/ legume
NSW Central	3.8	3.5	9.8	17.1
NSW NE / QLD SE	5.3	15.7	4.1	25.1
NSW NW / QLD SW	7.5	27.2	5.0	39.7
NSW / VIC Slopes	27.2	7.5	6.3	41.0
QLD Central	0.0	27.6	0.0	27.6
SA Mid North / Lower EP	11.1	26.8	12.5	50.4
SA / VIC Bordertown, Wimmera	16.9	18.0	10.6	45.5
SA / VIC Mallee	4.1	12.4	16.4	32.9
TAS	5.7	6.4	5.7	17.8
VIC High Rainfall	28.8	5.1	6.0	39.9
WA Central	18.1	11.2	22.2	51.5
WA Eastern	2.3	4.0	15.5	21.8
WA Mallee/Sandplain	30.7	9.5	23.1	63.3
WA Northern	10.7	18.0	4.2	32.9
NATIONAL AVERAGES	12.3	13.8	10.1	36.2

Cereal planted following a canola crop

Cereal crops were more likely to have been planted in 2016 following a canola crop in 2015 in the following AEZs:

- NSW/Victorian Slopes;
- Victorian High-Rainfall;
- WA Central; and
- WA Mallee/Sandplain.

The proportion of cereals sown following canola is relatively stable over time in NSW and much of WA, with more variability in Victoria and SA, where a decline was noted in 2016 (Table 52, Figure 60 and Figure 61).

Cereal sown following a previous pulse crop

Survey respondents were asked what proportion of their cereal crops sown followed a pulse crop. Cereal crops (nationally) planted in 2016 following a pulse crop in 2015 showed an increase over that reported in 2014, although not to the levels of 2011. Cereals sown in 2016 were more likely to have followed a pulse crop in 2015 in the following AEZs:

- NW NSW/SW Queensland;
- Central Queensland; and
- SA Mid North/Lower Eyre Peninsula.

TABLE 49 Average percentage of cereal crop area planted in 2014 following canola, pulses or legume-based pasture.

Agro-ecological zone	Following canola crop	Following pulse crop	Following legume pasture	Net: following canola/ pulse/ legume
NSW Central	7.4	4.6	5.3	17.3
NSW NE / QLD SE	3.4	9.7	5.5	18.5
NSW NW / QLD SW	2.9	16.6	5.2	24.6
NSW / VIC Slopes	23.4	5.2	7.2	35.8
QLD Central	0.0	17.8	5.5	23.3
SA Mid North / Lower EP	7.4	12.5	11.9	31.8
SA / VIC Bordertown, Wimmera	14.0	13.7	10.7	36.8
SA / VIC Mallee	6.5	10.2	15.2	30.5
TAS	0.0	1.2	1.3	2.6
VIC High Rainfall	20.5	6.5	6.7	33.3
WA Central	16.5	5.8	23.3	45.3
WA Eastern	8.9	6.4	9.4	24.0
WA Mallee/Sandplain	28.6	5.3	17.8	49.4
WA Northern	11.2	8.6	2.9	22.7
NATIONAL AVERAGES	10.8	8.9	9.1	28.3

TABLE 50 Average percentage of cereal crop area planted in 2016 following canola, pulses or legume-based pasture.

Agro-ecological zone	Following canola crop	Following pulse crop	Following legume pasture	Net: following canola/ pulse/ legume
NSW Central	7.5	9.1	5.6	22.2
NSW NE / QLD SE	1.8	15.1	3.8	20.8
NSW NW / QLD SW	2.0	21.4	4.2	27.1
NSW / VIC Slopes	24.5	5.5	7.2	36.9
QLD Central	0.0	22.3	8.3	27.7
SA Mid North / Lower EP	6.2	19.2	11.4	36.3
SA / VIC Bordertown, Wimmera	9.4	15.6	8.8	33.5
SA / VIC Mallee	3.8	13.2	15.1	32.0
TAS	1.5	3.1	8.2	12.7
VIC High Rainfall	19.3	5.4	5.9	30.6
WA Central	14.4	6.1	22.0	41.9
WA Eastern	5.8	6.2	17.0	26.4
WA Mallee/Sandplain	20.2	4.3	15.6	40.2
WA Northern	12.8	16.0	6.2	35.1
NATIONAL AVERAGES	9.2	11.6	9.9	30.2

Pulse crops were less likely have been used in rotation in the following AEZs:

- Central NSW;
- NSW/Victorian Slopes;
- Victorian High Rainfall; and
- WA Eastern and WA Mallee/Sandplain.

Data is shown in Table 53, Figure 62 and Figure 63.

Cereals sown following a previous legume-dominant pasture

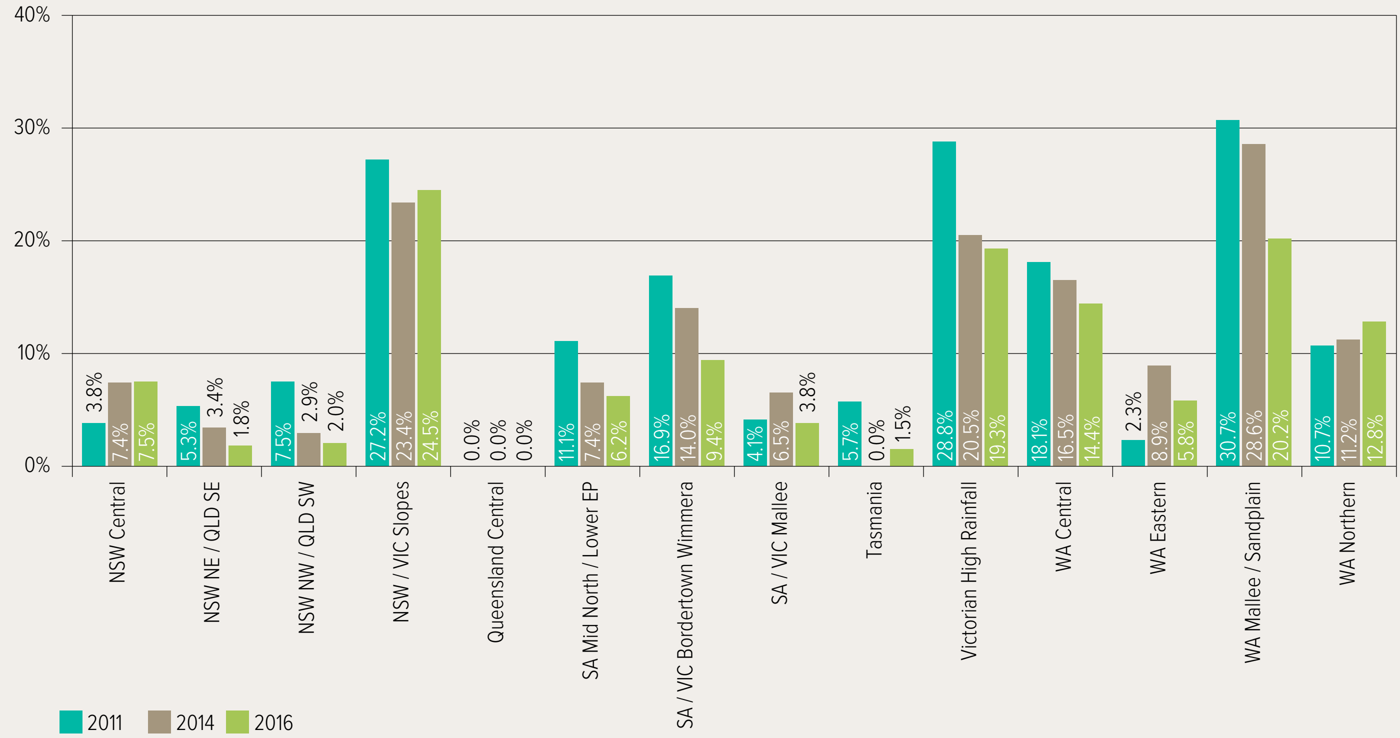
Legume pastures were more likely to be grown in the AEZs with higher levels of mixed crop and livestock enterprises. They are used for many purposes, including as a disease break crop in a crop rotation or sequence, for nitrogen fixation, weed management (also as a benefit for following cereal crops) and as feed for livestock. The 2016 survey shows that AEZs where growers reported substantial areas (greater than 15 per cent) of cereal crops being sown following legume-dominant pastures included:

- SA/Victorian Mallee;
- Central WA;

TABLE 51 Average percentage of cereal crop area planted following canola or pulses or legume-based pasture in 2011, 2014 and 2016.

Agro-ecological zone	Net: following canola/pulse/legume			Significant difference between years	
	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	17.1	17.3	22.2		
NSW NE / QLD SE	25.1	18.5	20.8		
NSW NW / QLD SW	39.7	24.6	27.1		***
NSW / VIC Slopes	41.0	35.8	36.9		
QLD Central	27.6	23.3	27.7		
SA Mid North / Lower EP	50.4	31.8	36.3		***
SA / VIC Bordertown, Wimmera	45.5	36.8	33.5		***
SA / VIC Mallee	32.9	30.5	32.0		
TAS	17.8	2.6	12.7	**	
VIC High Rainfall	39.9	33.3	30.6		
WA Central	51.5	45.3	41.9		***
WA Eastern	21.8	24.0	26.4		
WA Mallee/Sandplain	63.3	49.4	40.2		***
WA Northern	32.9	22.7	35.1	**	
NATIONAL AVERAGES	36.2	28.3	30.2		

FIGURE 60 Average percentage of cereal crop area planted following canola in previous year.



- Eastern WA; and
- WA Mallee/Sandplain.

Conversely, pasture legumes were less likely to be used in the crop rotation in the intensive grain production AEZs including:

- NSW/Queensland;
- Central Queensland;
- NSW/Victorian Slopes; and
- WA Northern.

The national average area of cereals sown following a legume-dominant pasture increased modestly in 2016 to 9.9 per cent, moving back close to where it was in 2011 (10.1 per cent) of the cropped area nationally (Table 54, Figure 64 and Figure 65).

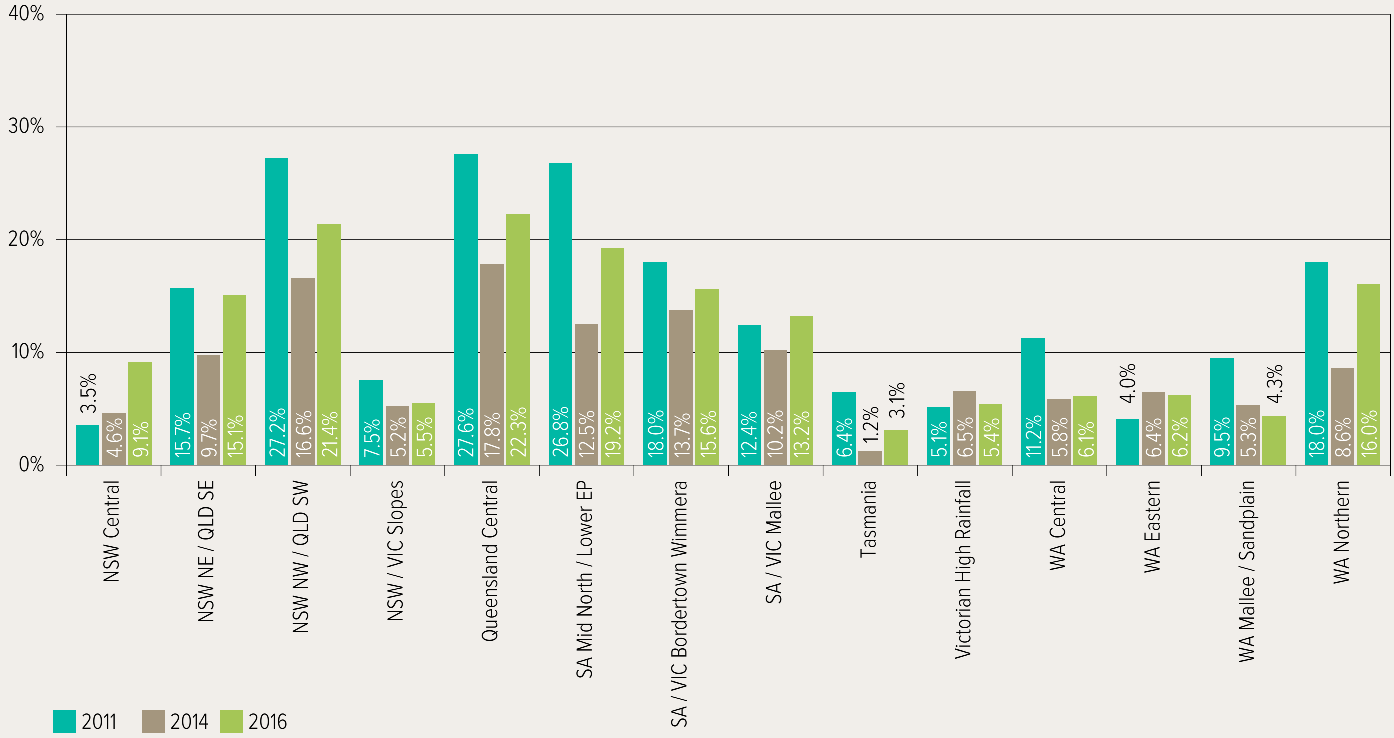
Planted following a long fallow

Data on use of a fallow period was presented in an earlier section of this report. An additional question was included in the 2016 survey:

TABLE 52 Average percentage of cereal crop area planted following canola in previous year.

Agro-ecological zone	Average area of cereal crop planted after canola (cool burn) (%)			Significant difference between years	
	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	3.8	7.4	7.5		**
NSW NE / QLD SE	5.3	3.4	1.8		
NSW NW / QLD SW	7.5	2.9	2.0		***
NSW / VIC Slopes	27.2	23.4	24.5		
QLD Central	0.0	0.0	0.0		
SA Mid North / Lower EP	11.1	7.4	6.2		***
SA / VIC Bordertown, Wimmera	16.9	14.0	9.4	**	***
SA / VIC Mallee	4.1	6.5	3.8	**	
TAS	5.7	0.0	1.5		
VIC High Rainfall	28.8	20.5	19.3		**
WA Central	18.1	16.5	14.4		
WA Eastern	2.3	8.9	5.8		**
WA Mallee/Sandplain	30.7	28.6	20.2		
WA Northern	10.7	11.2	12.8		
NATIONAL AVERAGES	12.3	10.8	9.2		

FIGURE 62 Average percentage of cereal crop area planted following a pulse crop in previous year.



respondents were also asked to estimate how much of their crop was planted following a period described as a long fallow.

In the GRDC southern and western regions a long fallow would generally be where the area had been kept free of plant growth from the previous season until sowing. The commencement of a fallow period could occur in the late winter of one year, with sowing occurring in the late autumn of the next, with the fallow period lasting up to nine months.

In the GRDC northern region, the situation is complicated by the opportunity to plant either summer or winter crops. In these areas a fallow may be as long as it takes to capture adequate soil moisture to give growers confidence that a successful crop (either winter or summer) can be grown. In these areas a fallow may be short (a month or so) between a winter crop harvest in October, and the sowing of a summer crop in November–December, or quite long, where 12 or more months may pass before rain received is such that adequate soil moisture is captured.

FIGURE 61 Percentage of cereal crop sown in 2016 following a canola crop in 2015.

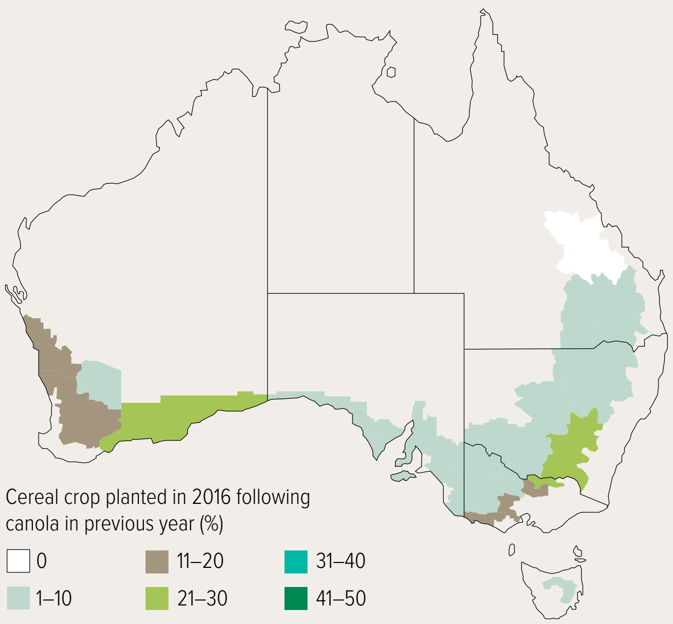


FIGURE 63 Percentage of cereal crop sown in 2016 following a pulse crop in 2015.

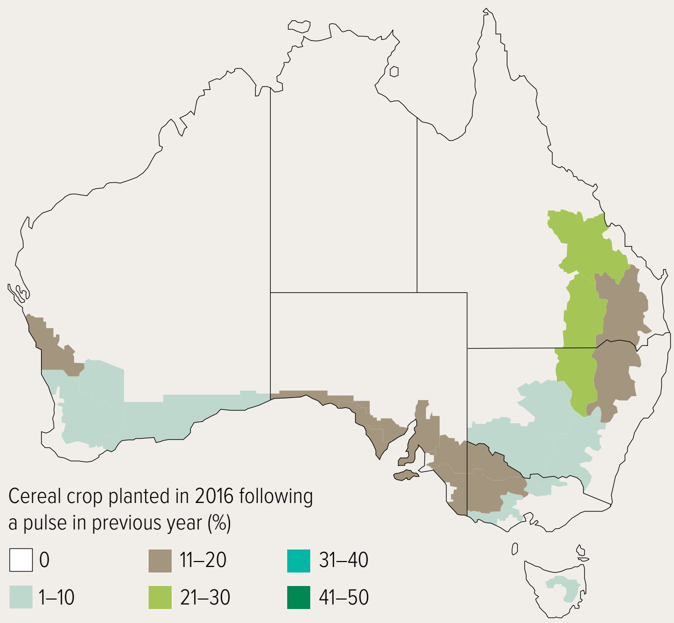
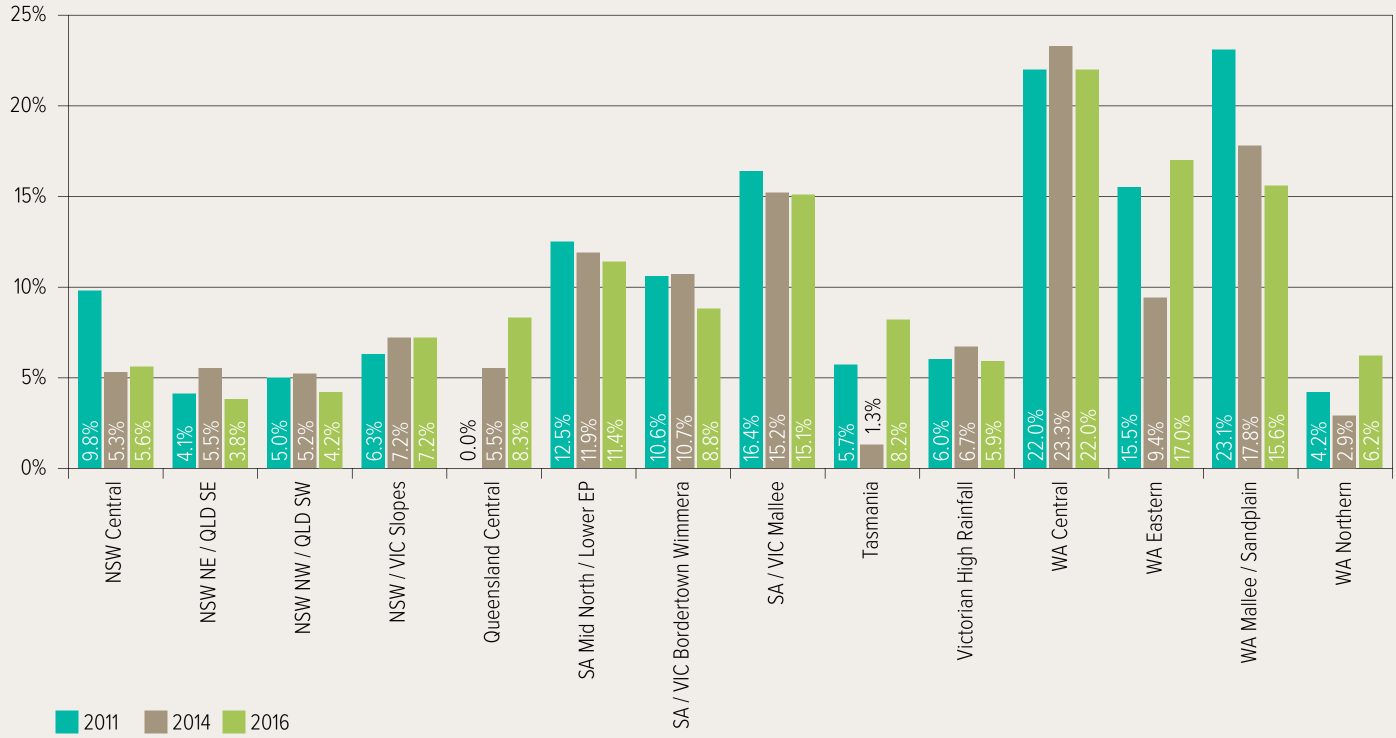


FIGURE 64 Average percentage of cereal crop area planted following a legume-dominant pasture in the previous year.



Long fallows have a range of purposes including: assisting with maximising soil moisture through an absence of plant growth, minimising weed-seed set, minimising hosting of diseases and allowing nitrogen mineralisation. Soil moisture accumulation is often considered the dominant purpose of a long fallow.

The survey data as presented in Table 55, Figure 66 and Figure 67, shows that 10.4 per cent of the cereal crop was sown into a long fallow in 2016 on a national basis. This is a reduction from almost 13 per cent in 2014. The proportion is higher in the northern AEZs, possibly reflecting the mixed winter and summer crop systems that are a feature of these zones, where fallows are frequently used to achieve a full soil moisture profile before sowing of any crop. In other AEZs where long fallow is a feature, this tends to be where soils have some clay content, and soil moisture is seen as able to be stored over a fallow (NSW Central, the Mallee areas, and WA Eastern).

The above sections describe the proportion of the 2016 cereal crop sown into paddocks that were 'break' crops or fallow in

TABLE 53 Average percentage of cereal crop area planted following a pulse crop in previous year.

Agro-ecological zone	Average area cereal crop planted following a pulse crop (%)			Significant difference between years	
	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	3.5	4.6	9.1	**	***
NSW NE / QLD SE	15.7	9.7	15.1	***	
NSW NW / QLD SW	27.2	16.6	21.4		
NSW / VIC Slopes	7.5	5.2	5.5		
QLD Central	27.6	17.8	22.3		
SA Mid North / Lower EP	26.8	12.5	19.2	***	***
SA / VIC Bordertown, Wimmera	18.0	13.7	15.6		
SA / VIC Mallee	12.4	10.2	13.2		
TAS	6.4	1.2	3.1		
VIC High Rainfall	5.1	6.5	5.4		
WA Central	11.2	5.8	6.1		***
WA Eastern	4.0	6.4	6.2		
WA Mallee/Sandplain	9.5	5.3	4.3		***
WA Northern	18.0	8.6	16.0	**	
NATIONAL AVERAGES	13.8	8.9	11.6		

TABLE 54 Average percentage of cereal crop area planted following a legume-dominant pasture in previous year.

Agro-ecological zone	Average area cereal crop planted following a legume-dominant pasture (%)			Significant difference between years	
	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	9.8	5.3	5.6		
NSW NE / QLD SE	4.1	5.5	3.8		
NSW NW / QLD SW	5.0	5.2	4.2		
NSW / VIC Slopes	6.3	7.2	7.2		
QLD Central	0.0	5.5	8.3		**
SA Mid North / Lower EP	12.5	11.9	11.4		
SA / VIC Bordertown, Wimmera	10.6	10.7	8.8		
SA / VIC Mallee	16.4	15.2	15.1		
TAS	5.7	1.3	8.2		
VIC High Rainfall	6.0	6.7	5.9		
WA Central	22.0	23.3	22.0		
WA Eastern	15.5	9.4	17.0		
WA Mallee/Sandplain	23.1	17.8	15.6		
WA Northern	4.2	2.9	6.2		
NATIONAL AVERAGES	10.1	9.1	9.9		

2015. In contrast, the following sections describe where growers have specifically chosen to plant crops with an identified purpose in mind, such as weed or disease management, or for nutrient reasons.

Percentage of crop planted to assist with weed control

One of the reasons some growers decide to sow break crops in a crop rotation or sequence is to assist with control of weeds.

In 2016 survey respondents were asked what proportion of their crop was a break crop where weed management was the primary purpose for sowing this crop. The data (Table 56, Figure 68 and Figure 69) shows that 16.9 per cent of the crop area is sown with weed control as a purpose, down slightly since 2014. AEZs where results were highest included: NSW and Queensland, NSW/ Victorian Slopes, some SA zones and WA Northern.

This suggests that growers are seeking to choose some crops (16 per cent to 18 per cent of the cropped area) for the opportunities these provide to control weeds.

FIGURE 65 Percentage of cereal crop planted in 2016 following a legume-dominant pasture in 2015.

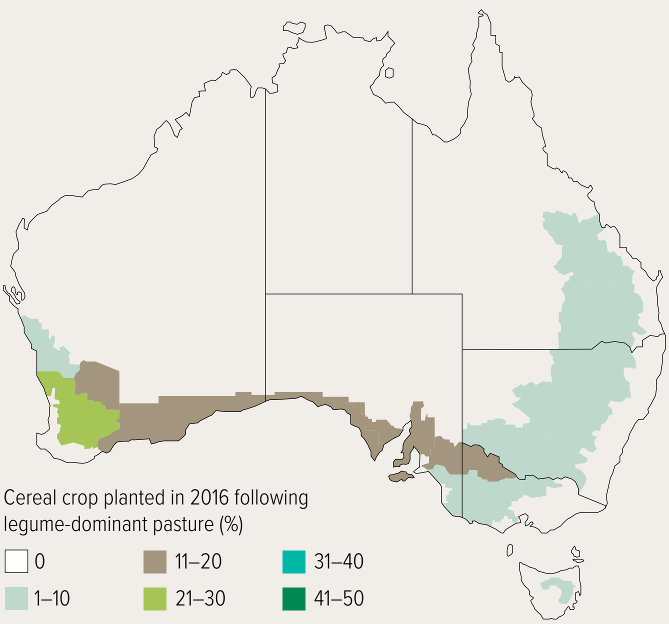
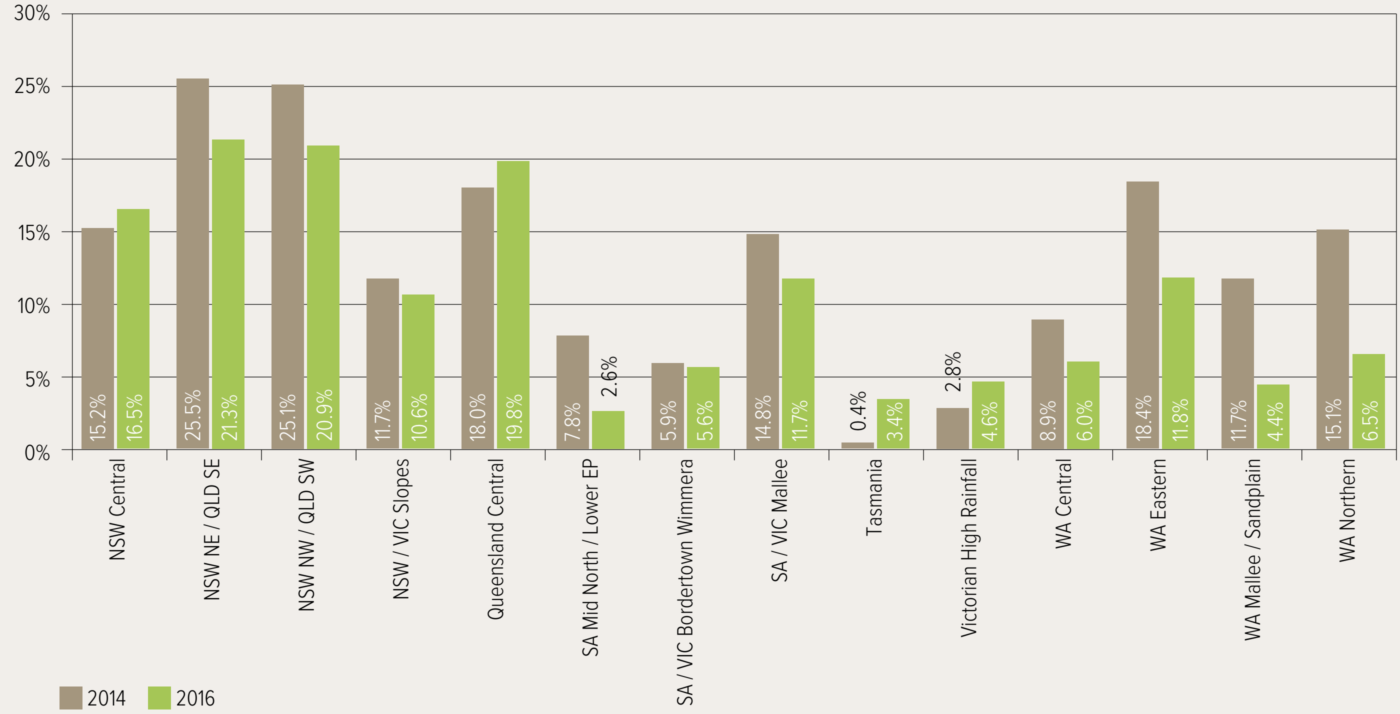


TABLE 55 Average percentage of cereal crop area planted after long fallow.

Agro-ecological zone	Average area cereal crop planted after long fallow (%)		Significant difference between years
	2014	2016	
NSW Central	15.2	16.5	
NSW NE / QLD SE	25.5	21.3	
NSW NW / QLD SW	25.1	20.9	
NSW / VIC Slopes	11.7	10.6	
QLD Central	18.0	19.8	
SA Mid North / Lower EP	7.8	2.6	**
SA / VIC Bordertown, Wimmera	5.9	5.6	
SA / VIC Mallee	14.8	11.7	
TAS	0.4	3.4	
VIC High Rainfall	2.8	4.6	
WA Central	8.9	6.0	
WA Eastern	18.4	11.8	
WA Mallee/Sandplain	11.7	4.4	
WA Northern	15.1	6.5	
NATIONAL AVERAGES	12.9	10.4	

FIGURE 66 Average percentage of cereal crop area planted into long fallow.



Percentage of crop planted to assist with disease control

Another reason for growers choosing a particular crop to grow in a particular paddock can be for the opportunities it provides to control diseases, either by providing a 'break' to the life cycle of the disease pathogen, or for other control options afforded by that crop.

Growers were asked in 2016 what proportion of their crop area was sown with a crop chosen for the opportunities it provides for disease management. The data (Table 57, Figure 70 and Figure 71) shows that the proportion of crop sown with disease management as a reason varies and averages about 14.9 per cent nationally, similar to the 2014 survey. The highest use of this practice is in the AEZs in NSW and Queensland, the NSW/Victorian Slopes and SA/ Victoria Bordertown/Wimmera.

FIGURE 68 Average percentage of cropped area planted in 2014 and 2016 with a break crop specifically for weed control.

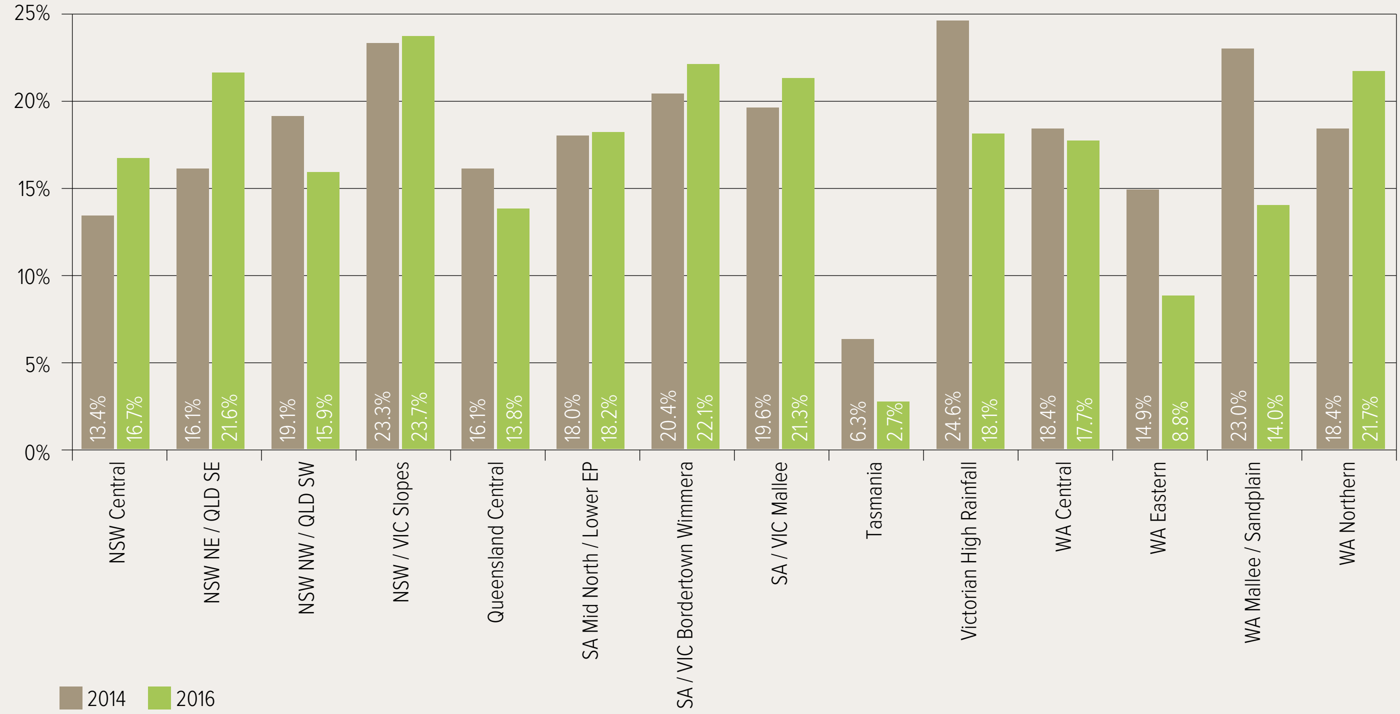


FIGURE 67 Percentage of cereal crop planted in 2016 following a long fallow.

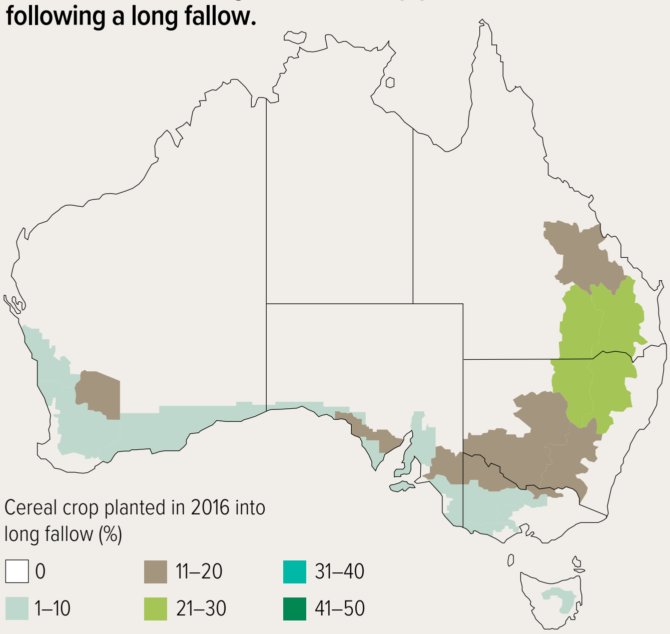
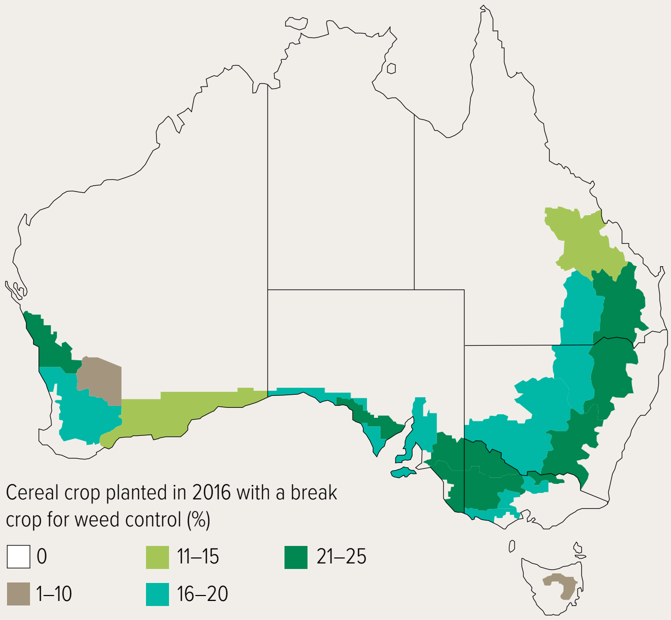


FIGURE 69 Crop area planted in 2016 with a break crop for weed control.



It is possible that the higher use of this practice in the GRDC northern region is due to diseases such as crown rot, stripe rust and yellow spot in wheat and durum, and perhaps aschochyta in chickpeas.

Percentage of crop planted (break crop) sown for nutritional reasons

As per the above datasets for crops planted for weed or disease control reasons, the 2016 survey also asked about the proportion of crop planted for nutrition management reasons.

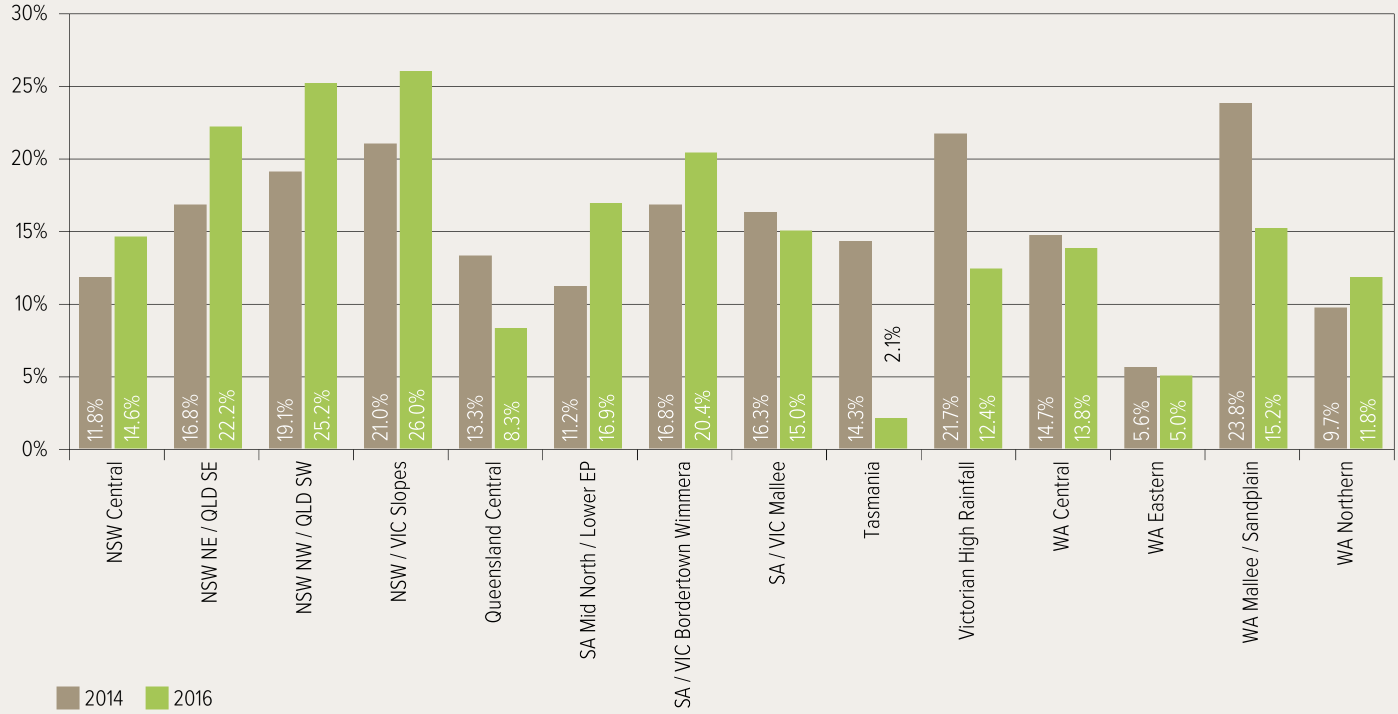
TABLE 56 Average percentage of cropped area planted with a break crop specifically for weed control

Agro-ecological zone	Average break crop for weed control % of total crop area		Significant difference between years
	2014	2016	
NSW Central	13.4	16.7	
NSW NE / QLD SE	16.1	21.5	
NSW NW / QLD SW	19.1	15.9	
NSW / VIC Slopes	23.3	23.7	
QLD Central	16.1	13.8	
SA Mid North / Lower EP	18.0	18.2	
SA / VIC Bordertown, Wimmera	20.4	22.1	
SA / VIC Mallee	19.6	21.3	
TAS	6.3	2.7	
VIC High Rainfall	24.6	18.1	
WA Central	18.4	17.7	
WA Eastern	14.9	8.8	
WA Mallee/Sandplain	23.0	14.0	
WA Northern	18.4	21.7	
NATIONAL AVERAGES	18.0	16.9	

TABLE 57 Average percentage of cropped area planted with a break crop specifically for disease control.

Agro-ecological zone	Average break crop for disease control % of total crop area		Significant difference between years
	2014	2016	
NSW Central	11.8	14.6	
NSW NE / QLD SE	16.8	22.2	
NSW NW / QLD SW	19.1	25.2	
NSW / VIC Slopes	21.0	26.0	
QLD Central	13.3	8.3	
SA Mid North / Lower EP	11.2	16.9	
SA / VIC Bordertown, Wimmera	16.8	20.4	
SA / VIC Mallee	16.3	15.0	
TAS	14.3	2.1	
VIC High Rainfall	21.7	12.4	**
WA Central	14.7	13.8	
WA Eastern	5.6	5.0	
WA Mallee/Sandplain	23.8	15.2	
WA Northern	9.7	11.8	
NATIONAL AVERAGES	15.4	14.9	

FIGURE 70 Average percentage of cropped area planted in 2014 and 2016 with a break crop specifically for disease control.



The data for proportion of crop sown in 2016 for nutritional reasons (Table 58, Figure 72 and Figure 73) shows almost 14.9 per cent of crops were identified by growers to have been sown for this reason, which was an increase on the 2014 result. The most prevalent use of this practice occurred in the AEZs in northern NSW, Queensland and the SA/Victorian Mallee, while it was less prevalent in much of WA.

There may be some correlation with the increase in the use of pulse crops in this regard, in that growers in the northern region may have been more interested in the nitrogen benefits from these crops, along with the disease management benefits that they offer.

It is also likely that several 'break' crops bring more than one potential benefit, with this stimulating the use of these crops in a crop program. Canola is well known for its ability to assist

FIGURE 72 Average percentage of cropped area planted in 2014 and 2016 with a break crop specifically for nutritional benefits.

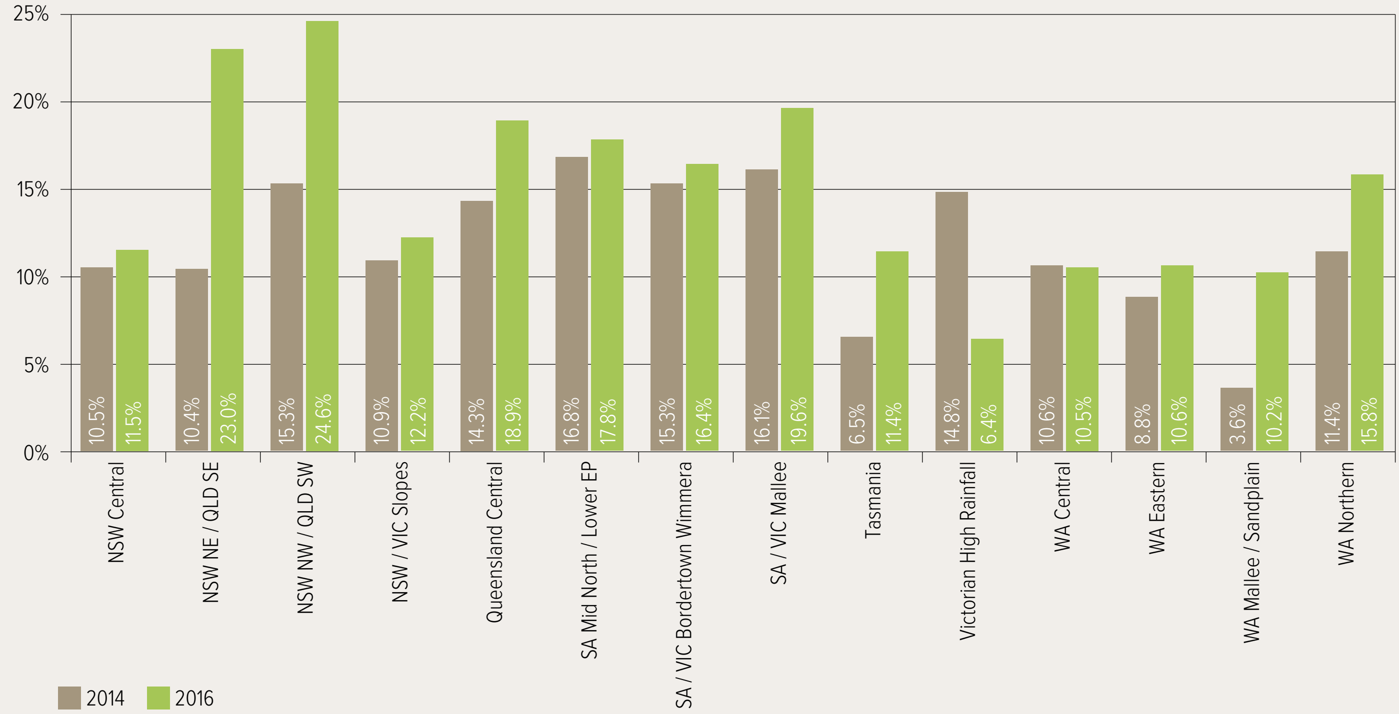


FIGURE 71 Average percentage of cropped area planted in 2016 with a break crop specifically for disease management.

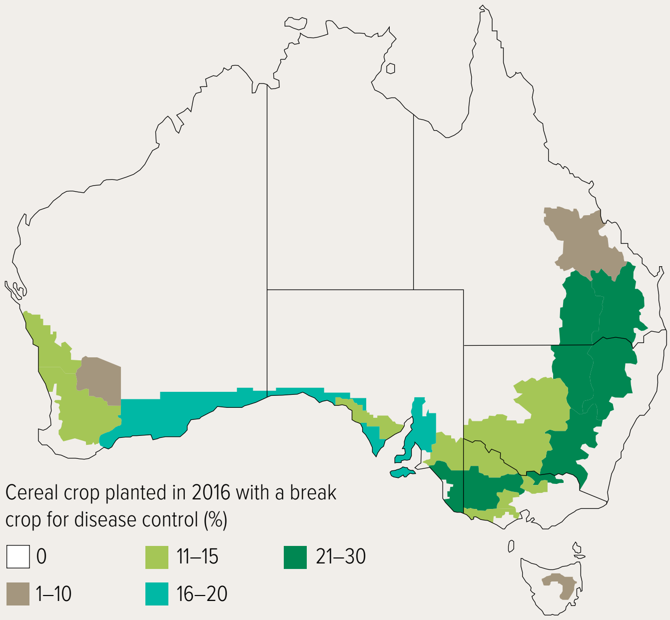
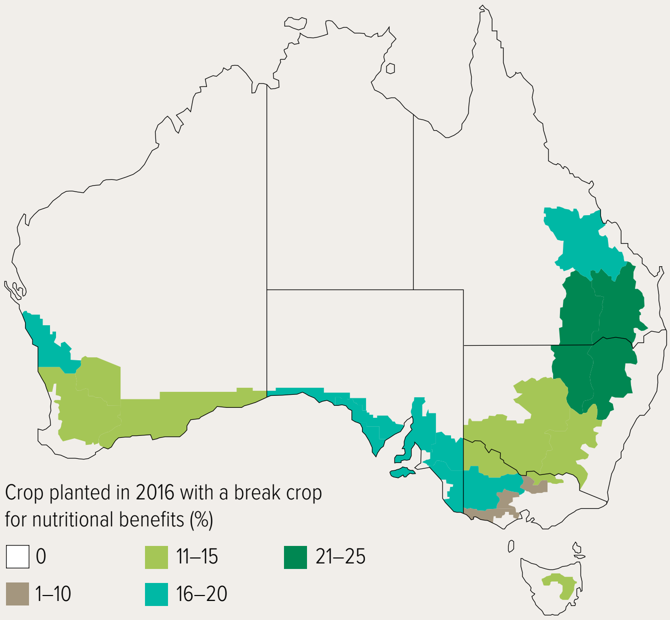


FIGURE 73 Average percentage of cropped area planted in 2016 with a break crop specifically for nutritional benefits.



with management of soil-borne fungal diseases in cereals, and provision of weed management options (in the case of triazine-tolerant (TT) and Roundup Ready® canola in particular), while pulses are often used for these same benefits as well as their nitrogen fixation attributes. It can be difficult for some growers to identify only one of these benefits when they choose a break crop, as often they are seeking more than one.

TABLE 58 Average percentage of cropped area planted with a break crop specifically for nutritional benefits in 2014 and 2016.

Agro-ecological zone	Average crop area planted with a break crop for nutritional benefit (%)		Significant difference between years
	2014	2016	
NSW Central	10.5	11.5	
NSW NE / QLD SE	10.4	23.0	***
NSW NW / QLD SW	15.3	24.6	**
NSW / VIC Slopes	10.9	12.2	
QLD Central	14.3	18.9	
SA Mid North / Lower EP	16.8	17.8	
SA / VIC Bordertown, Wimmera	15.3	16.4	
SA / VIC Mallee	16.1	19.6	
TAS	6.5	11.4	
VIC High Rainfall	14.8	6.4	**
WA Central	10.6	10.5	
WA Eastern	8.8	10.6	
WA Mallee/Sandplain	3.6	10.2	**
WA Northern	11.4	15.8	
NATIONAL AVERAGES	11.8	14.9	

Where these crops are profitable in their own right (as was the case with some pulse crops in 2016) these choices can be driven by the profitability of the crop itself as much as the weed, disease or nutritional benefits.

Soil management in 2016

A range of soil-management practices were included in the 2016 survey. These practices included: lime application, soil testing and fertiliser use as informed by soil testing or crop need.

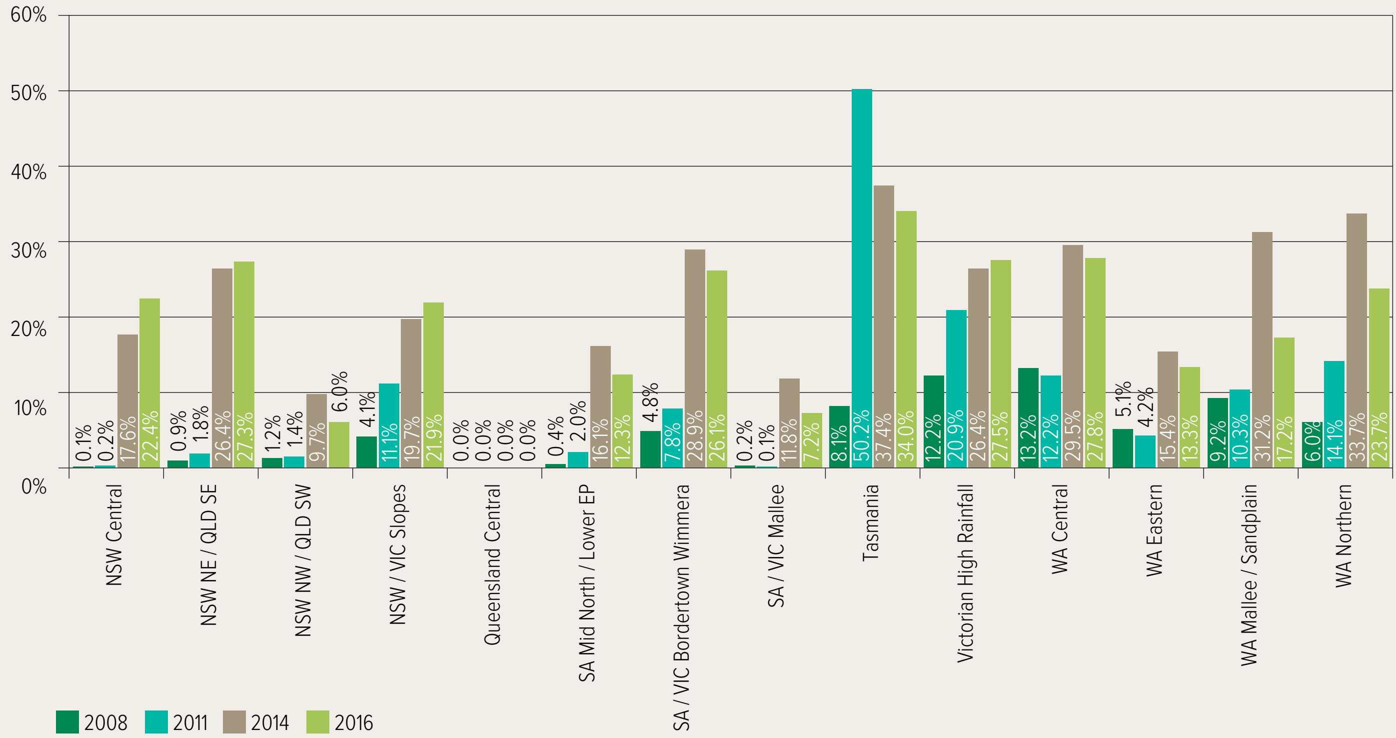
Questions raised in 2016 were:

- What was the area and use rate of lime applied?
- What percentage of your crops (broken by crop type) were soil tested in 2014?
- What area of your crop was soil tested to 10cm depth?
- What area of crop had a comprehensive, deep soil test in 2016?
- What area of crop was treated with fertiliser at rates based on soil test results?
- What area of crop was treated with fertiliser at rates based on estimates or calculations of nutrient removal by the crop?
- What area of crop had a leaf or petiole test?
- What area of crop had an in-season application or top-dressing of fertiliser?

TABLE 59 Average percentage of crop area where lime was applied.

Agro-ecological zone	Average cropping area limed (%)				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	0.1	0.2	17.6	22.4		
NSW NE / QLD SE	0.9	1.8	26.4	27.3		
NSW NW / QLD SW	1.2	1.4	9.7	6.0		
NSW / VIC Slopes	4.1	11.1	19.7	21.9		
QLD Central	0.0	0.0	0.0	0.0		
SA Mid North / Lower EP	0.4	2.0	16.1	12.3		
SA / VIC Bordertown, Wimmera	4.8	7.8	28.9	26.1		
SA / VIC Mallee	0.2	0.1	11.8	7.2		
TAS	8.1	50.2	37.4	34.0		
VIC High Rainfall	12.2	20.9	26.4	27.5		
WA Central	13.2	12.2	29.5	27.8		
WA Eastern	5.1	4.2	15.4	13.3		
WA Mallee/Sandplain	9.2	10.3	31.2	17.2	**	
WA Northern	6.0	14.1	33.7	23.7		
NATIONAL AVERAGES	4.7	9.7	21.7	19.1		

FIGURE 74 Average percentage of crop area where lime was applied.



Crops sown in 2016 where lime was applied in the period leading to sowing

Survey respondents were asked what proportion of their 2016 crop area had they had applied lime to. The data (Table 59 and Figure 74) shows that lime was applied to 19.1 per cent of crop area in 2016, down from 21.7 per cent in 2014.

In those AEZs where the application of lime is a common practice, such as the NSW/Victorian Slopes and much of WA, survey results show that, on average, growers apply lime to 20 per cent to 25 per cent of their cropped area each year.

Percentage of grain farms applying lime in 2016

Figure 75 shows the proportion of farms that reported applying lime in 2016. Based on the map data, it can be seen that lime is used on more farms in WA, central and south-east NSW and Victoria. In northern NSW and Queensland lime is generally not needed for addressing low soil pH. This is driven by the soil pH prevalent in these areas, with more acid soils in WA, central and southern NSW and Victoria, with higher pH soils found in northern NSW and Queensland, the Mallee and across much of SA.

TABLE 60 Average use rate of lime (t/ha) on area where it was applied.

Agro-ecological zone	Average lime use rate (t/ha)				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	2.00	1.60	0.8	1.7	***	
NSW NE / QLD SE	1.13	1.81	1.2	1.8		
NSW NW / QLD SW	1.22	1.59	1.0	2.0		
NSW / VIC Slopes	1.51	1.47	0.8	1.8	***	**
QLD Central	0.0	0.0	0.0			
SA Mid North / Lower EP	1.57	1.57	0.5	2.1	***	
SA / VIC Bordertown, Wimmera	1.75	1.00	3.9	1.8		**
SA / VIC Mallee	1.66	0.50	0.8	1.4		
TAS	3.96	2.59	0.3	4.0	***	
VIC High Rainfall	1.90	1.36	1.5	2.0		
WA Central	1.07	1.10	1.3	1.6		
WA Eastern	1.12	1.23	0.8	1.5	***	
WA Mallee/Sandplain	1.36	1.23	0.8	1.7	***	**
WA Northern	1.18	1.48	0.8	1.9	***	
NATIONAL AVERAGES	1.53	1.32	1.0	1.9		

FIGURE 75 Percentage of grain farms applying lime in 2016.

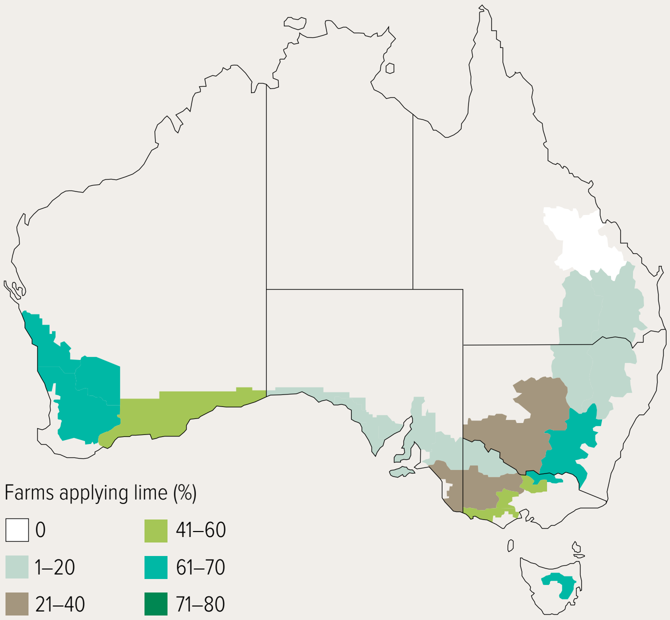
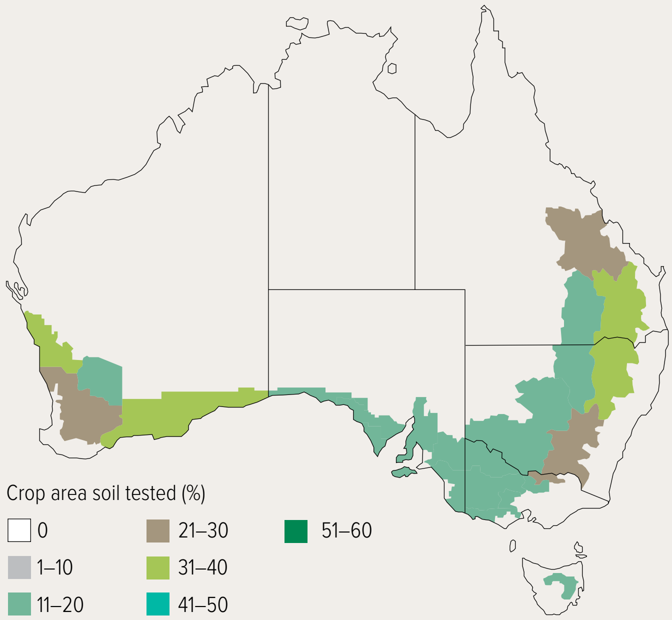


FIGURE 77 Percentage of cropped area soil tested in 2016.



Amount of lime applied

Respondents were asked the rate of lime applied (in tonnes per hectare) to the area treated in 2016. The survey data (Table 60) shows a general increase in the amount of lime where applied over the period 2008 to 2016, with 1.9t/ha applied in 2016 as a national average.

Significant increases in lime application rates are noted for many individual AEZs, mostly where low soil pH has been identified.

However, it also appears that lime application rates have increased in all AEZs even in areas where low soil pH is not necessarily a major factor, for example, in the SA/Victorian Mallee.

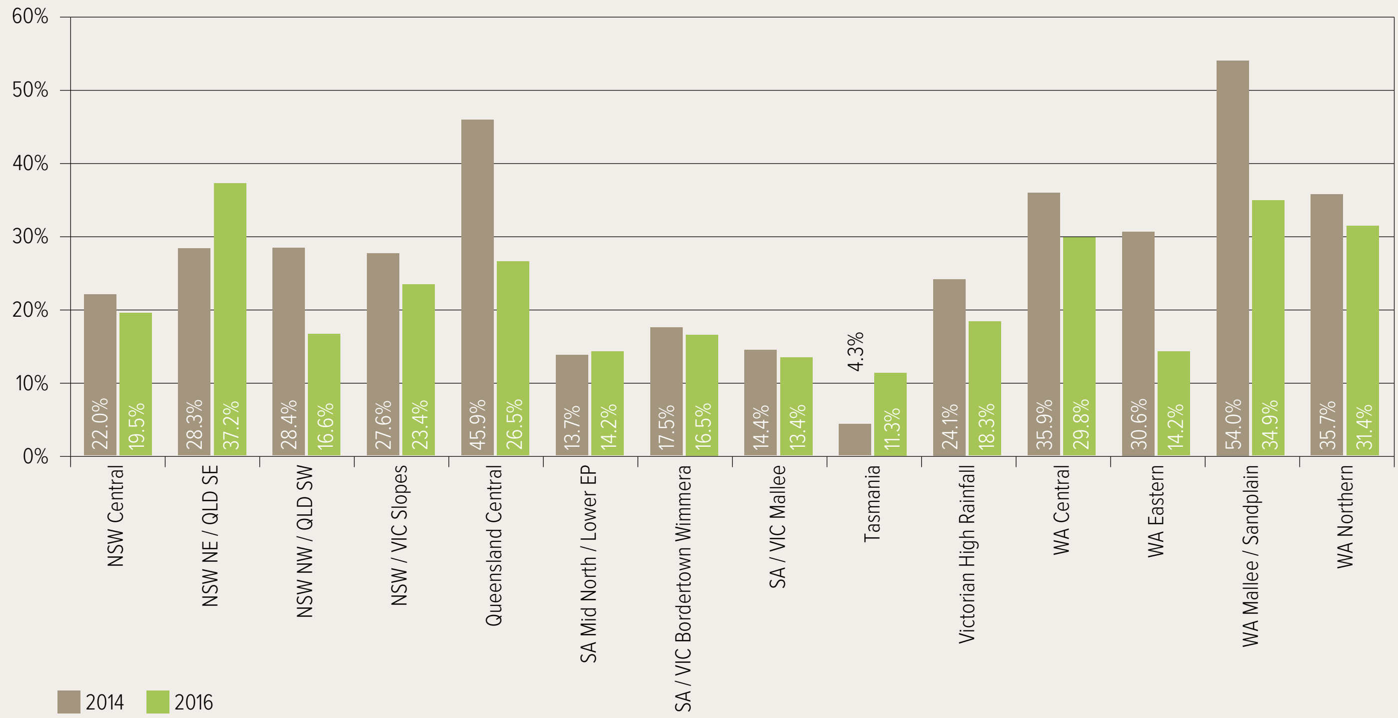
TABLE 61 Average percentage of crop area soil tested.

Agro-ecological zone	Average cropping area soil tested (%)		Significant difference between years
	2014	2016	
NSW Central	22.0	19.5	
NSW NE / QLD SE	28.3	37.2	**
NSW NW / QLD SW	28.4	16.6	
NSW / VIC Slopes	27.6	23.4	
QLD Central	45.9	26.5	
SA Mid North / Lower EP	13.7	14.2	
SA / VIC Bordertown, Wimmera	17.5	16.5	
SA / VIC Mallee	14.4	13.4	
TAS	4.3	11.3	
VIC High Rainfall	24.1	18.3	
WA Central	35.9	29.8	
WA Eastern	30.6	14.2	***
WA Mallee/Sandplain	54.0	34.9	**
WA Northern	35.7	31.4	
NATIONAL AVERAGES	27.3	21.9	

TABLE 62 Average percentage of winter cereal crop area soil tested.

Agro-ecological zone	Average winter cereal crop area soil tested (%)		Significant difference between years
	2014	2016	
NSW Central	24.8	22.3	
NSW NE / QLD SE	36.2	37.2	
NSW NW / QLD SW	30.4	19.4	**
NSW / VIC Slopes	31.6	22.8	**
QLD Central	46.9	30.6	
SA Mid North / Lower EP	16.4	16.2	
SA / VIC Bordertown, Wimmera	22.0	20.4	
SA / VIC Mallee	18.1	15.9	
TAS	8.5	46.9	
VIC High Rainfall	25.4	18.3	
WA Central	39.7	30.6	**
WA Eastern	33.9	13.2	***
WA Mallee/Sandplain	58.8	37.9	**
WA Northern	43.5	36.7	
NATIONAL AVERAGES	31.1	26.3	

FIGURE 76 Average percentage of crop area soil tested.



Reasons for this would need to be confirmed through detailed interviews with growers.

As an overall observation it appears that growers are seeking to actively address soil acidity using the application of lime.

Soil testing for nutrition management

Average percentage of cropped area soil tested

Table 61 shows survey results for the percentage of the cropped area survey respondents reported as having been soil tested in 2016.

FIGURE 78 Average percentage of winter cereal crop area soil tested.

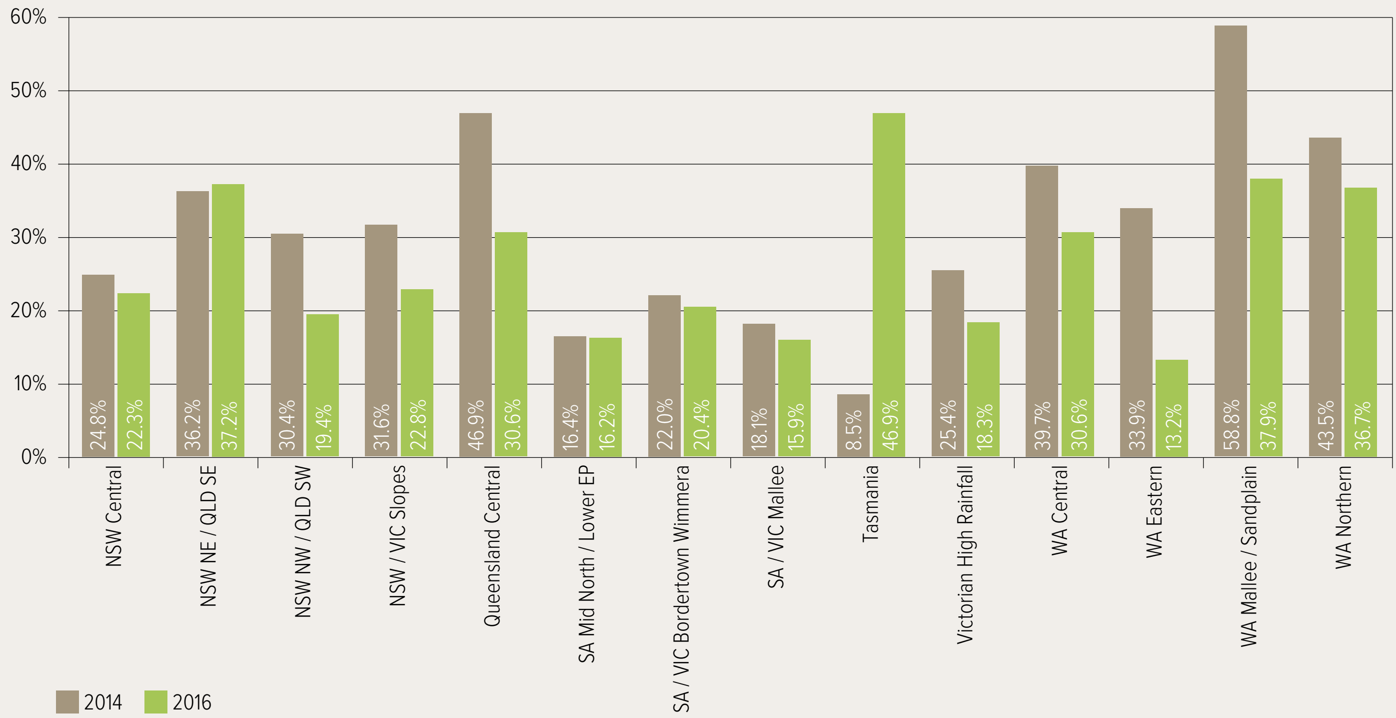


FIGURE 79 Percentage of winter cereal crop area soil tested in 2016.

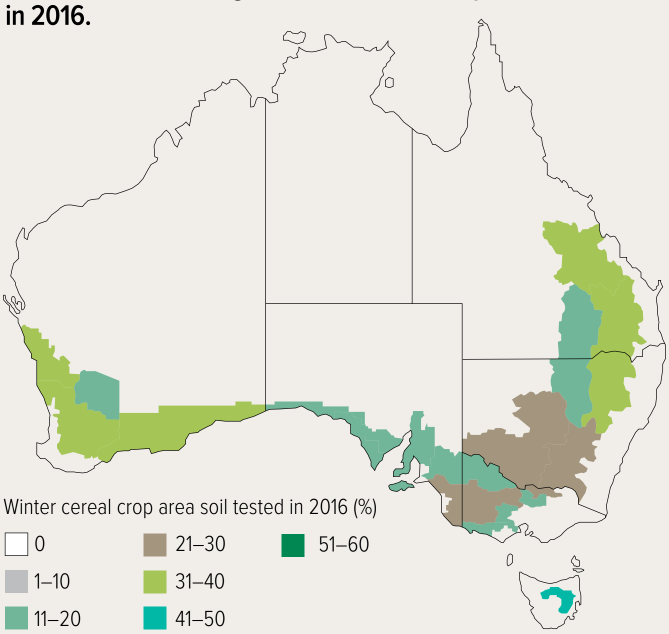
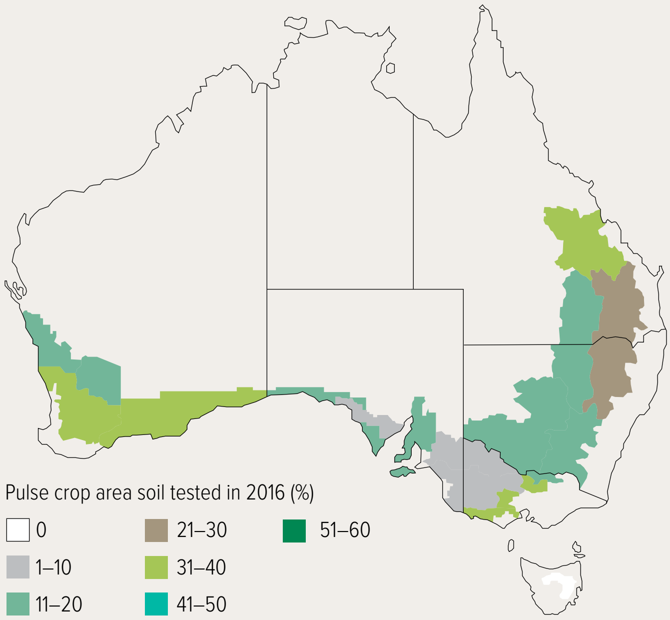


FIGURE 81 Percentage of pulse crop area soil tested in 2016.



Nationally 21.9 per cent of the cropped area was soil tested in 2016, a decrease as compared with 2014. Soil testing has declined, although the proportion of the crop where soil testing was carried out remained relatively high in several AEZs, for example, much of WA and NE NSW/SE Queensland (Table 61, Figure 76 and Figure 77). Reasons for this decrease are difficult to identify without more detailed enquiry, but could be related to growers moving to in-season testing, or nutrient budgeting used in partnership with a more strategic use of soil testing.

Survey respondents in 2016 were then asked about how much of their cropped area (i.e. area of cereals, pulses, oilseeds, etc) was soil tested in advance of sowing in 2016.

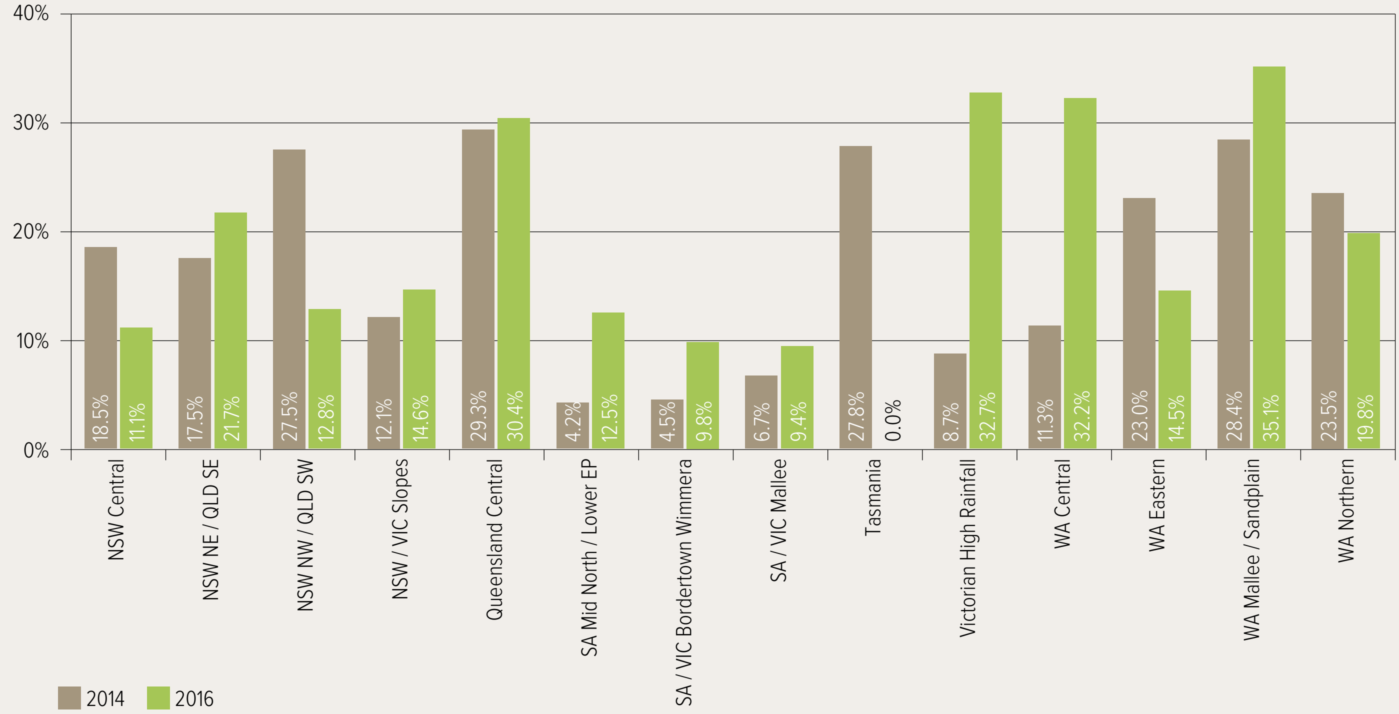
TABLE 63 Average percentage of pulse crop area soil tested.

Agro-ecological zone	Average pulse crop area soil tested (%)		Significant difference between years
	2014	2016	
NSW Central	18.5	11.1	
NSW NE / QLD SE	17.5	21.7	
NSW NW / QLD SW	27.5	12.8	
NSW / VIC Slopes	12.1	14.6	
QLD Central	29.3	30.4	
SA Mid North / Lower EP	4.2	12.5	**
SA / VIC Bordertown, Wimmera	4.5	9.8	
SA / VIC Mallee	6.7	9.4	
TAS	27.8	0.0	
VIC High Rainfall	8.7	32.7	***
WA Central	11.3	32.2	***
WA Eastern	23.0	14.5	
WA Mallee/Sandplain	28.4	35.1	
WA Northern	23.5	19.8	
NATIONAL AVERAGES	17.4	18.3	

TABLE 64 Average percentage of oilseed crop area soil tested.

Agro-ecological zone	Average oilseed crop area soil tested (%)		Significant difference between years
	2014	2016	
NSW Central	36.9	36.9	
NSW NE / QLD SE	42.8	28.0	
NSW NW / QLD SW	29.0	14.2	
NSW / VIC Slopes	38.1	34.6	
QLD Central			
SA Mid North / Lower EP	10.7	8.8	
SA / VIC Bordertown, Wimmera	24.3	30.9	
SA / VIC Mallee	12.7	18.8	
TAS	0.0	50.0	
VIC High Rainfall	36.9	30.1	
WA Central	40.5	33.2	
WA Eastern	26.7	35.6	
WA Mallee/Sandplain	54.0	22.3	***
WA Northern	44.0	37.6	
NATIONAL AVERAGES	30.5	29.3	

FIGURE 80 Average percentage of pulse crop area soil tested.



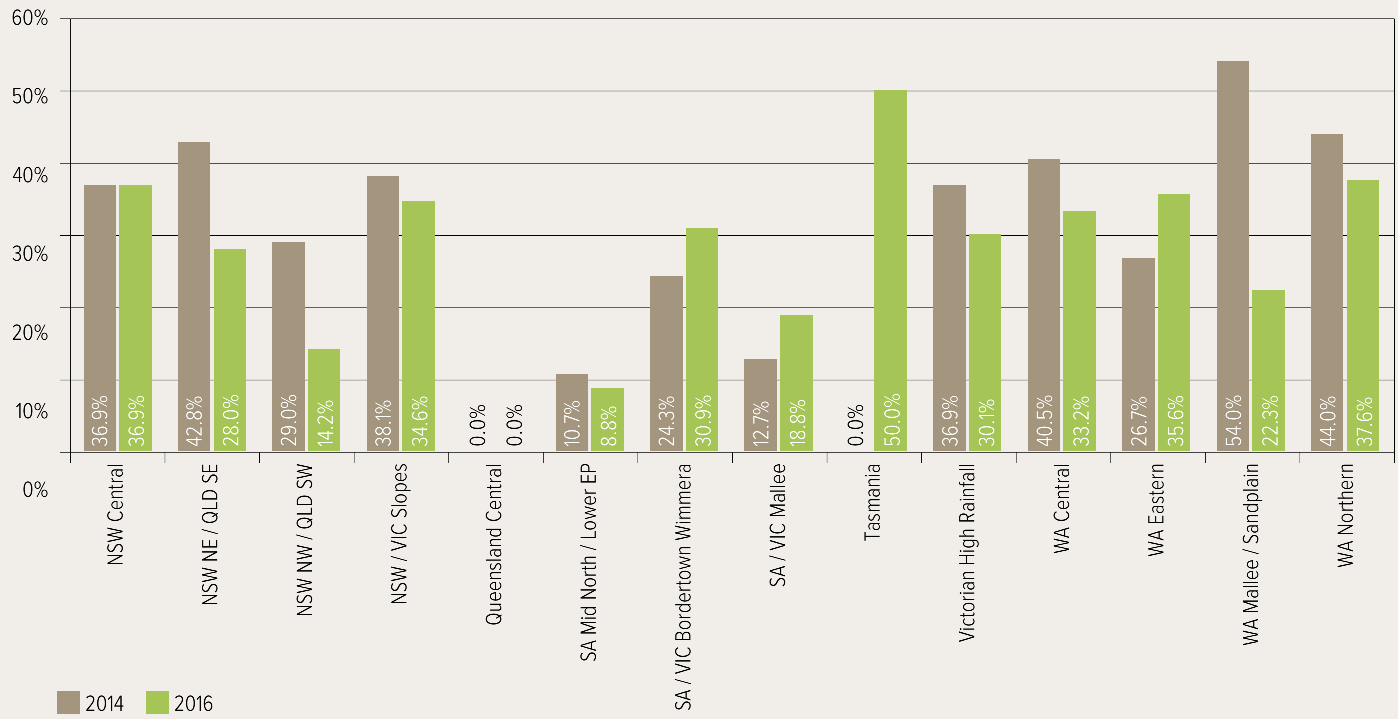
Average percentage of winter cereal crop area soil tested

The data for the proportion of the winter cereal crop soil tested in 2016 are presented in Table 62, Figure 78 and Figure 79.

Nationally 26.3 per cent of the total crop area had soil testing in advance of sowing cereal crops, a decrease since 2014. The decrease was most notable in the NSW/Victorian Slopes, Central Queensland, NW NSW/SW Queensland and the WA AEZs.

Reasons for a change in the amount of soil testing of paddocks planned for cereal crops may be due to growers either moving to in-season soil or plant tissue testing, or budgeting their fertiliser use based on soil moisture levels, forecast yield and the use of some more strategic testing in this approach.

FIGURE 82 Average percentage of oilseed crop area soil tested.



Average percentage of pulse crop area soil tested

The data for the proportion of pulse crop area soil tested in 2016 are presented in Table 63, Figure 80 and Figure 81.

The proportion of the pulse crop where soil was tested varies widely between individual AEZs, from below 10 per cent in much of SA and Victoria to more than 20 per cent of the pulse crop area in parts of WA and NW NSW/SW Queensland. It is also suggested that the overall level of soil testing for pulse crops is lower than that for cereal crops (see previous section). Less than 20 per cent of the pulse crop area is tested, as compared with well over 20 per cent of the cereal crop area. This is potentially in line with the differences in the amount of pulses as compared with cereals, and also potentially reflects that growers may be less concerned with knowing soil nitrogen levels for pulse crops as compared with cereals.

Average percentage of oilseed crop area soil tested

The data for the proportion of the oilseed crop that was soil tested in 2016 is presented in Table 64, Figure 82 and Figure 83.

Nationally 29.3 per cent of the oilseed crop area was soil tested in 2016, similar to that in 2014. While the results vary between individual AEZs, on average around 30 per cent or more of the oilseed area is soil tested in the main canola growing AEZs.

It is likely that the common oilseed crop, canola, tends to require higher inputs of nutrients than some other crops. The testing of these areas to assist with planning the fertiliser strategy would be understandable.

Average percentage of cropped area soil tested only to 10cm deep in 2016

Nationally survey respondents in 2014 reported that, on average, 32.9 per cent of the total cropped area was soil tested to a depth of 10cm. In 2016 this proportion fell to 25.6 per cent nationally. This aligns with the data for soil testing per se as reported in the previous section (Table 61) averaging about 26 per cent of the cropped area.

Where soil testing is carried out the depth is always at least 10cm, and so all areas tested would be included in the above results.

FIGURE 83 Percentage of winter oilseed crop area soil tested in 2016.

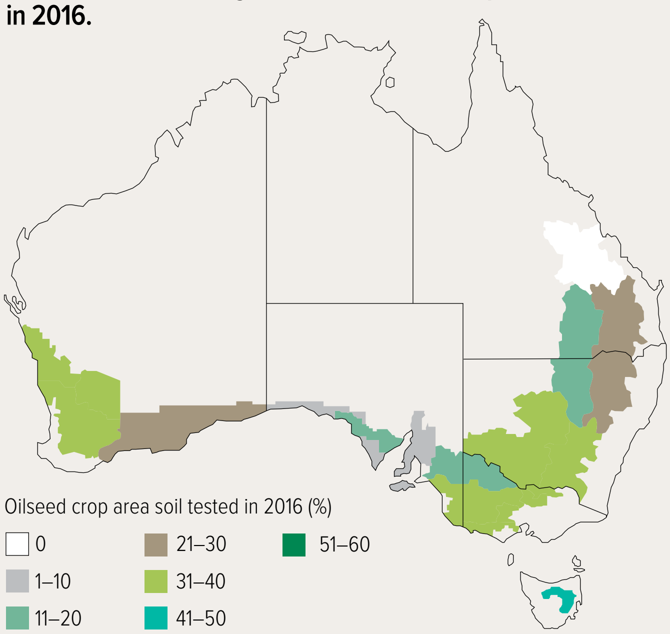


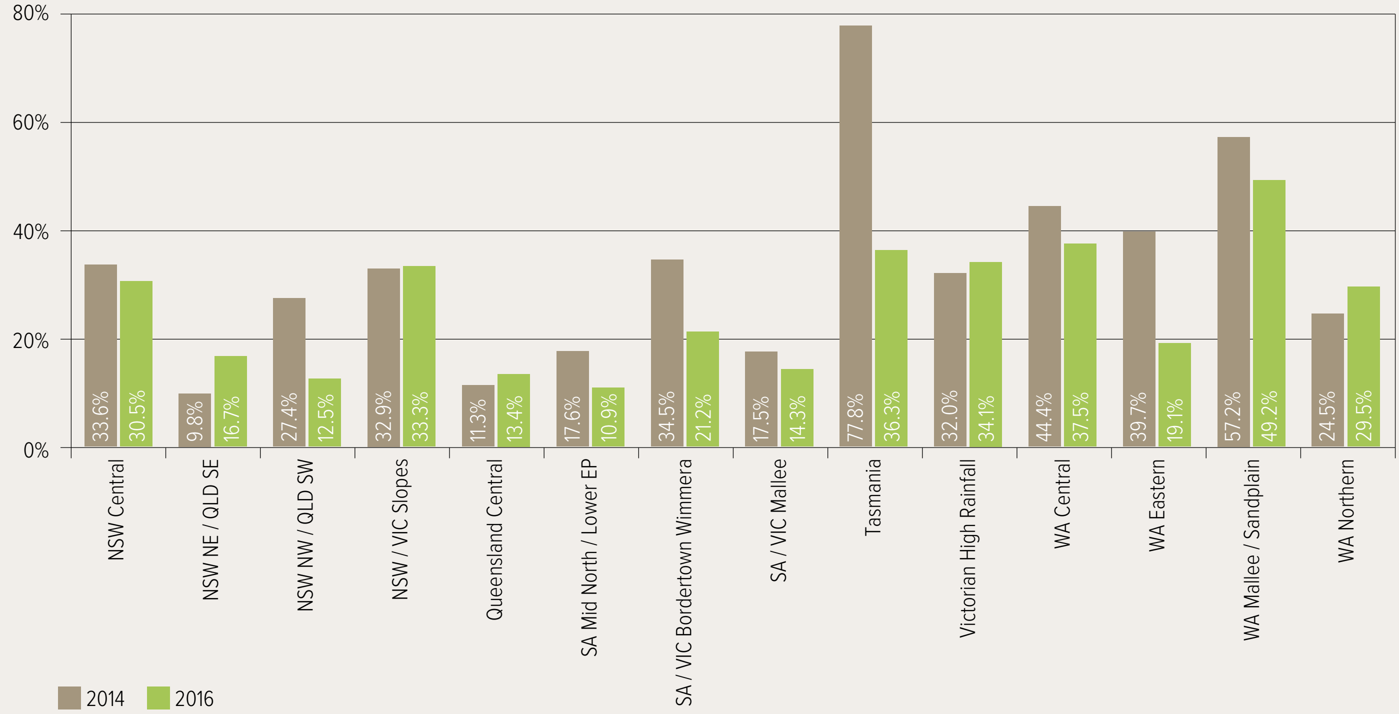
TABLE 65 Average percentage of cropped area soil tested only to a depth of 10cm.

Agro-ecological zone	Average crop area soil tested to 10cm depth (%)		Significant difference between years
	2014	2016	
NSW Central	33.6	30.5	
NSW NE / QLD SE	9.8	16.7	
NSW NW / QLD SW	27.4	12.5	
NSW / VIC Slopes	32.9	33.3	
QLD Central	11.3	13.4	
SA Mid North / Lower EP	17.6	10.9	
SA / VIC Bordertown, Wimmera	34.5	21.2	
SA / VIC Mallee	17.5	14.3	
TAS	77.8	36.3	
VIC High Rainfall	32.0	34.1	
WA Central	44.4	37.5	
WA Eastern	39.7	19.1	***
WA Mallee/Sandplain	57.2	49.2	
WA Northern	24.5	29.5	
NATIONAL AVERAGES	32.9	25.6	

TABLE 66 Average percentage of cropped area having deep soil test in the past 5 years.

Agro-ecological zone	Average crop area deep soil tested in past 5 years (%)		Significant difference between years
	2014	2016	
NSW Central	11.6	35.0	***
NSW NE / QLD SE	31.6	55.9	***
NSW NW / QLD SW	16.8	30.1	
NSW / VIC Slopes	12.8	27.3	***
QLD Central	43.4	63.3	
SA Mid North / Lower EP	6.4	20.7	***
SA / VIC Bordertown, Wimmera	5.4	25.8	***
SA / VIC Mallee	12.1	26.7	***
TAS	8.5	50.0	
VIC High Rainfall	7.0	16.4	**
WA Central	9.7	36.5	***
WA Eastern	9.3	27.7	**
WA Mallee/Sandplain	13.5	28.0	
WA Northern	32.4	42.4	
NATIONAL AVERAGES	15.8	34.7	

FIGURE 84 Average percentage of crop area soil tested to 10cm depth in 2014 and 2016.



Average percentage of cropped area having a deep soil test in the past 5 years

Survey respondents in 2016 were also asked how much of their cropped area was covered by a deep soil test (generally to 60cm) in the past five years.

The data (Table 66 and Figure 85) shows that while 15.8 per cent of the cropped area was deep soil tested across a five-year period as reported in 2014, this has increased significantly in 2016 to 34.7 per cent. The results show how much has been tested to depth in the past five years and does not represent the amount of this testing in any one (single) year.

FIGURE 85 Average percentage of crop area having deep soil test in the past 5 years.

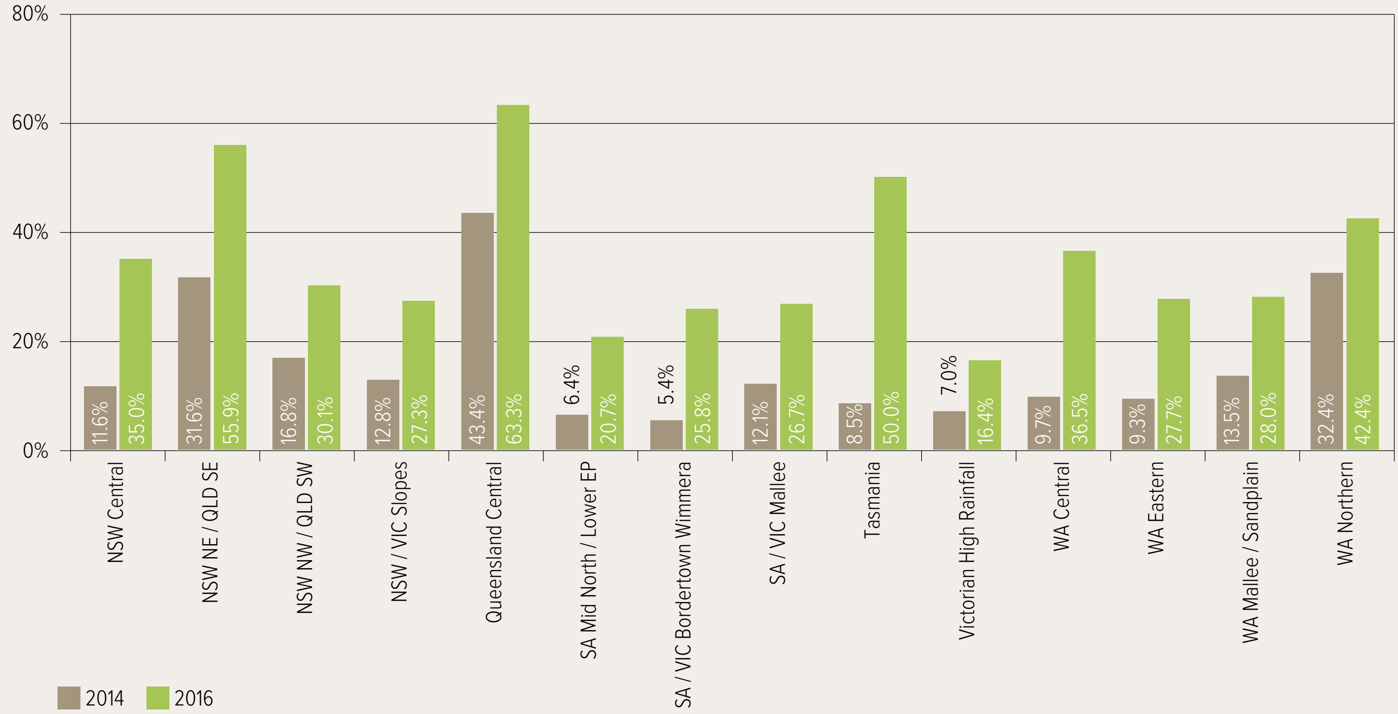


FIGURE 86 Average percentage of crop area where the fertiliser program was informed by soil testing.

The proportion of the cropped area soil tested to depth appears to be higher in the GRDC northern region (Central Queensland, NE NSW/SE Queensland, Central NSW), as well as AEZs in northern and central WA. Deep soil testing is generally useful for estimating nitrogen levels through the soil profile, and this may be more valuable in deeper soils (often found in central and northern NSW and Queensland), and also becomes an important input to development of fertiliser application programs, notably for crops where nitrogen is more important, for example, canola and higher protein wheat and durum.

Average percentage of crop area where the fertiliser program in 2016 was informed by soil testing

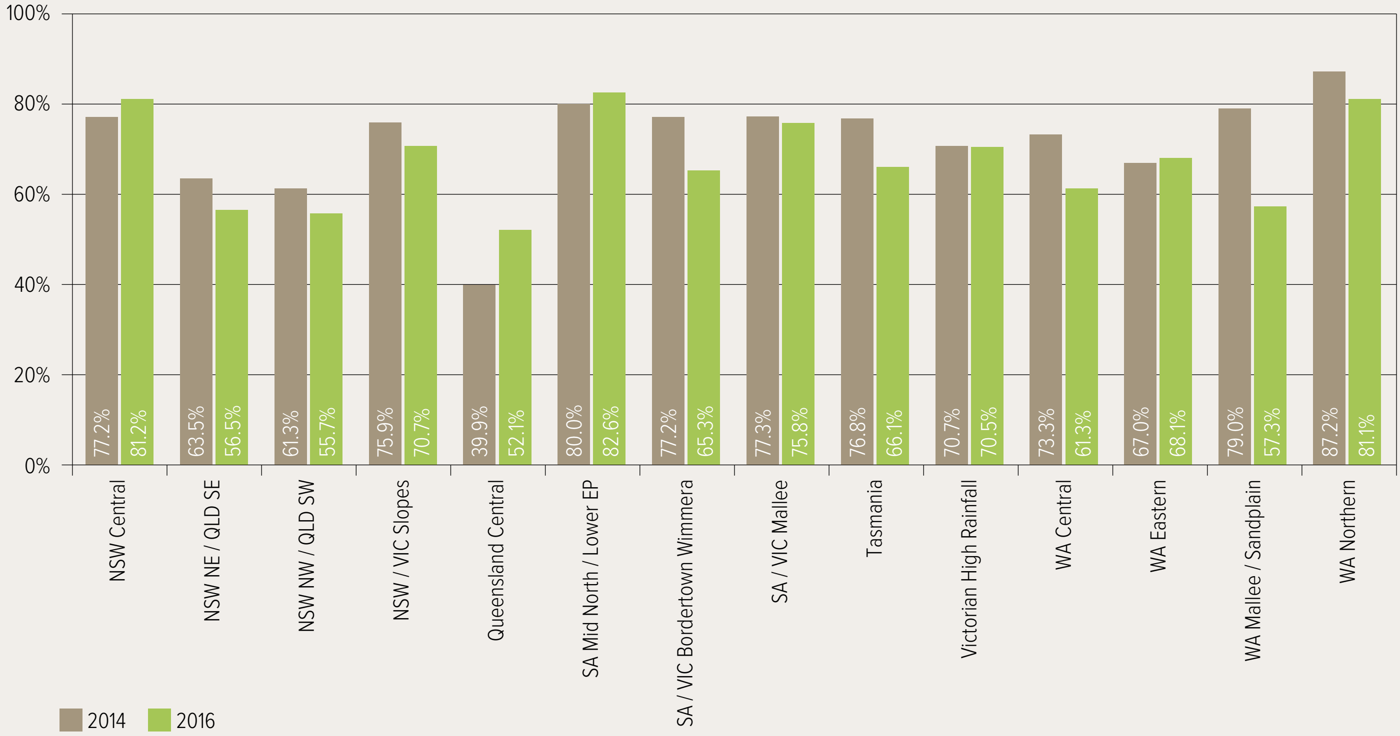
Grower respondents in 2016 were asked about how much of their cropping program had the fertiliser program informed by soil testing. The data are shown in Table 67, Figure 86 and Figure 87.

There continues to appear to be a healthy amount of the crop area where the fertiliser program was informed by soil testing in 2016 (65.0 per cent), only slightly lower than the data for 2014 (67.7 per cent).

TABLE 67 Average percentage of crop area where the fertiliser program was informed by soil testing.

Agro-ecological zone	Average crop area where fertiliser program informed by soil testing (%)				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	41.7	38.9	53.7	69.6		***
NSW NE / QLD SE	50.9	51.9	69.9	73.0		***
NSW NW / QLD SW	34.2	37.0	51.1	37.8		
NSW / VIC Slopes	58.8	60.8	60.7	65.2		
QLD Central	23.9	37.9	72.0	54.9		
SA Mid North / Lower EP	36.3	48.6	55.9	50.7		
SA / VIC Bordertown, Wimmera	40.4	43.5	59.6	69.9		***
SA / VIC Mallee	40.1	39.9	53.5	53.4		
TAS	75.0	77.9	88.9	82.1		
VIC High Rainfall	53.6	54.4	63.7	56.7		
WA Central	67.2	70.9	81.5	83.1		***
WA Eastern	44.8	51.8	76.5	79.7		***
WA Mallee/Sandplain	59.3	76.1	79.7	57.1		
WA Northern	66.3	73.1	81.1	75.9		
NATIONAL AVERAGES	49.5	54.5	67.7	65.0		

FIGURE 88 Average percentage of crop area treated with fertiliser at rates based on estimates of nutrient removal rates by the crop.



There have been some increases in the use of soil testing for fertiliser programs, notably in NE NSW/SE Queensland, and central Queensland, SA/Victoria Bordertown /Wimmera, although in other AEZs the area has decreased or remained stable.

The results for this measure are considerably higher than that for the use of soil testing per se (Table 65), where less than 30 per cent of the cropped area was reported to have been soil tested in 2016. It is possible that while growers report that the fertiliser program for a considerable proportion of their crop was informed by soil testing, carried out in this year, and could be by referring to previous soil tests, in conjunction with knowledge of crop performance since that test, as being used in a fertiliser budgeting approach.

FIGURE 87 Average percentage of crop area where the fertiliser program in 2016 was informed by soil testing.

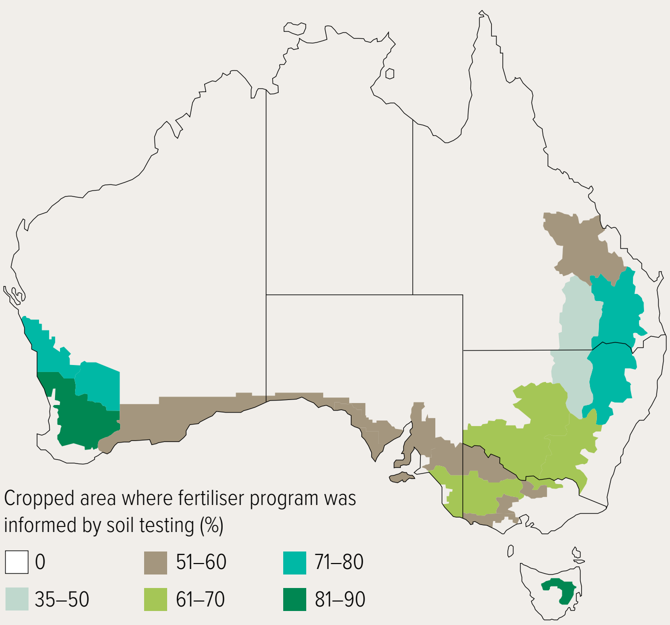
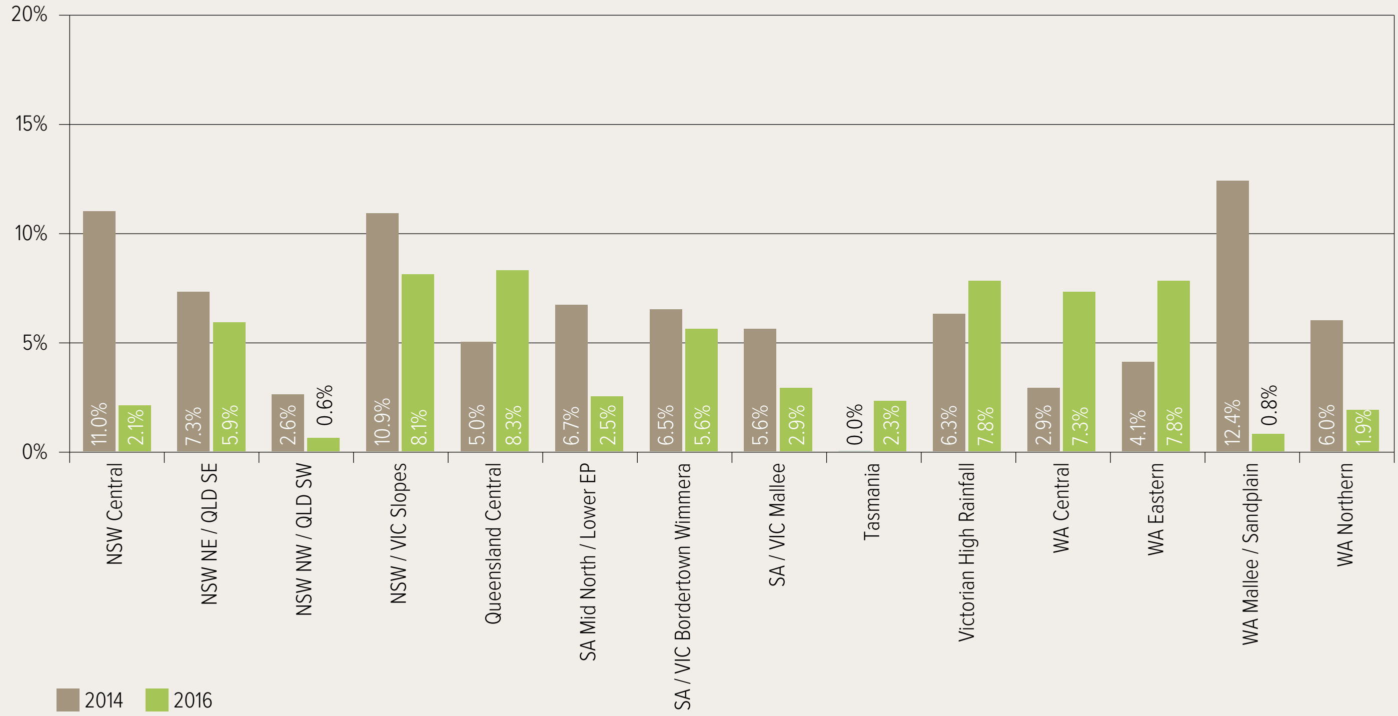


TABLE 68 Average percentage of crop area treated with fertiliser at rates based on estimates of nutrient removal rates by the crop.

Agro-ecological zone	Average crop area treated with fertiliser based on nutrient removal estimates (%)		Significant difference between years
	2014	2016	
NSW Central	77.2	81.2	
NSW NE / QLD SE	63.5	56.5	
NSW NW / QLD SW	61.3	55.7	
NSW / VIC Slopes	75.9	70.7	
QLD Central	39.9	52.1	
SA Mid North / Lower EP	80.0	82.6	
SA / VIC Bordertown, Wimmera	77.2	65.3	
SA / VIC Mallee	77.3	75.8	
TAS	76.8	66.1	
VIC High Rainfall	70.7	70.5	
WA Central	73.3	61.3	**
WA Eastern	67.0	68.1	
WA Mallee/Sandplain	79.0	57.3	
WA Northern	87.2	81.1	
NATIONAL AVERAGES	71.9	67.4	

FIGURE 89 Average percentage of crop area having an in-season soil test.



In any case, there appears to be evidence that growers are using soil tests (whenever these are carried out) to assist with their fertiliser program.

Average percentage of crop area where fertiliser rates applied in 2016 were based on estimates of nutrient removal by the crop

Within the survey growers were asked over what proportion of their cropped area in 2016 was the fertiliser program informed by estimates of nutrient removal rates by the crop (generally the crop in 2015, with estimates of crop needs in 2016).

The data (Table 68 and Figure 88) shows that a relatively high proportion of the crop has fertiliser usage informed by estimates of nutrient removal from the current and previous crops, averaging 67.4 per cent nationally, and higher in some AEZs (for example, some of SA and WA, and NSW Central).

When considered in conjunction with the measure detailed in the previous section (i.e. where fertiliser program was reported as being informed by soil test data), it is likely that growers are developing their fertiliser program based on a combination of soil tests (even if done in the recent past) in combination with estimates of nutrient removal by crop performance leading up to this year, perhaps with estimates for crop need in 2016. This suggests a strong adoption of the practice of using various tools and calculations to determine fertiliser needs, including soil testing, and estimates of nutrient needs based on historic and expected crop performance.

This may assist with explaining the decline in the crop area reported as being soil tested in 2016, whereby growers may be using soil test results from previous tests, and also estimating nutrient needs based on crop performance, in place of a sole reliance on soil testing in the crop year.

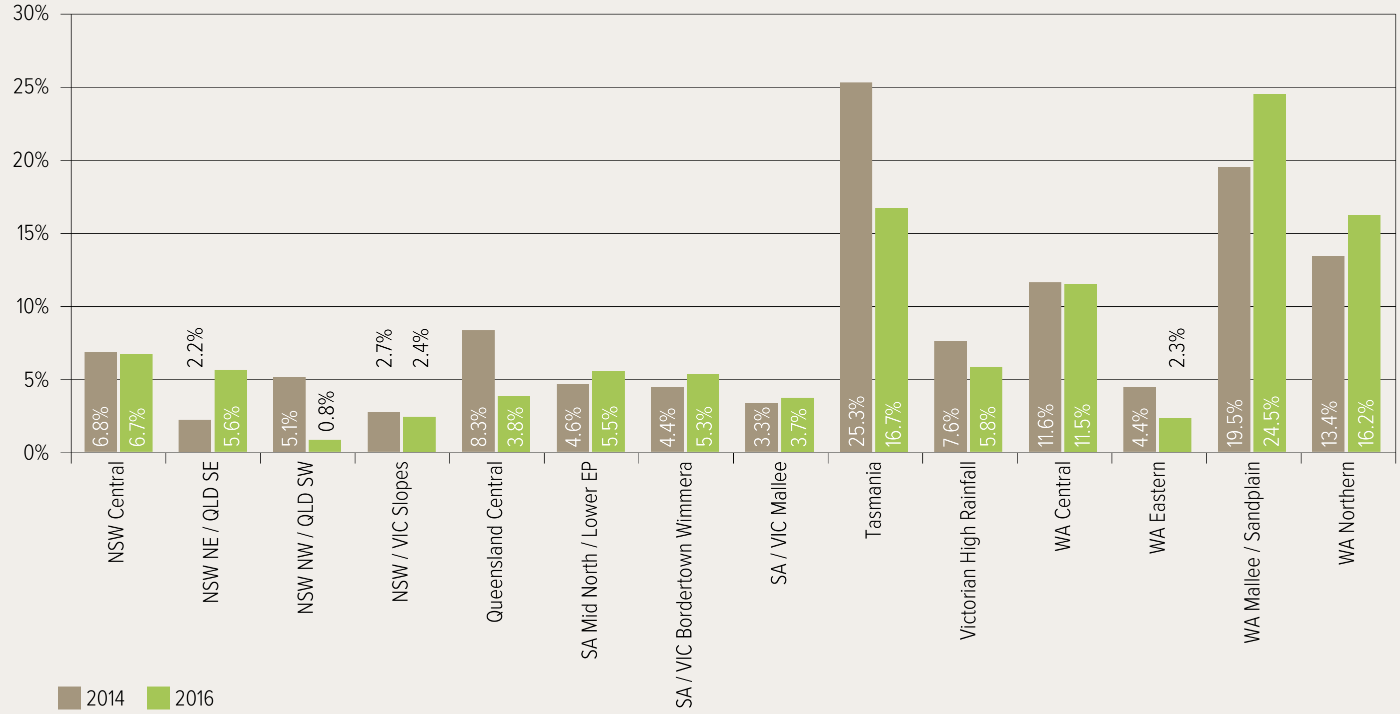
Average percentage of crop area having an in-season soil test in 2016

Some growers undertake soil testing during the season in the interests of informing their in-season fertiliser program. The data for the 2016 survey (Table 69 and Figure 89) shows that only 4.6 per cent of the cropped area is soil tested in-season, with this declining further since 2014 (6.2 per cent).

TABLE 69 Average percentage of crop area having an in-season soil test in 2014 and 2016.

Agro-ecological zone	Average crop area in-season soil tested (%)		Significant difference between years
	2014	2016	
NSW Central	11.0	2.1	**
NSW NE / QLD SE	7.3	5.9	
NSW NW / QLD SW	2.6	0.6	
NSW / VIC Slopes	10.9	8.1	
QLD Central	5.0	8.3	
SA Mid North / Lower EP	6.7	2.5	
SA / VIC Bordertown, Wimmera	6.5	5.6	
SA / VIC Mallee	5.6	2.9	
TAS	0.0	2.3	
VIC High Rainfall	6.3	7.8	
WA Central	2.9	7.3	
WA Eastern	4.1	7.8	
WA Mallee/Sandplain	12.4	0.8	**
WA Northern	6.0	1.9	
NATIONAL AVERAGES	6.2	4.6	

FIGURE 90 Average percentage of crop area having a leaf or petiole test.



When it comes to determining in-season fertiliser needs many growers consider soil moisture levels at least as much as soil nutrient status, which may help explain the data reported here, since 2016 in a general sense was a good rainfall year across much of Australia.

Average percentage of crop area with plant testing in 2016

Other tools available for growers to use in assessing the need for in-season fertiliser applications are leaf and/or petiole testing (plant testing), which can assist by providing data about plant nutrient

TABLE 70 Average percentage of crop area having a leaf or petiole test.

Agro-ecological zone	Average crop area with leaf or petiole test (%)		Significant difference between years
	2014	2016	
NSW Central	6.8	6.7	
NSW NE / QLD SE	2.2	5.6	**
NSW NW / QLD SW	5.1	0.8	
NSW / VIC Slopes	2.7	2.4	
QLD Central	8.3	3.8	
SA Mid North / Lower EP	4.6	5.5	
SA / VIC Bordertown, Wimmera	4.4	5.3	
SA / VIC Mallee	3.3	3.7	
TAS	25.3	16.7	
VIC High Rainfall	7.6	5.8	
WA Central	11.6	11.5	
WA Eastern	4.4	2.3	
WA Mallee/Sandplain	19.5	24.5	
WA Northern	13.4	16.2	
NATIONAL AVERAGES	8.5	7.9	

FIGURE 91 Average percentage of crop area having a leaf or petiole test in 2016.

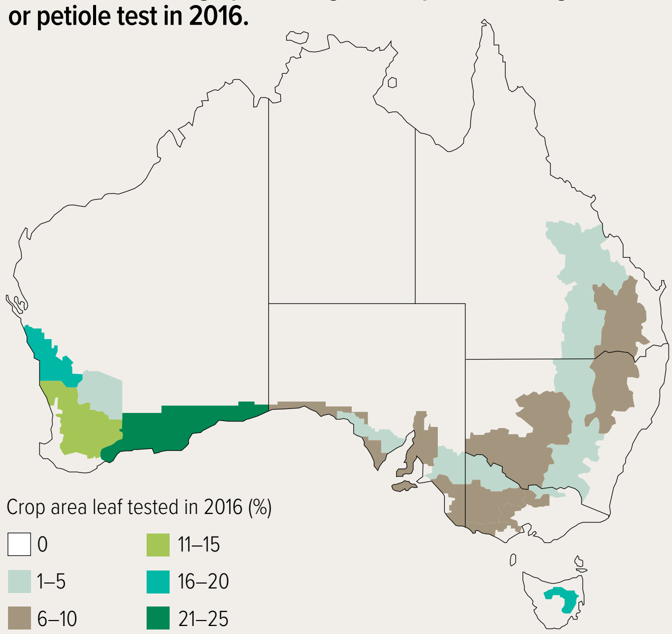


FIGURE 92 Average percentage of crop area having an in-season application or top-dressing of fertiliser.

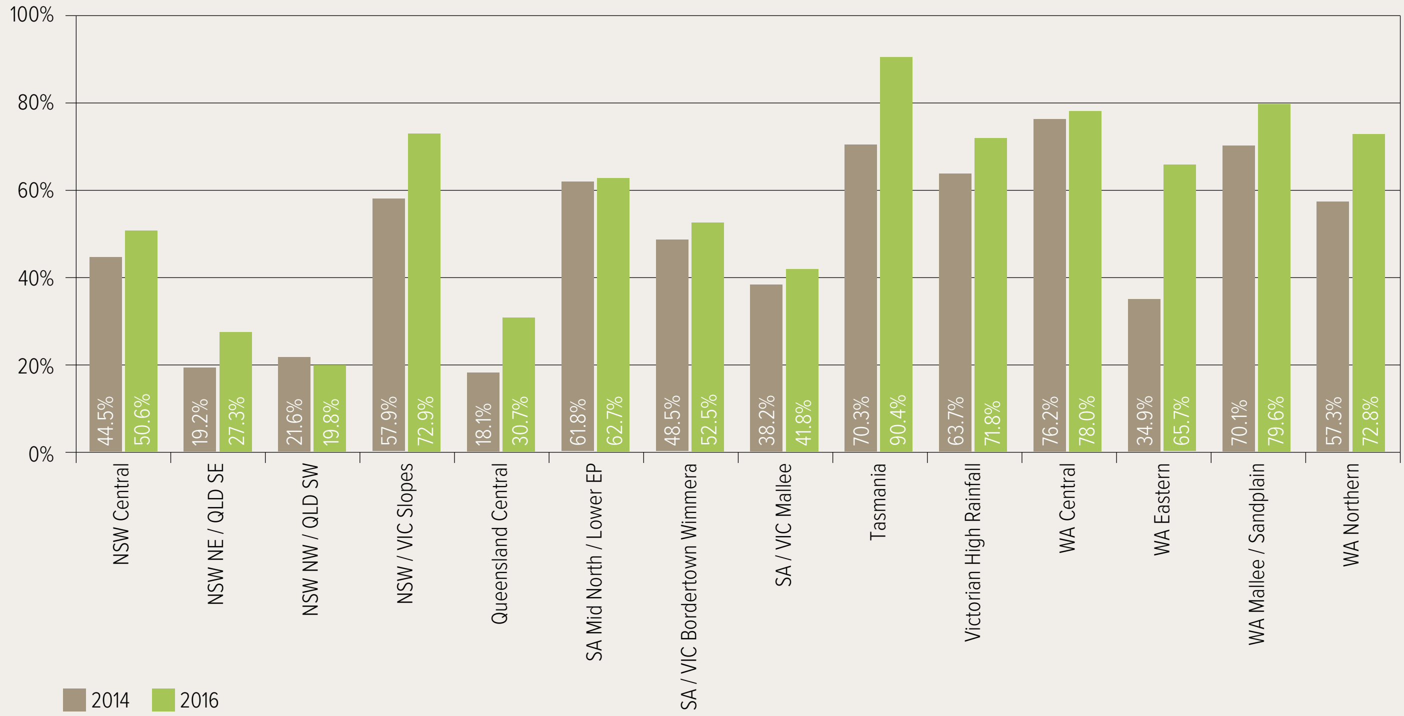


TABLE 71 Average percentage of crop area having an in-season application or top-dressing of fertiliser.

Agro-ecological zone	Average crop area given in-season fertiliser application (%)		Significant difference between years
	2014	2016	
NSW Central	44.5	50.6	
NSW NE / QLD SE	19.2	27.3	**
NSW NW / QLD SW	21.6	19.8	
NSW / VIC Slopes	57.9	72.9	***
QLD Central	18.1	30.7	
SA Mid North / Lower EP	61.8	62.7	
SA / VIC Bordertown, Wimmera	48.5	52.5	
SA / VIC Mallee	38.2	41.8	
TAS	70.3	90.4	
VIC High Rainfall	63.7	71.8	
WA Central	76.2	78.0	
WA Eastern	34.9	65.7	***
WA Mallee/Sandplain	70.1	79.6	
WA Northern	57.3	72.8	**
NATIONAL AVERAGES	48.7	58.3	

levels from testing plant sap from leaves or petioles. The data for the proportion of the crop area using these tools in 2016 are presented in Table 70, Figure 90 and Figure 91, and suggest that these tools are used nationally on only 7.9 per cent of the cropped area, with this being lower than the result for 2014 (8.5 per cent).

The use of leaf and petiole tests remains relatively strong in much of WA, which may be related to the use of foliar fertiliser and trace element applications commonly used in WA.

Average percentage of crop area receiving an in-season application (top-dressing) of fertiliser in 2016

Survey respondents were asked how much of their crop program in 2016 received an in-season, or top-dressing, application of fertiliser. The data (Table 71 and Figure 92) shows that nationally 58.3 per cent of the cropped area received an in-season application of fertiliser in 2016, with this lower in the GRDC northern region, and higher in the NSW/Victorian Slopes, the high-rainfall areas of Victoria, parts of SA and much of WA.

There is likely some relationship between seasonal conditions (principally rainfall and soil moisture levels) and in-season fertiliser applications that would be a significant factor in growers choosing to apply top-dressing fertiliser, with these data suggesting that the generally good seasonal rainfall in 2016 may have been a stronger influencer on fertiliser use than in-season soil or plant testing.

Soil moisture management in 2016

Soil moisture is often the greatest limiting resource for crop production in Australia. Soil moisture levels determine how well crops germinate, establish and grow, and from a management viewpoint, how well crops can respond to additional inputs or management (fertiliser, weed and disease-control measures).

Two questions were asked in 2016 regarding the assessment of soil moisture at planting and through the crop's life:

- What area of your crop did you assess soil moisture at planting?
- What area of your crop did you measure or assess soil moisture through the season?

Assessment of soil moisture at planting to assist in crop decisions

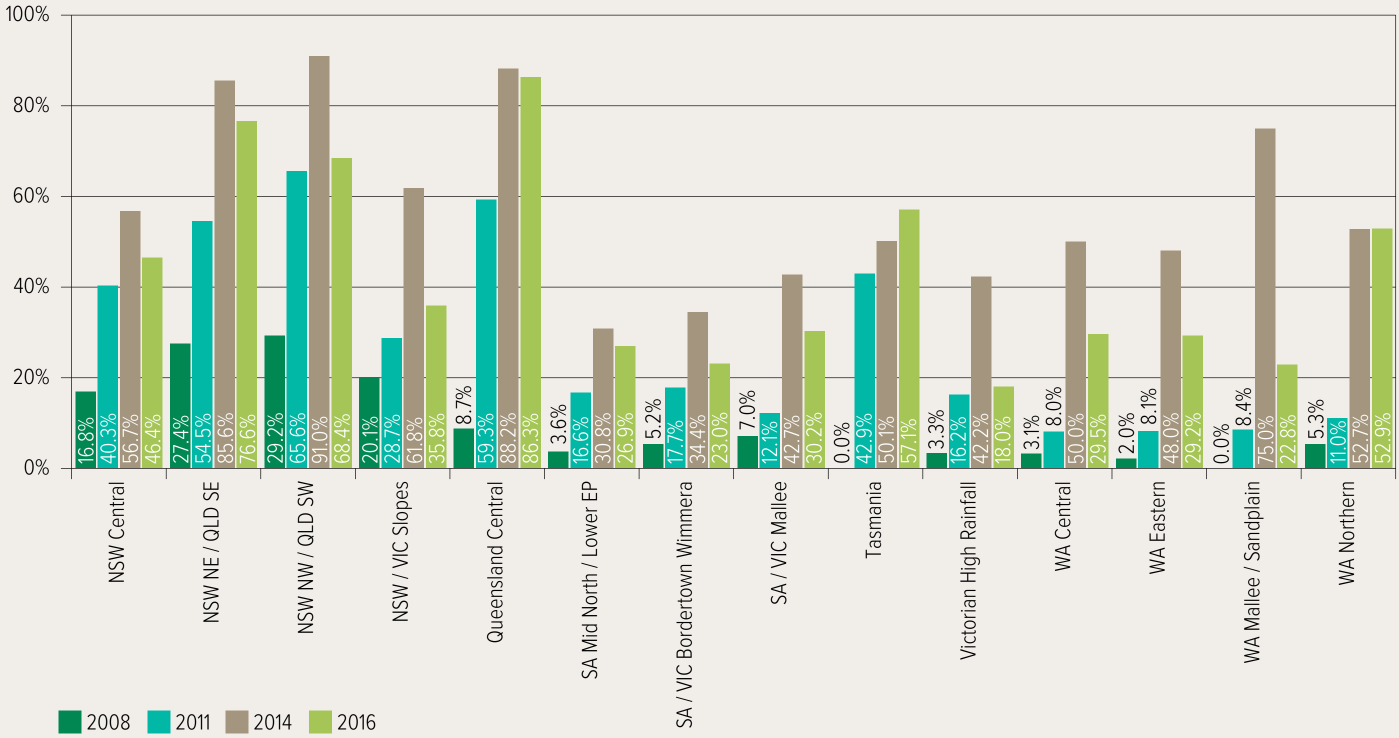
Knowing the level of soil moisture when planning or carrying out management decisions is seen as an important element in a cropping program, both at planting and through the period of the crop.

Assessing soil moisture at planting was more highly practised in NSW and southern Queensland than elsewhere in previous surveys. This trend remains, although this practice is now more common generally in crop production in most AEZs.

TABLE 72 Average percentage of crop area where plant-available water was assessed at planting.

Agro-ecological zone	Average crop area where PAW assessed at planting (%)				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	16.8	40.3	56.7	46.4		
NSW NE / QLD SE	27.4	54.5	85.6	76.6	**	***
NSW NW / QLD SW	29.2	65.6	91.0	68.4	***	
NSW / VIC Slopes	20.1	28.7	61.8	35.8	***	
QLD Central	8.7	59.3	88.2	86.3		***
SA Mid North / Lower EP	3.6	16.6	30.8	26.9		**
SA / VIC Bordertown, Wimmera	5.2	17.7	34.4	23.0		
SA / VIC Mallee	7.0	12.1	42.7	30.2	**	***
TAS	0.0	42.9	50.1	57.1		
VIC High Rainfall	3.3	16.2	42.2	18.0	***	
WA Central	3.1	8.0	50.0	29.5	***	***
WA Eastern	2.0	8.1	48.0	29.2		**
WA Mallee/Sandplain	0.0	8.4	75.0	22.8	***	
WA Northern	5.3	11.0	52.7	52.9		***
NATIONAL AVERAGES	9.4	27.8	57.8	43.1		

FIGURE 93 Average percentage of crop area where plant-available water was assessed at planting.



A significant increase in the proportion of crop area where plant-available water is measured at planting has occurred since 2008 and can be seen to have peaked in 2014. The data from the 2016 survey suggest this practice remains well adopted, although at a lower level than in 2014 (Table 72, Figure 93 and Figure 94).

Proportion of crop where plant-available water was assessed through the crop period

The practice of assessing soil moisture through the crop season is one that can assist with strategic decisions, including the application of in-crop fertilisers (for example, nitrogen – refer to the section on fertiliser use, notably the data on in-crop fertiliser applications) and some insecticide or herbicide applications.

TABLE 73 Average percentage of crop area where soil moisture was measured or assessed through the season.

Agro-ecological zone	Average crop area where soil moisture assessed through the season (%)				Significant difference between years	
	2008	2011	2014	2016	2014 to 2016	2011 to 2016
NSW Central	11.5	32.5	37.5	24.8	**	
NSW NE / QLD SE	18.0	33.8	47.1	46.1	**	**
NSW NW / QLD SW	18.5	46.9	60.0	39.5		
NSW / VIC Slopes	19.2	29.4	44.3	20.9	***	
QLD Central	0.0	37.4	45.9	44.8		
SA Mid North / Lower EP	2.4	17.9	17.0	13.0		
SA / VIC Bordertown, Wimmera	4.0	18.3	17.0	13.9		
SA / VIC Mallee	2.8	12.4	18.3	13.4		
TAS	0.0	40.0	52.2	57.1		
VIC High Rainfall	6.0	13.3	22.5	12.2		
WA Central	3.0	17.5	24.9	14.8	**	
WA Eastern	0.9	10.2	31.2	6.8	***	
WA Mallee/Sandplain	1.5	20.7	35.6	17.2		
WA Northern	5.5	21.1	27.8	19.2		
NATIONAL AVERAGES	6.7	25.1	34.4	24.6		

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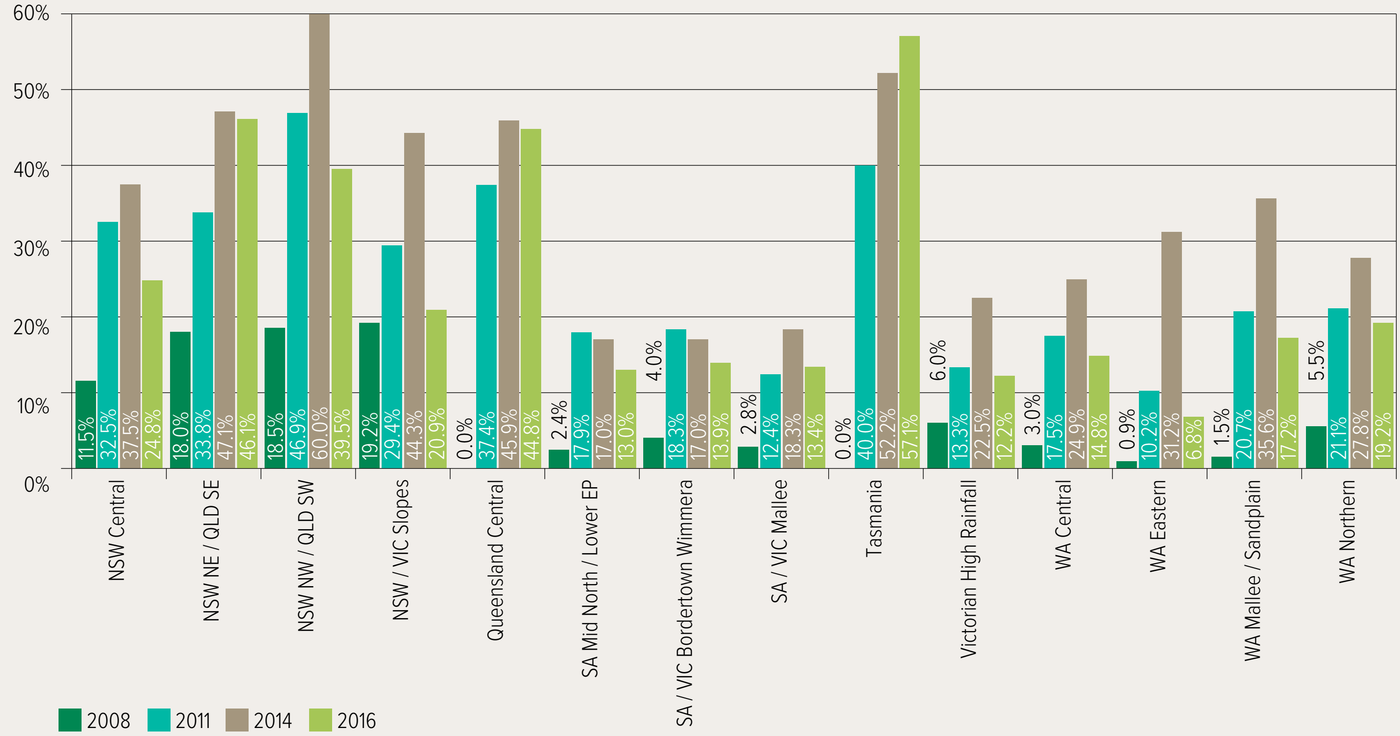
FIGURE 95 Average percentage of crop area where soil moisture was measured or assessed through the season.



Combined with information on soil moisture at planting, this can assist with these and other crop management practices and gives producers confidence for some strategic marketing decisions.

The proportion of the crop area where soil moisture is being assessed through the crop period had increased substantially in 2014, but appears to have reverted to similar levels as it was in 2011. The change in the use of this practice appears to be in almost all AEZs, though the extent does vary.

Measuring soil moisture through the season is still more used in the GRDC Northern Region (Table 73, Figure 95 and Figure 96).

FIGURE 94 Percentage of crop area where plant-available water was assessed at planting in 2016.

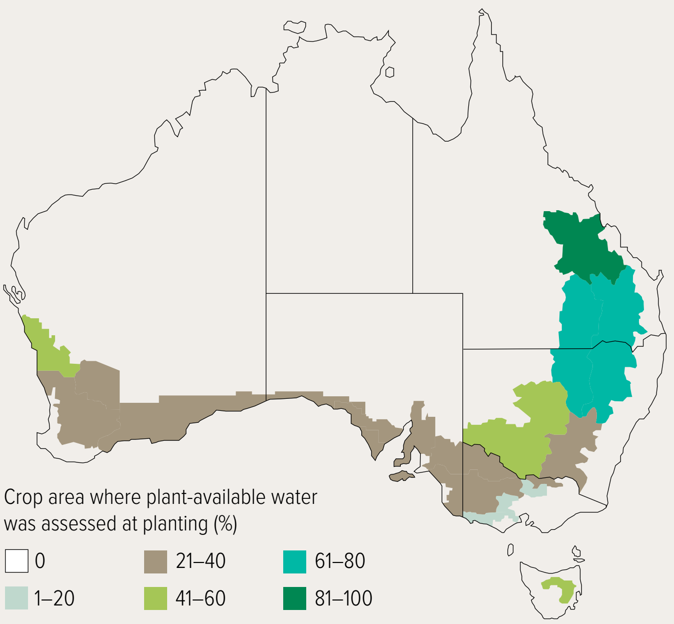
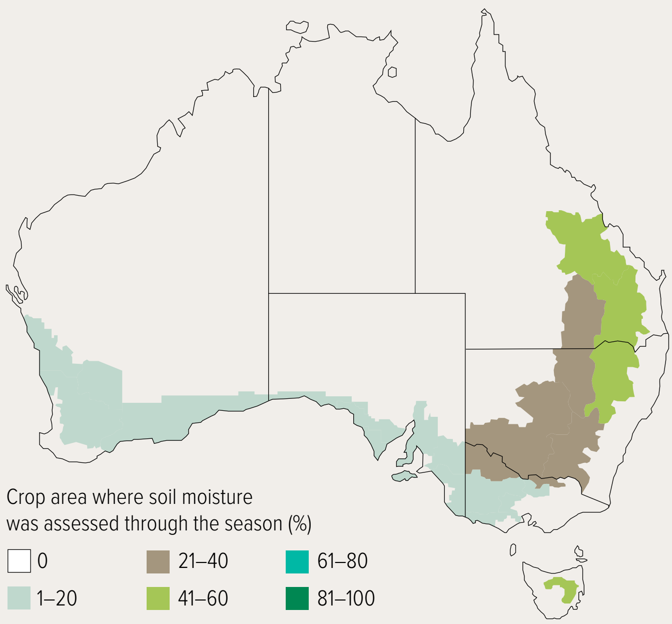


FIGURE 96 Percentage of crop area where soil moisture was assessed though.



Miscellaneous questions in 2016

Several questions were included in the survey of 2016 which were of a miscellaneous nature. These included:

- How many tonnes of grain can you store on-farm?
- What area of your farm has been tested for soil nematodes in the past five years?
- What area of your farm do you have where you know you have herbicide-resistant weeds?
- What area of your fallow have you used the 'Double Knock' herbicide technique for the management of weeds?
- What area have you used the double knock technique where tillage was the second knock used in the fallow period?
- On what area where you have used non-herbicide techniques to help the management of herbicide-resistant weeds, for example, tillage or grazing, or the use of harvest weed-seed control techniques?
- On what area of your fallow have used residual herbicides?
- What's your best estimate of the area of your crop where you've used Group A herbicides?
- What's your best estimate of the area of your crop where you've used Group B herbicides?
- Are you using some kind of Quality or Environmental Assurance Program that assists in market access or price?

Average grain storage capacity on farms in 2016

On-farm grain storage capacity as reported by growers in the 2016 survey is shown in Table 74 and Figure 97.

The survey data shows that on-farm grain storage capacity nationally has increased from an average of 1353 tonnes per farm in 2008 to 1555t in 2016. The largest on-farm storage capacities per farm are in the GRDC northern region, where many growers can store more than 4000 tonnes on-farm.

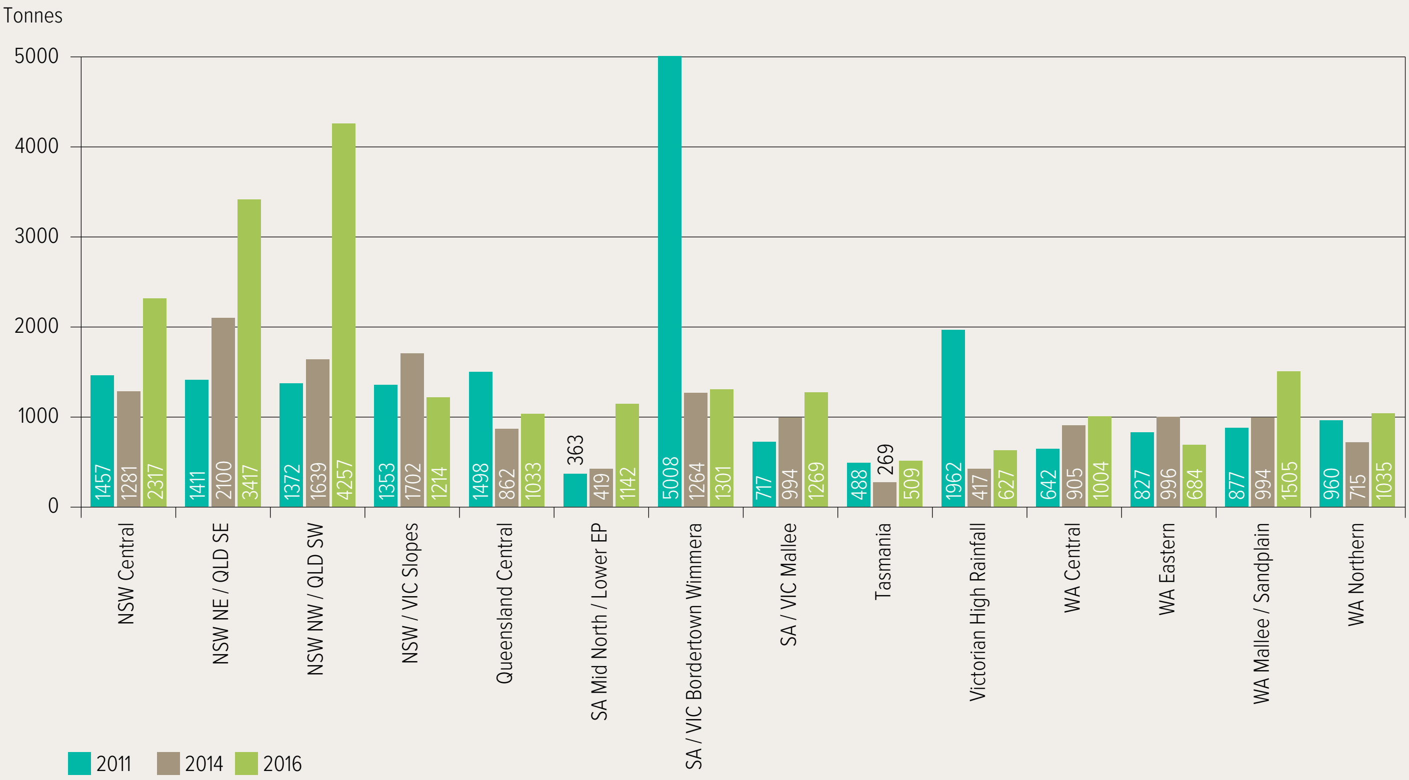
Average percentage of farm area tested for presence of nematodes in the past 5 years

Soil-borne, parasitic nematodes can cost growers crop yield. DNA-based soil testing is available (for example, Predicta® B), and growers were asked how much of their crop area they had tested for nematodes over the past five years. The data (Table 75

TABLE 74 Average tonnes of grain that can be stored on-farm.

Agro-ecological zone	On-farm grain storage capacity (tonnes)			Significant difference between years
	2008	2014	2016	2014 to 2016
NSW Central	1457	1281	2317	
NSW NE / QLD SE	1411	2100	3417	
NSW NW / QLD SW	1372	1639	4257	
NSW / VIC Slopes	1353	1702	1214	
QLD Central	1498	862	1033	
SA Mid North / Lower EP	363	419	1142	**
SA / VIC Bordertown, Wimmera	5008	1264	1301	
SA / VIC Mallee	717	994	1269	
TAS	488	269	509	
VIC High Rainfall	1962	417	627	
WA Central	642	905	1004	
WA Eastern	827	996	684	
WA Mallee/Sandplain	877	994	1505	
WA Northern	960	715	1035	
NATIONAL AVERAGES	1353	1040	1522	

FIGURE 97 Average tonnes of grain that can be stored on-farm.



and Figure 98), shows a relatively minor proportion of the total crop area was tested for the presence of soil-borne nematodes in the past five years, apart from some area in northern NSW and Queensland, the high-rainfall areas of Victoria and southern WA.

In general, the amount of nematode testing has remained similar to what was reported in 2014.

Average percentage of farm area known to be affected by herbicide-resistant weeds

In 2016 survey respondents were asked what percentage of their farm was affected by herbicide-resistant weeds. The data (Table 76 and Figure 99) shows that in some AEZs herbicide-resistant weeds are known to occupy well over 20 per cent of the farm area (for example, much of SA and central, eastern and northern WA).

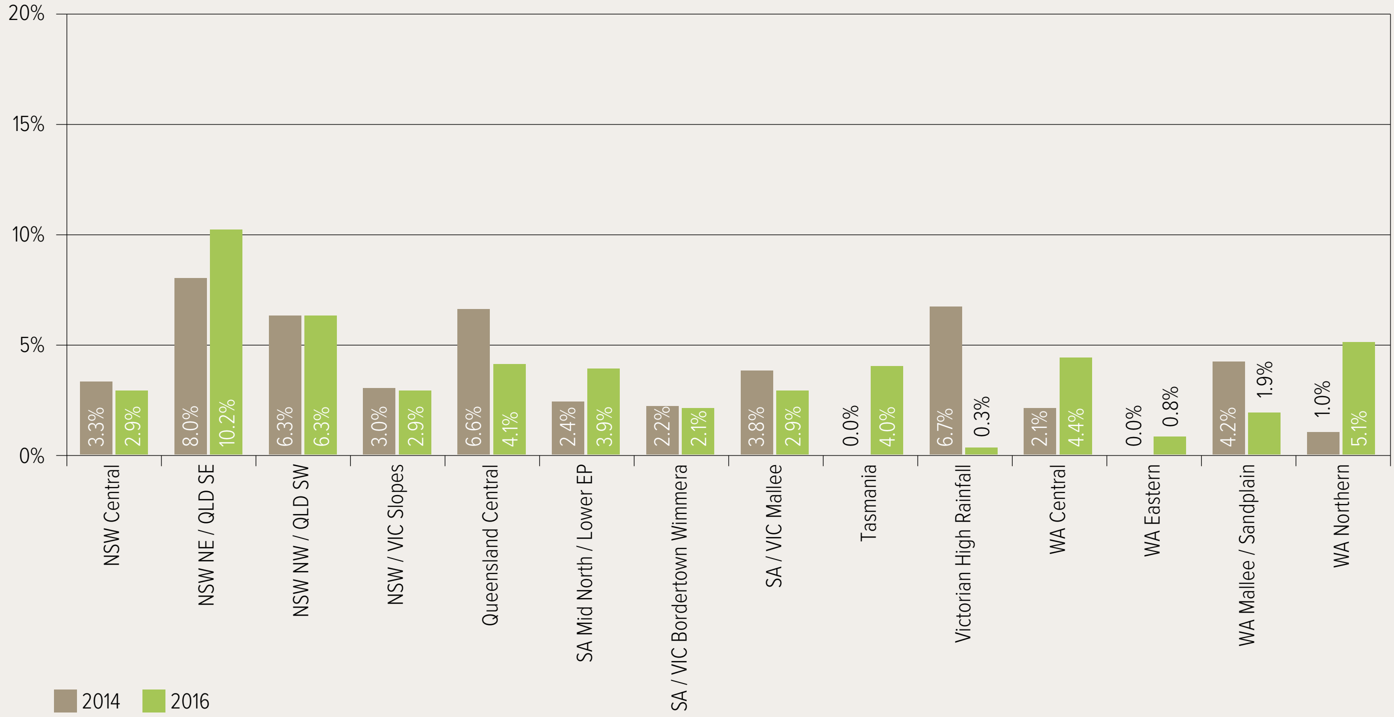
TABLE 75 Average percentage of farm area tested for nematodes in the past five years.

Agro-ecological zone	Average farm area tested for nematodes in past 5 years (%)		Significant difference between years
	2014	2016	
NSW Central	3.3	2.9	
NSW NE / QLD SE	8.0	10.2	
NSW NW / QLD SW	6.3	6.3	
NSW / VIC Slopes	3.0	2.9	
QLD Central	6.6	4.1	
SA Mid North / Lower EP	2.4	3.9	
SA / VIC Bordertown, Wimmera	2.2	2.1	
SA / VIC Mallee	3.8	2.9	
TAS	0.0	4.0	
VIC High Rainfall	6.7	0.3	***
WA Central	2.1	4.4	
WA Eastern	0.0	0.8	
WA Mallee/Sandplain	4.2	1.9	
WA Northern	1.0	5.1	
NATIONAL AVERAGES	3.5	3.7	

TABLE 76 Average percentage of farm area known to be affected by herbicide-resistant weeds.

Agro-ecological zone	Average farm area affected by herbicide-resistant weeds (%)		Significant difference between years
	2014	2016	
NSW Central	7.9	12.2	No significant differences
NSW NE / QLD SE	17.7	13.6	
NSW NW / QLD SW	10.5	8.0	
NSW / VIC Slopes	16.7	20.2	
QLD Central	14.4	3.7	
SA Mid North / Lower EP	23.9	27.6	
SA / VIC Bordertown, Wimmera	18.2	23.0	
SA / VIC Mallee	10.8	14.4	
TAS	8.6	4.4	
VIC High Rainfall	15.5	16.2	
WA Central	23.1	26.2	
WA Eastern	14.8	24.7	
WA Mallee/Sandplain	11.0	11.0	
WA Northern	34.0	24.5	
NATIONAL AVERAGES	16.2	16.4	

FIGURE 98 Average percentage of farm area tested for nematodes in the past five years.



While nationally any increase in the reported area of herbicide-resistant weeds is minor, there are some notable increases in some AEZs, such as the NSW/Victorian Slopes, all of SA, and central and eastern WA. In contrast, a decrease was reported in northern WA.

TABLE 77 Average percentage of crop area planted to assist with weed competition (e.g. higher seeding rate or narrower row spacing) in 2016.

Agro-ecological zone	Average crop area planted to compete more against weeds (%) 2016	Significant difference between AEZs
NSW Central	20.8	
NSW NE / QLD SE	25.7	
NSW NW / QLD SW	21.2	
NSW / VIC Slopes	26.9	
QLD Central	33.5	
SA Mid North / Lower EP	24.9	
SA / VIC Bordertown, Wimmera	29.0	
SA / VIC Mallee	16.1	
TAS	0.0	
VIC High Rainfall	29.2	
WA Central	36.3	
WA Eastern	17.6	
WA Mallee/Sandplain	33.0	
WA Northern	14.6	
NATIONAL AVERAGES	23.5	

Average percentage of crop area planted in such a way to assist with weed competition

In 2016 survey respondents were asked what percentage of their crop they had planted in such a way as to assist with providing competition against weeds. Techniques can include higher seeding rates, narrower row spacing, or banding fertiliser directly beneath crop seeds rather than more widely.

TABLE 78 Average percentage of fallow area where the double-knock herbicide technique has been used.

Agro-ecological zone	Average fallow area where double-knock used (%)		Significant difference between years
	2014	2016	
NSW Central	19.4	28.0	
NSW NE / QLD SE	31.5	36.4	
NSW NW / QLD SW	25.3	17.8	
NSW / VIC Slopes	31.4	31.8	
QLD Central	28.7	9.0	
SA Mid North / Lower EP	37.5	33.8	
SA / VIC Bordertown, Wimmera	30.3	32.7	
SA / VIC Mallee	30.7	26.9	
TAS	0.0	33.3	
VIC High Rainfall	36.4	43.7	
WA Central	47.4	66.0	**
WA Eastern	38.1	62.0	
WA Mallee/Sandplain	53.8	74.7	
WA Northern	59.7	54.9	
NATIONAL AVERAGES	33.6	39.4	

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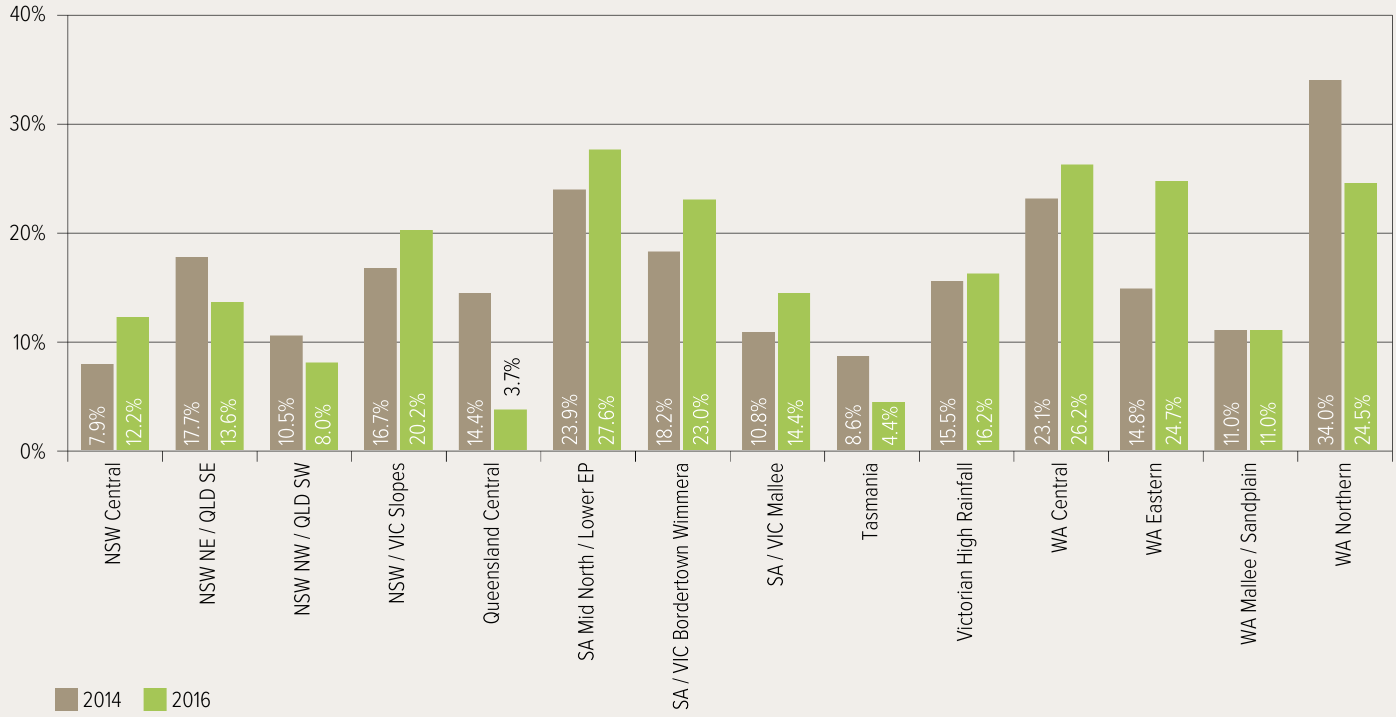
FIGURE 99 Average percentage of farm area known to be affected by herbicide-resistant weeds.



The data (Table 77) shows that more than 23.5 per cent of the cropped area nationally, and more than 30 per cent of the cropped area in Queensland Central, WA Central and WA Mallee/Sandplain, are planted in a way to assist with weed competition.

Average percentage of the fallow area where the double-knock weed management technique has been used

One technique for managing difficult-to-control or suspected herbicide-resistant weeds in fallow is the 'double knock', where weeds receive two treatments separated by several days (for example, 10 days). The first treatment (or 'knock') is usually a

FIGURE 100 Average percentage of fallow area where the double-knock herbicide technique was used in 2014 and 2016.

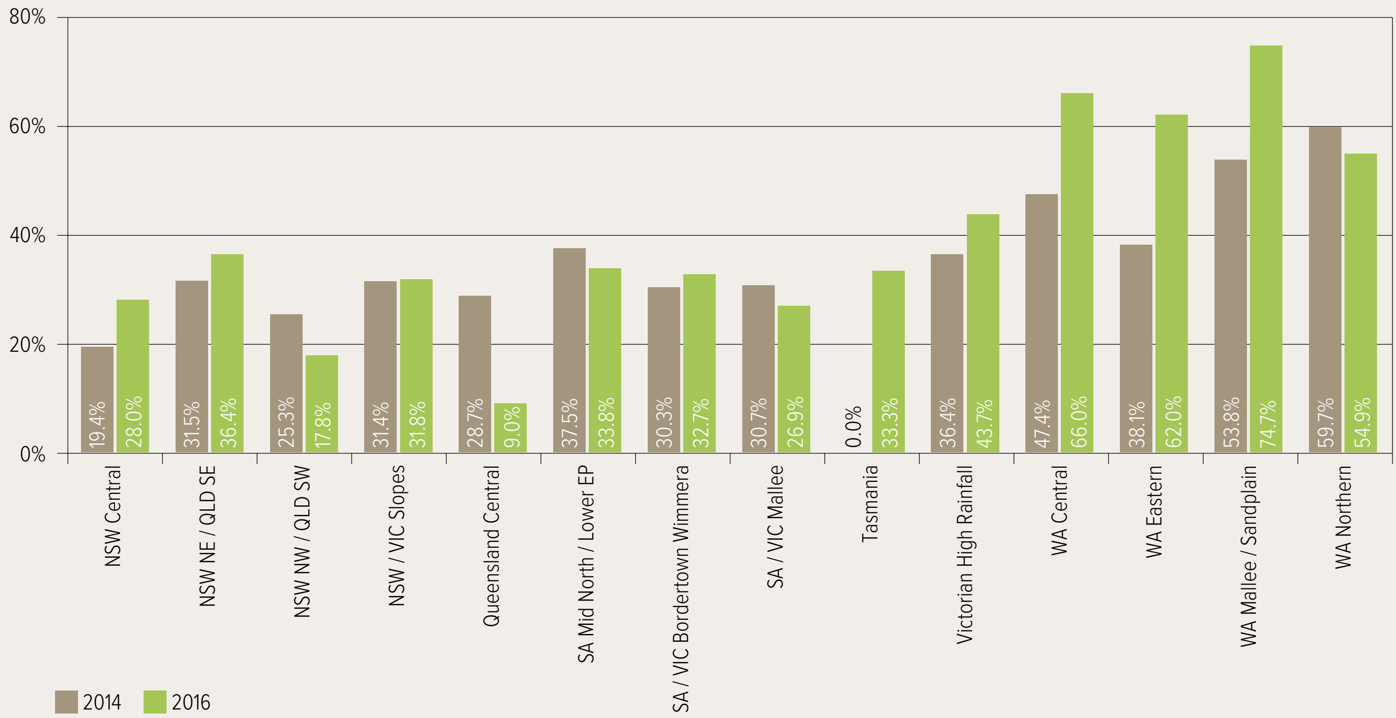
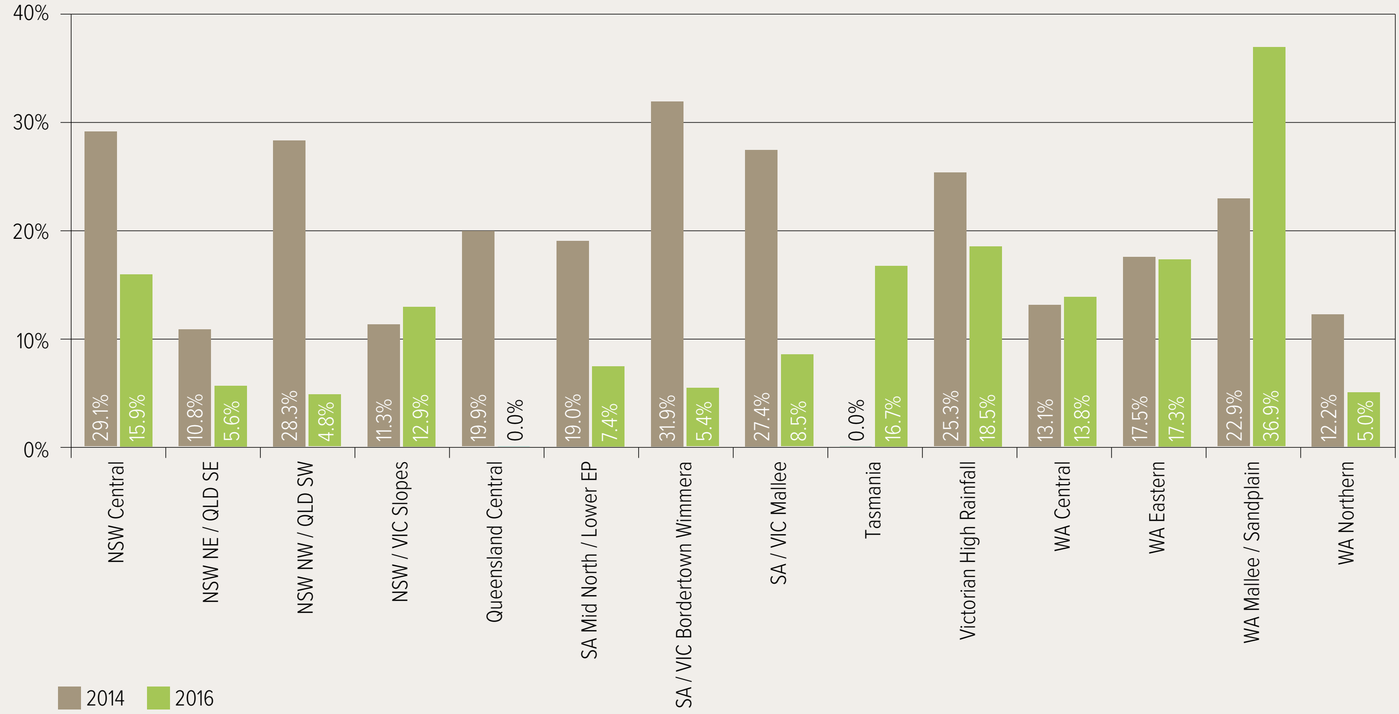


FIGURE 101 Average percentage of fallow area where tillage was used as the second knock in a double knock treatment.



herbicide, often glyphosate (alone or in a tank mix with other herbicides). The second 'knock' can be a different herbicide, generally with an alternative mode of action, or a cultivation with a tillage implement for weed control.

The data for the proportion of the fallow area that was reported as treated in 2014 and 2016 with a double knock, where both knocks were herbicides, is presented in Table 78 and Figure 100.

TABLE 79 Average percentage of fallow area where tillage has been used as the second knock in a double knock.

Agro-ecological zone	Average fallow area where tillage used as second knock (%)		Significant difference between years
	2014	2016	
NSW Central	29.1	15.9	
NSW NE / QLD SE	10.8	5.6	
NSW NW / QLD SW	28.3	4.8	**
NSW / VIC Slopes	11.3	12.9	
QLD Central	19.9	0.0	***
SA Mid North / Lower EP	19.0	7.4	
SA / VIC Bordertown, Wimmera	31.9	5.4	**
SA / VIC Mallee	27.4	8.5	***
TAS		16.7	
VIC High Rainfall	25.3	18.5	
WA Central	13.1	13.8	
WA Eastern	17.5	17.3	
WA Mallee/Sandplain	22.9	36.9	
WA Northern	12.2	5.0	
NATIONAL AVERAGES	20.7	12.1	

Nationally 39.4 per cent of the fallow area had a double herbicide knock used in 2016. The proportion was higher in WA than elsewhere, potentially showing an awareness of this technique and herbicide-resistance management.

It should be noted that in the 2014 survey report, the data presented was calculated as a proportion of total crop area, whereas the data presented here are calculated as a proportion of the fallow area.

The 2014 data presented here are re-calculated on that basis for consistency of comparison.

Average percentage of fallow area where tillage has been the second knock where double knock was used

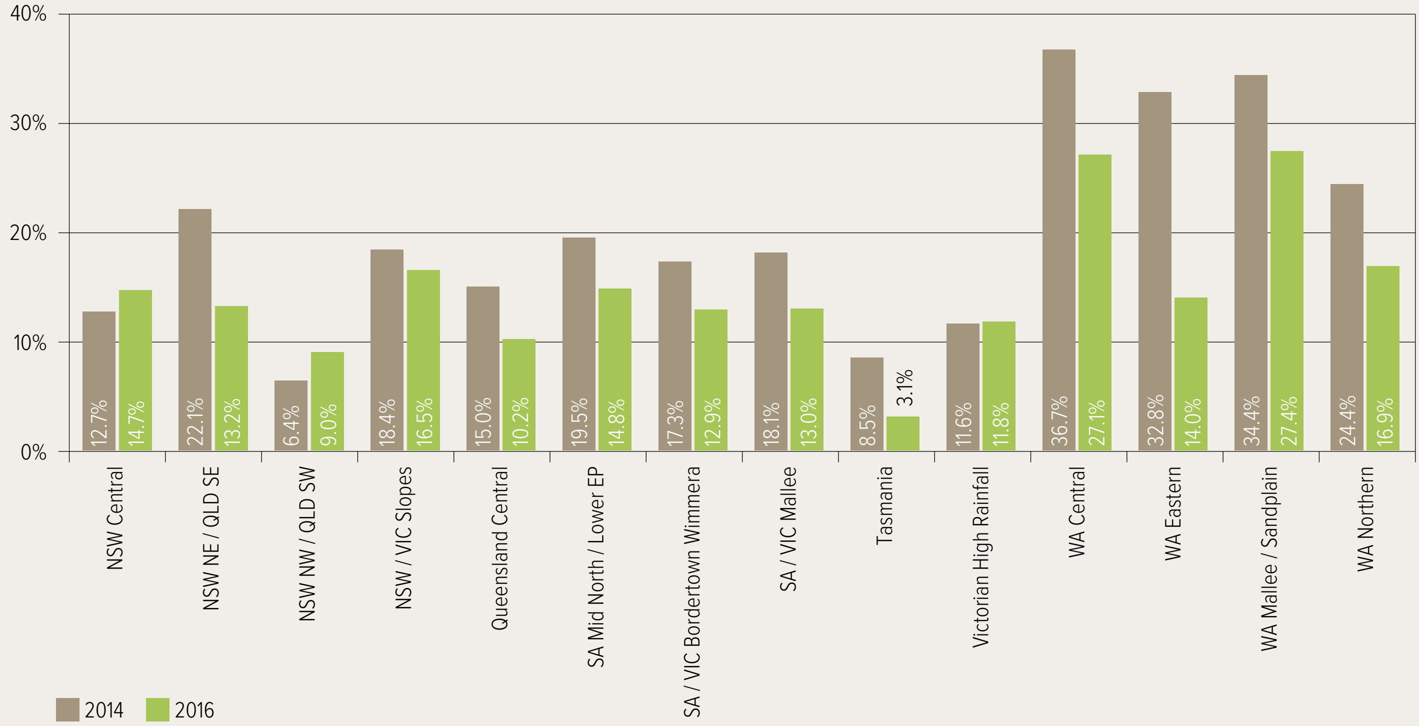
Survey respondents in 2014 and 2016 were asked on what proportion of their fallow area tillage had been used as the second knock where a double knock technique was used for weed control. The data are shown in Table 79 and Figure 101. Nationally 12.1 per cent of the fallow area received tillage as a second knock, down from 2014 (20.7 per cent).

Survey results suggest that growers are most commonly utilising herbicides as the second knock rather than tillage.

Average percentage of farm area where non-herbicide techniques were used for management of herbicide-resistant weeds

Where herbicide-resistant weeds are present (or strongly suspected) the effectiveness of herbicides can be limited, and if used, can potentially increase problems with resistance. Survey respondents were asked to what proportion of their farm area did they apply non-herbicide techniques for weed control in 2014 and 2016. The data (Table 80 and Figure 102) shows that 14.6 per cent

FIGURE 102 Average percentage of farm area where non-herbicide techniques have been used to help management of herbicide-resistant weeds.



of the farm area nationally is treated with non-herbicide techniques for weed control, with the level higher in some individual AEZs, notably in WA. This may not be surprising given that these AEZs in WA also tend to report higher levels of herbicide-resistant weeds being present (see previous section).

TABLE 80 Average percentage of farm area where non-herbicide techniques have been used to help management of herbicide-resistant weeds.

Agro-ecological zone	Average farm area where non-herbicide techniques used to manage resistant weeds (%)		Significant difference between years
	2014	2016	
NSW Central	12.7	14.7	
NSW NE / QLD SE	22.1	13.2	***
NSW NW / QLD SW	6.4	9.0	
NSW / VIC Slopes	18.4	16.5	
QLD Central	15.0	10.2	
SA Mid North / Lower EP	19.5	14.8	
SA / VIC Bordertown, Wimmera	17.3	12.9	
SA / VIC Mallee	18.1	13.0	
TAS	8.5	3.1	
VIC High Rainfall	11.6	11.8	
WA Central	36.7	27.1	***
WA Eastern	32.8	14.0	***
WA Mallee/Sandplain	34.4	27.4	
WA Northern	24.4	16.9	
NATIONAL AVERAGES	19.9	14.6	

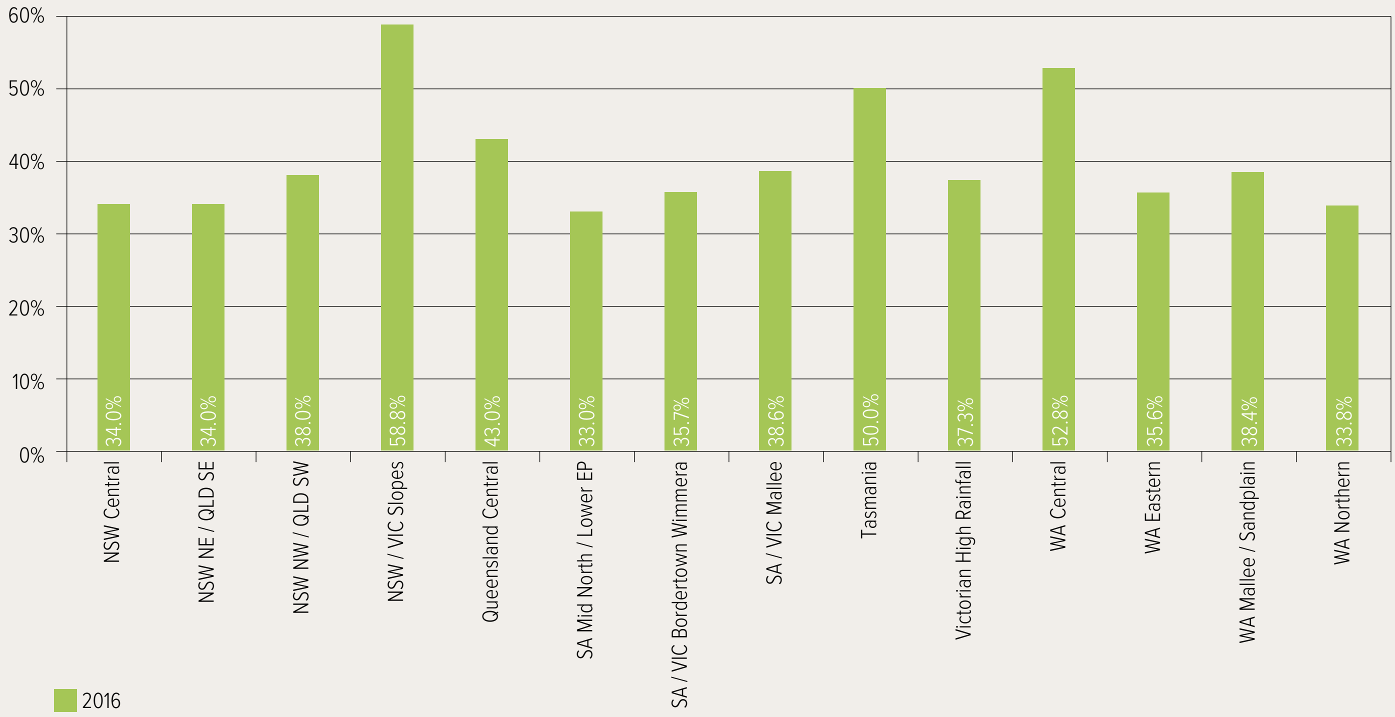
Average percentage of fallow area where residual herbicides have been used

Residual herbicides can be used in fallows to provide protection from weed germinations over a period of time. They can be mixed with knockdown herbicides and can play a role in maintaining weed-free fallows. Survey respondents were

TABLE 81 Average percentage of fallow area where residual herbicides have been used.

Agro-ecological zone	Average fallow area where residual herbicides used (%)		Significant difference between years
	2014	2016	
NSW Central		34.0	
NSW NE / QLD SE		34.0	
NSW NW / QLD SW		38.0	
NSW / VIC Slopes		58.8	
QLD Central		43.0	
SA Mid North / Lower EP		33.0	
SA / VIC Bordertown, Wimmera		35.7	
SA / VIC Mallee		38.6	
TAS		50.0	
VIC High Rainfall		37.3	
WA Central		52.8	
WA Eastern		35.6	
WA Mallee/Sandplain		38.4	
WA Northern		33.8	
NATIONAL AVERAGES		40.2	

FIGURE 103 Average percentage of fallow area where residual herbicides were used in 2016.



asked to what proportion of their fallow areas they applied residual herbicides in 2016. The data (Table 81 and Figure 103) shows that residual herbicides were used on 40.2 per cent of the fallow area nationally. This result appears somewhat questionable, since anecdotally the use of residual herbicides in fallow would not be considered as common as 40 per cent of the fallow area. Further enquiry may clarify this figure.

Average percentage of crop area where Group A herbicides were used in 2016

Herbicides belonging to the Group A mode of action appear to have decreased in their use, from 30.6 per cent of the cropped area in 2014 to 25.2 per cent in 2016 (Table 82 and Figure 104). Their use has significantly declined in the NSW/Victorian Slopes and Victorian high-rainfall AEZs.

TABLE 82 Average percentage of crop area where Group A herbicides were used.

Agro-ecological zone	Average crop area where Group A herbicides applied (%)		Significant difference between years
	2014	2016	
NSW Central	40.9	31.4	
NSW NE / QLD SE	30.8	36.4	
NSW NW / QLD SW	35.9	23.8	
NSW / VIC Slopes	36.9	28.4	***
QLD Central	31.9	18.4	
SA Mid North / Lower EP	31.7	24.6	
SA / VIC Bordertown, Wimmera	29.9	23.5	
SA / VIC Mallee	26.6	23.4	
TAS	30.4	34.8	
VIC High Rainfall	33.7	22.4	**
WA Central	28.8	27.4	
WA Eastern	16.6	14.5	
WA Mallee/Sandplain	29.4	28.1	
WA Northern	25.6	16.3	
NATIONAL AVERAGES	30.6	25.2	

TABLE 83 Average percentage of crop area where Group B herbicides were used.

Agro-ecological zone	Average crop area where Group B herbicides applied (%)		Significant difference between years
	2014	2016	
NSW Central	41.1	36.3	
NSW NE / QLD SE	32.7	33.2	
NSW NW / QLD SW	41.9	36.4	
NSW / VIC Slopes	33.6	30.4	
QLD Central	53.3	31.5	**
SA Mid North / Lower EP	38.8	30.0	**
SA / VIC Bordertown, Wimmera	31.4	27.4	
SA / VIC Mallee	31.3	24.0	**
TAS	8.3	32.7	
VIC High Rainfall	36.8	25.4	
WA Central	41.4	33.7	**
WA Eastern	46.8	39.9	
WA Mallee/Sandplain	39.4	19.2	***
WA Northern	36.4	27.9	
NATIONAL AVERAGES	36.7	30.6	

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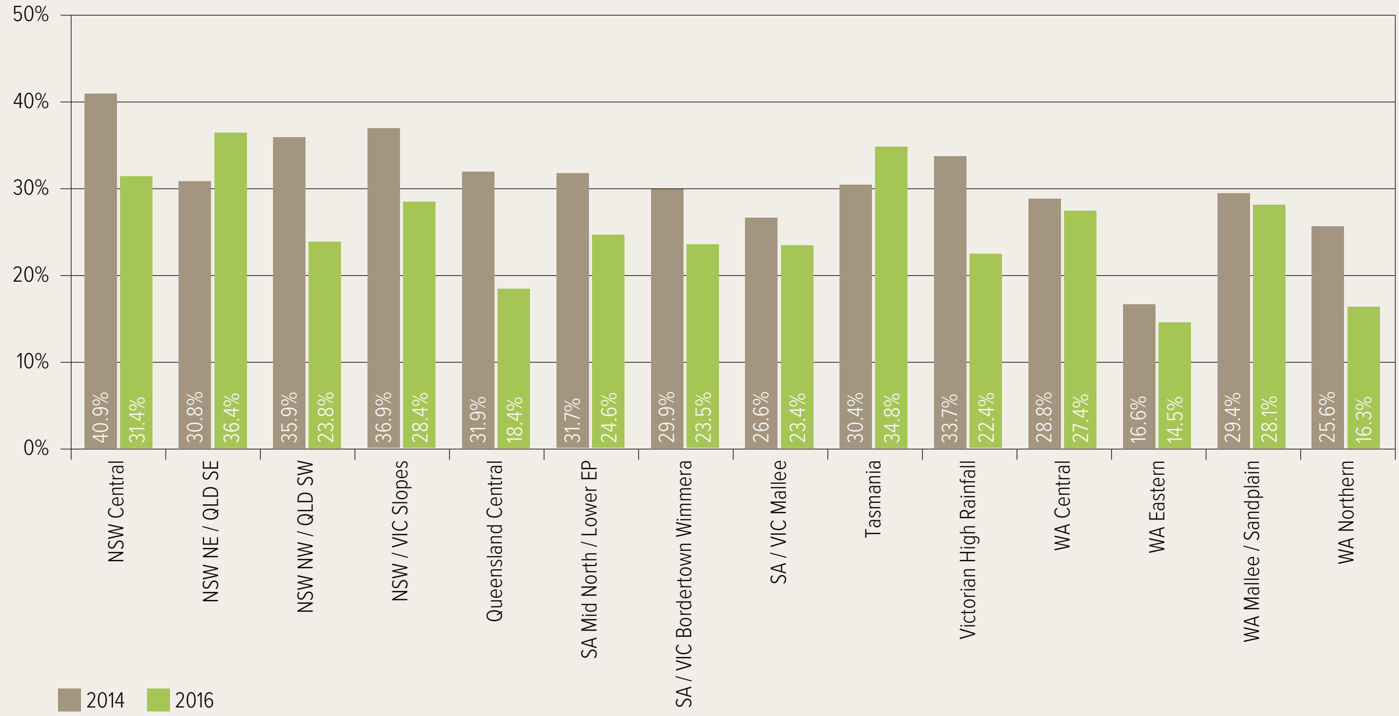
FIGURE 104 Average percentage of crop area where Group A herbicides were used.



Average percentage of crop area where Group B herbicides have been used in 2016

Group B mode of action herbicides have fallen in use from 36.7 per cent of the cropped area in 2014 to 30.6 per cent in 2016 (Table 83 and Figure 105). This decline is statistically significant in some AEZs.

Average percentage of farms with a Quality or Environmental Assurance program that assists in market access or deriving a price premium

In 2014 and 2016 growers were asked if they used a Quality Assurance (QA) or Environmental Assurance (EA) program that they saw as assisting them in market access or in receiving a price premium. The data for the proportion of farms that reported the

FIGURE 105 Average percentage of crop area where Group B herbicides were used.

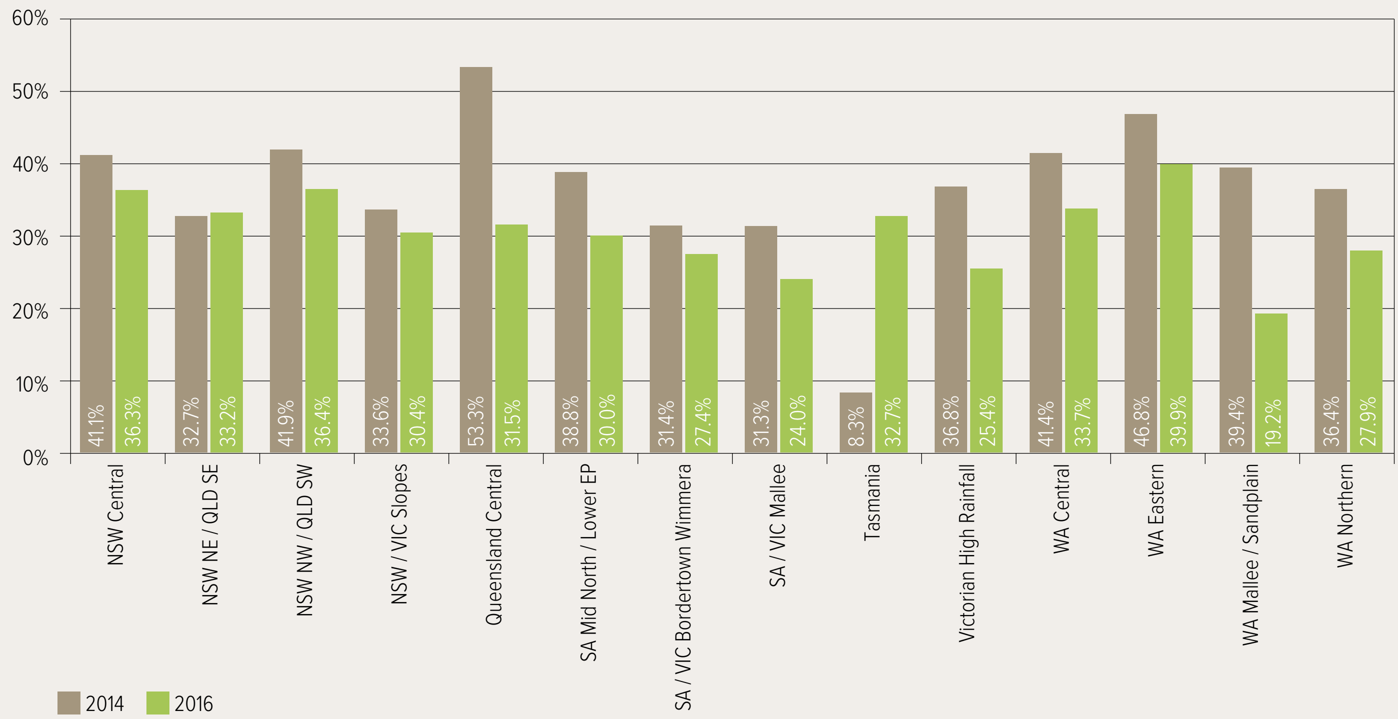


FIGURE 106 Average percentage of farms with a Quality Assurance or Environmental Assurance Program that assists in market access or deriving a price premium.

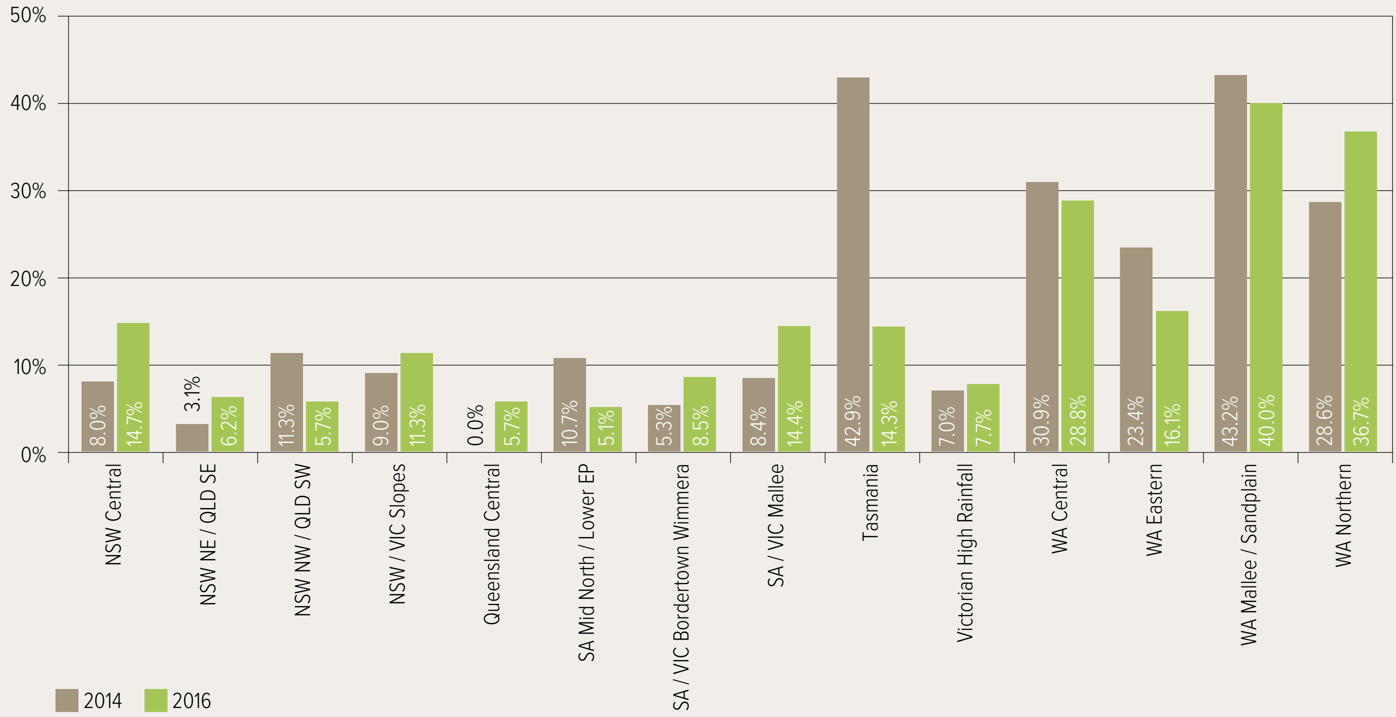


TABLE 84 Average percentage of farms with a Quality or Environmental Assurance program that assists in market access or deriving a price premium.

Agro-ecological zone	Farms utilising a QA/EA program (%)		Significant difference between years
	2014	2016	
NSW Central	8.0	14.7	No significant differences
NSW NE / QLD SE	3.1	6.2	
NSW NW / QLD SW	11.3	5.7	
NSW / VIC Slopes	9.0	11.3	
QLD Central	0.0	5.7	
SA Mid North / Lower EP	10.7	5.1	
SA / VIC Bordertown, Wimmera	5.3	8.5	
SA / VIC Mallee	8.4	14.4	
TAS	42.9	14.3	
VIC High Rainfall	7.0	7.7	
WA Central	30.9	28.8	
WA Eastern	23.4	16.1	
WA Mallee/Sandplain	43.2	40.0	
WA Northern	28.6	36.7	

use of such programs is shown in Table 84 and Figure 106. Survey results show little change in general between survey years, with higher proportions of farms in utilising such programs located in WA, Tasmania, and some of the AEZs in the GRDC northern region.

There are few direct market signals for programs such as these, although there is one in place in WA, aligned with the main bulk grain handler in that which offers growers a small price incentive to participate. This is likely to have assisted with the reported use of a Quality Assurance program in those AEZs.

Notes

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GRAINS RESEARCH & DEVELOPMENT CORPORATION

GRDC, PO Box 5367, Kingston ACT 2604   T 02 6166 4500   F 02 6166 4599

grdc.com.au