Agriculture Canada

Research Branch | Direction générale de la recherche

Technical Bulletin 1992–1E

Identification of crop production risk areas in Manitoba based on agroecological resources

Canada

Identification of crop production risk areas in Manitoba based on agroecological resources

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Technical Bulletin 1992-1E

Research Branch
Agriculture Canada
1992

Copies of this publication are available from
Director
Centre for Land and Biological Resources Research
Research Branch, Agriculture Canada
Room B149, K.W. Neatby Building
Ottawa, Ontario
K1A 0C6

Produced by Research Program Service

Cat. No. A54-8/1992-1E
ISBN 0-662-19319-9

Cover illustration
The dots on the map represent
Agriculture Canada research establishments.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

SUMMARY

Federal - provincial crop insurance programs were established in the early 1960's to reduce the impacts of crop failure due to natural causes. However, with the increased frequency of drought in recent years and the poor performance of grain markets, there is need to improve the performance of these programs and to design new ones.

Central to all safety net programs is the ability to define and map different levels of production risk. This information, normally called risk areas, is the foundation on which new programs are designed and administerd, since they are used to calculate coverage levels and premium rates.

This study reports on the development of new risk areas for Manitoba. Yield data for spring wheat were integrated with maps of agroecological resource areas (ARAs), using a geographic information system. Risk was evaluated on the basis of yield variability in this study, in contrast to earlier work where risk was equated with long-term mean yields. Dimensions of both space and time were used to define levels of risk. Emphasis was on natural risk, i.e. that part of yield variability that is beyond the ability of the farmer to control through management.

Three objectives were identified for this project:

1) to develop a methodology which describes crop yield variability in each ARA in Manitoba;
2) to identify any statistically significant differences between the yield distributions for each ARA;
3) to use the identified statistical differences to group ARA's into areas of similar risk, and to develop new risk areas.

Crop yield data were obtained from the Manitoba Crop Insurance Corporation annual questionnaires for the years 1960 to 1988. Approximately 1.6 million records (for many different crops) were available for this time period, representing information from about 56 per cent of the producers in the province. These values were spatially registered and overlaid onto the ARA map, using the ARC/info geographic information system. The data were then selected according to the following criteria:

1) only spring wheat records were chosen;
2) management practises were standardised such that only stubble yields were used, and nitrogen application was at least 44.8 kg/ha (40 lb/ac);
3) ARAs were included only if wheat yields were available for at least ten years in the time period 1960 to 1988, and each year had to include yields in at least ten locations.

These restrictions ensured that the variability being studied was due to natural effects, and that the sample sizes were large enough to produce statistically reliable results. Approximately 125,000 records were selected for analyses, in 31 ARAs.

Risk levels were evaluated by studying spatial and temporal yield variablility in each ARA. A series of parametric statistics were calculated for each ARA, and the mean, standard deviation and the pattern of mean yields over time were selected for testing. The objective of the testing was to identify which of the ARAs could be grouped to form new risk areas (no significant differences between their yield populations), and which could not. Testing was done using ANOVAs and product-moment correlation coefficients, and the level of significance was selected at $p<=0.05$. The yield populations in each ARA (mean, standard deviation and pattern) were tested against the yield populations of all other ARAs. Any groups formed by this procedure were then retested using the same criteria. Three iterations were needed to identify 15 groups of ARAs that were statistically unique. At this point the groups were compared against soil, climate and landscape data, to verify the validity of the groupings. After final retesting, 11 new groups were created, three of which were subdivided into sugroups A and B. These constituted the new risk areas for Manitoba, and a final map with supporting statistics was produced.

The risk areas produced by this study differ from risk areas currently used in Manitoba in several ways. There is an increased use of natural features to define boundaries, because natural features are a characteristic of the original ARA boundaries. Also, the areas are defined on the basis of means, standard deviations and the pattern of mean yield. This adds new dimensions to the identification of risk areas, in that it incorporates the evaluation of yield variability as an integral component in defining levels of risk. The ARAs are required to have similar mean yields and standard deviations overall, as well as similar patterns in annual mean yield to be identified as areas of equal production risk.

Another difference from the traditional approach in Manitoba is that the risk areas defined in this study are sometimes comprised of several non-contiguous units. The cause of the yield variability within each unit in a single risk area may be different, but all units are similar in terms of yield variability.

The risk areas developed in this study are specific to spring wheat. Although other spring seeded cereals (except maize) could be expected to perform somewhat similarly, this is not the case for crops such as oilseeds or forages, and new risk areas would have to be produced. The methodology, however, could be used for other crops, providing there are adequate numbers of observations, spread over a sufficient number of years.

RÉSUMÉ

Les programmes fédéraux-provinciaux d'assurance-récolte établis au début des années 1960 avaient pour objet de réduire les répercussions des mauvaises récoltes dues à des fléaux naturels. Mais compte tenu de la fréquence accrue de la sécheresse ces dernières années et de la morosité du marché des céréales, il faut améliorer le rendement de ces programmes et en concevoir de nouveaux.

Une condition essentielle de tout programme de protection du revenu est sa capacité d'établir et de délimiter géographiquement les niveaux de risques inhérents à la production. Ces renseignements qui déterminent les zones dites à risques forment la base de la conception et de l'administration des nouveaux programmes puisqu'ils servant à calculer les niveaux de couverture et les taux de prime.

La présente étude fait état de la création de nouvelles zones à risques pour le Manitoba. Pour ce faire, on a intégré des données sur les rendements du blé de printemps à des cartes de zones de ressources agroécologiques (ZRA) au moyen d'un système d'information géographique. Dans cette étude, on a évalué le risque d'après la variabilité du rendement, contrairement aux travaux précédents où le risque a été assimilé aux rendements moyens à long terme. Les dimensions spatiale et temporelle ont servi à déterminer le niveaux de risque. On a mis l'accent sur le risque d'origine naturele, c'est-à-dire cette partie de la variabilitié du rendement qui échappe à la capacité de gestion de l'agriculteur.

On a fixé trois objectifs dans le cadre de ce projet:

1) mettre au point une méthodologie capable de décrire la variabilité des rendements des cultures dans chaque ZRA du Manitoba;
2) déterminer toute différenece statistiquement significative entre les répartitions des rendements dans chaque ZRA;
3) utiliser ces différeneces statistiques pour regrouper les ZRA en zones de risques comparables et pour créer de nouvelles zones à risques.

On a tiré les données sur les rendements des cultures des questionnaires annuels de la Manitoba Crop Insurance Corporation pour les annés 1960 à 1988. Près de 1,6 million de dossiers (pour de nomabreuses cultures différentes) étaient ainsi disponibles sur cette période de temps et comportaient des renseignements sur environ 56% des producteurs de la province. Ces données ont été spatialement enregistrées et superposées sur la carte des ZRA à l'aide du système d'information géographique, ARC/INFO. On a ensuite choisi les données selon les critères suivantes:

1) seuls les dossiers sur le blé de printemps ont été choisis;
2) les pratiques de gestion ont été normalisées de sorte que sels les rendements sur chaume ont été utilisés; en plus, la fumure azotée était d'au moins 44,8 kg/ha (40 lb/ac);
3) les ZRA n'ont été inclus que lorsque les rendements étaient disponibles pendant au moins dix ans dans l'intervalle de 1960 à 1988; en plus, chaque année devait comprendre les rendements d'au moins dix endroits.

Ces restrictions ont permis d'assurer que la variabilité étudiée était réellement attribuable à des effets naturels et que la taille des échantillons était suffisante pour donner des résultats statistiquement fiables. Environ 125 000 dossiers ont été retenus aux fins d'analyse dans 31 ZRA.

On a évalué les niveaux des risque en étudiant la variabilité spatiale et temporelle des rendements dans chaque ZRA. On a calculé une série de statistiques paramétriques pour chaque ZRA et on a choisi la moyenne, l'écart-type et la courbe des rendements moyens dans le temps à des fins d'essai. Les essais avaient pour but de déterminer lesquelles des ZRA pouvaient être regroupées pour former de nouvelles zones à risques (pas de différences significatives dans leurs profils de rendement) et lesquelles ne le pouvaient pas. On a utilisé des analyses de variance et des coefficients de corrélation linéaire et on a choisi un seuil de signification de 0,05. Les profils de rendement dans chaque ZRA (moyenne, écarttype et courbe) ont été confrontés à ceux de toutes les autres ZRA. Les groupes formés grâce à cette méthode ont ensuite fait l'objet d'une autre essai en utilisant les mêmes critères. Il a fallu trois itérations pour établir 15 groupes de ZRA statistiquement singuliers. Les groupes ont ensuite été confrontés à des données pédologiques, climatiques et topographiques pour vérifier la validité des regroupements. Après un dernier contre-essai, on a fini par établir 11 nouveaux groupes, dont trois étaient subdivisés en sous-groupes A et B, qui constituaient les nouvelles zones à risques pour le Manitoba; à partir de là, on a produit une carte définitive avec statistiques à l'appui.

Les zones à risques produites grâce à cette étude diffèrent à maints égards de celles actuellement utilisées au Manitoba. En effet, on constate une utilisation accrue* de formations géographiques naturelles pour délimiter les frontières car ces formations sont une caractéristique des frontières originales des ZRA. Les zones sont également établies d'après les moyennes, les écarts-types et la courbe des rendements moyens; cette façon de procéder ajoute de nouvelles dimensions à la détermination des zones à risques du fait qu'elle intègre l'évaluation de la variabilité des rendements à l'établissement des niveaux de risque. Cependant, les ZRA doivent avoir des rendements moyens et des écarts-types généralement semblables, ainsi que des profils de rendements annuels moyens analogues, pour être qualifiées de zones à risques des production comparables.

Une autre différence par rapport à la démarche habituelle au Manitoba tient au fait que les zones à risques établies dans cette étude se composent parfois de plusieurs unités non contiguës. La cause de la variabilité des rendements à l'intérieur de chaque unité d'une même zone à risques peut être différente, mais toutes les unités sont similaires en termes de variabilité des rendements.

Les zones à risques établies dans la présente étude intéressent le blé de printemps. Même si di'autres céréales de printemps (sauf la maïs) pourraient se comporter un peu de la même façon, ce n'est pas le cas pour des cultures comme les oléagineux et les fourrages, de sorte qu'il faudrait créer de nouvelles zones à risques. La même méthodologie pourrait néanmoins servir à d'autres cultures, pourva que le nombre d'observations soit suffisant et que celles-ci embrassent suffisamment d'années.

ACKNOWLEDGEMENTS

The authors wish to thank the Manitoba Crop Insurance Corporation and the various staff who assisted in the project. In particular the assistance and support of Mr. Henry Nelson, General Manager, Dr. Neil Hamilton, Director of Research, and Mr. Murray Swan, Manager, Soils, are gratefully acknowledged. Thanks are also due to Mr. Mike Ellis, A/Director, Mr. Bill Boddis and Mr. Richard Hill, Crop Insurance Division, Agriculture Canada, and to Dr. W. W. Pettapiece, Research Branch, Agriculture Canada, for advising on the work and for reviewing the manuscript.

The assistance of Ms. Valerie D. Kirkwood in the use of ARC/info and in map preparation is gratefully acknowledged.

1. INTRODUCTION

Farm safety net programs, providing producers with protection from loss of income due to crop production loss, have encountered many difficulties over the past half century. Prior to the enactment of the Crop Insurance Act (FCIA, 1959), these programs were generally handled in an ad hoc manner and as disaster relief. This created many inequities for producers and many financial and administrative problems for governments. It was clear that a program based on natural production risk was essential, but on what basis could such a program be structured? Further, although realizing that production risk varied from area to area, how should the knowledge of this variability be reflected in coverage levels and premiums?

The Federal Crop Insurance Act (1959) was the enabling legislation within which each province could establish a crop insurance program. Under this legislation, the design and administration of these programs were provincial responsibilities, but the federal government covered some administration costs and contributed to a portion of the premiums. It was the responsibility of each province to define the geographic distribution of natural risk (identify Risk Areas) and to determine premiums and coverage levels for producers within each of these areas. All programs were to be actuarially sound, that is financially self sustaining. Initially coverage levels were to be limited to 60 per cent of the area average yields (calculated as arithmetic means) and premiums were to be determined according to levels of risk.

1.1. THE CANADA-MANITOBA CROP INSURANCE PROGRAM

Manitoba was the first province to develop a crop insurance program. This was enacted in 1960 and the program was divided into the following elements:

1) Risk Areas. These areas were defined early in the program, and they have remained essentially unchanged. Each risk area was intended to reflect a distinct level of natural production risk as defined by a combination of legal and natural boundaries. Agro-climatic characteristics considered in the development of these areas included:
    - mean precipitation during the growing season;
    - frequency of precipitation;
    - average temperature during the growing season;
    - average length of the growing season;
    - average number of frost free days;
    - soil factors (fertility, texture, drainage);
    - elevation of the land.

2) Area Average Yields. These values were based on historical crop yields within a risk area. Because of restrictions in the original legislation, only arithmetic means could be calculated, with the result that all

extreme values and all years had to be included.

3) Coverage levels. This was the proportion of the risk area average yield for which a producer may insure. Production guarantees for an individual producer were determined by multiplying the risk area average yield by the coverage level. The maximum coverage level in Manitoba was originally 60 per cent, but this has been increased recently to 80 per cent of the risk area yield.

4) Soil Productivity Index. Historical yield data were integrated with soil profile and climatic factors to create 10 soil productivity classes. Variables included such factors as growing season length, frost free period, precipitation, evapotranspiration and so on. The best soil in the province (top yielding) was assigned a value of 100, and all other soils were down-rated on a point system, depending on the kind and severity of soil limitations. These points were then subdivided into productivity classes A to J. Each cultivated quarter section or river lot was assigned a soil productivity rating or index. The index represented the considered opinion of a field assessor as to the effects of the soil-climate interactions on crop yields in that quarter section. 'A' soils were the most productive and 'J' soils were the least productive.

5) Research Questionnaire. An annual, voluntary questionnaire was completed by producers to help track yield performance over time in each area, and to help identify some reasons for deviations (Figure 1 is a sample of the 1986 version of the Manitoba questionnaire). A detailed description of the producer's management decisions was collected for each yield reported, including:

    - type of crop rotation (fallow or stubble);
    - amounts and types of fertilizer applied;
    - level of weed control;
    - herbicide and insecticide application;
    - type of drainage;
    - seeding methods and dates;
    - tillage methods in spring and/or fall;
    - varieties of crop planted.

1.2. FEDERAL-PROVINCIAL CROP INSURANCE REVIEW

The most recent Federal-Provincial review of crop insurance programs was concluded in May 1989. The principles of each crop insurance program were examined in the context of the main objective of the Crop Insurance Act:

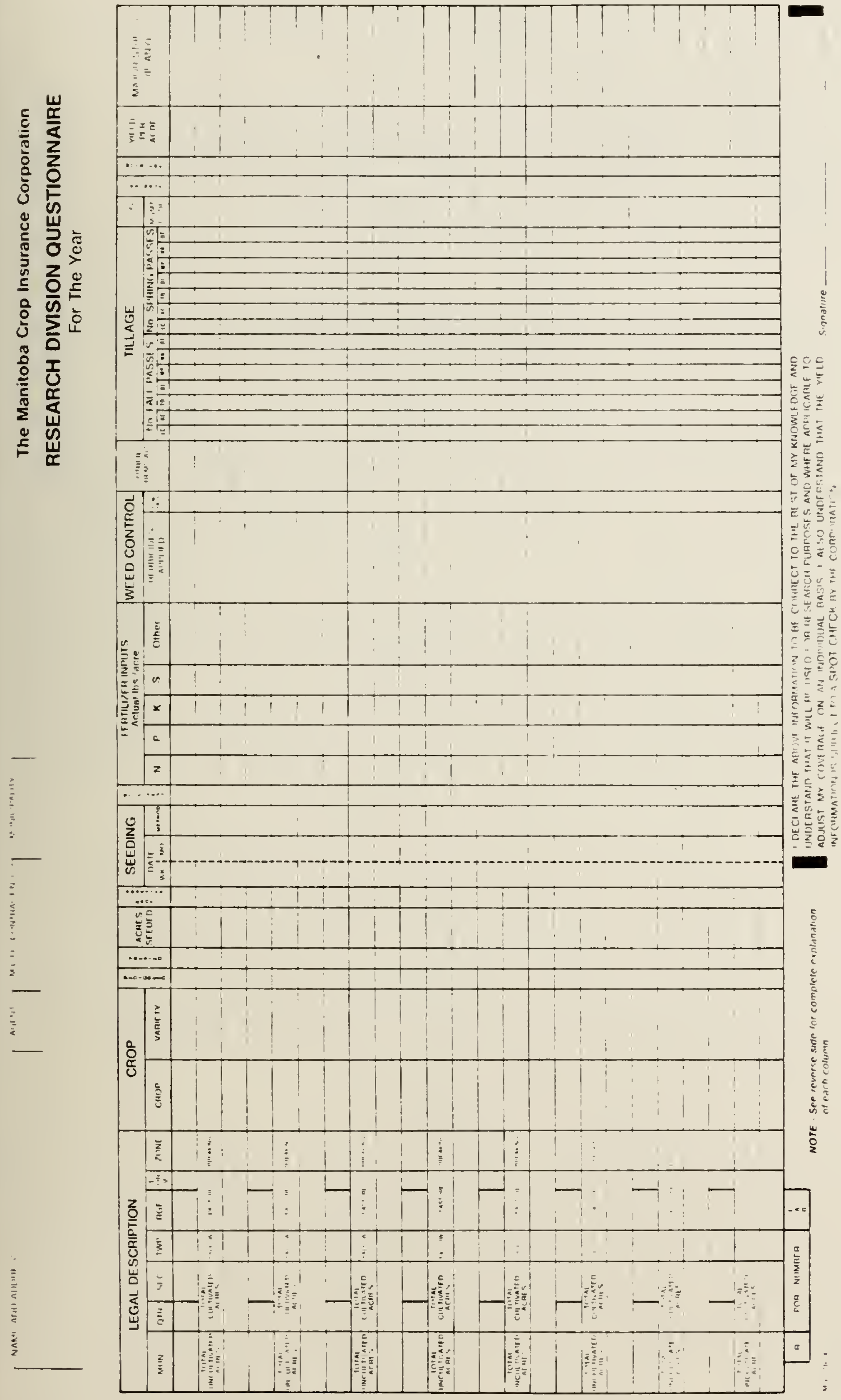

Fig. 1. Questionnaire used by the Manitoba Crop Insurance Corporation in 1986.

> " To provide insurance protection to farmers, on an actuarially sound basis, against crop losses caused by natural perils that cannot be reasonably controlled" (Discussion Paper, May 1989).

Although the programs were found to be performing reasonably well, several elements of current crop insurance programs and other government programs and policies were identified as requiring improvement and/or fine tuning. These included:

1) Ad hoc payments for disaster relief were causing some disruptions in the actuarial performance of the crop insurance programs. It was felt that producers may be relying on disaster relief payments rather than crop insurance to protect against production risk.

2) Existing delineations of risk areas were found to be inaccurate and inadequate. Because of the importance of risk areas to the actuarial soundness and administration of the programs, these inaccuracies were found to bias the programs in an unfavourable way. Also, after 25 years of experience, it was felt that the soil productivity indices had to be updated and revised. Accurate delineations of risk areas and reliable estimates of yield are fundamental to the actuarial performance of crop insurance programs.

3) Indemnities and premiums were not always in balance to ensure actuarial soundness (financial self sustainability). This was due to many factors, not the least of which was the inaccurate delineation of risk areas and the definition of soil indices.

4) Uneven participation of producers in the programs was identified to be a problem. These often were due to premium rates, but also because of inadequate coverage levels and premium differentials, related again to problems in risk area definitions and soil productivity indices. All crop insurance programs are voluntary and hence it is important that the program accurately reflects the individual's level of risk if high participation rates are to be encouraged.

These problems illustrate that the definition of levels of natural risk and yield variability are central to all concerns. It was realized that risk areas should be redefined and this should be done in a manner which is statistically and scientifically sound. Once completed, premiums and coverage levels could then be related to yield probabilities and production risk.

1.3. REACTION TO THE CROP INSURANCE REVIEW

The review initiated the re-examination of the current risk areas in Manitoba. In this task, emphasis moved from the use of arithmetic long term mean yields towards evaluation of natural yield variability. Risk areas had always been defined in relation to long term mean yields and these values were used to determine premiums and coverage levels. This method, however, did not capture all the attributes of variability in the yield populations, and it is precisely this variability which must be evaluated in order to quantify natural production risk.

It was felt that the study of yield variability should not be handled by treating the entire agricultural area of the province as one area, but rather it should be subdivided to reflect "natural" areas of differing yield potential. The Agroecological Resource Area (ARA) map of Manitoba was compiled on the basis of interactions among soils, landforms and climate, and this was adopted as the geographical framework within which to examine yield variability and risk.

1.4. OBJECTIVES FOR THIS STUDY

The research project described in this report was designed to test the hypothesis that ARAs may be a possible alternative to the current risk areas used for crop insurance in Manitoba. The major requirement of the research was that the resultant risk areas must be statistically valid and scientifically sound.

Three objectives were identified for this project:

1) to develop a methodology which describes crop yield variability in each ARA in Manitoba;

2) to identify any statistically significant differences between the yield distributions calculated for each ARA;

3) to use the identified statistical differences to group ARAs into areas of similar risk, and to develop new risk areas.

2. METHODS AND RESULTS

2.1. AGROECOLOGICAL RESOURCE AREA (ARA) MAP

The ARAs were developed using the extensive research experience of available soils and climate experts in Manitoba. The map delineates 50 relatively uniform areas, with similar properties of soil texture and parent material, landforms, climate and soil processes, at a scale of 1:2 million. The main sources of information used in the compilation of the ARA map and development of a relational database were:

1) Generalized Soil Landscape Map of Manitoba (LRRC,1989);
2) Eco-climatic Regions (Mills et al.,1985);
3) Agricultural Resource Region Map of southern Manitoba (University of Manitoba, Faculty of Agriculture,1973);
4) Consultation with soil and landscape experts in Manitoba.

Figure 2 illustrates the ARA Map of Manitoba. The shaded areas indicate ARAs which were included in this study.

2.2. DATA SOURCES

Three sources of data were used in this study:

1) Manitoba Crop Insurance Corporation annual questionnaire files. These files contain all crop yield and management information for the years 1960 to 1988 inclusive. Approximately 1.6 million crop yield records are available for this time period. These yield records represent just over 56 per cent of all producers in the province (about 75 per cent of producers participate in crop insurance programs and 75 per cent of those insured will complete the questionnaire (H. Nelsen, personal communication)). In the earlier years, however, the data are less complete.

2) The ARA database for Manitoba, as developed by the Land Resource Research Centre and stored on the ARC/INFO Geographic Information System. ARA attributes such as soil texture, growing season length, degree days greater than 5 degrees, accumulated precipitation during the summer and moisture stress were extracted from this database to describe the proposed risk areas. Information on soil parent material, surface form, method of deposition, slope and average elevation for each risk area were obtained from the Soil Landscape Map of Manitoba (LRRC, 1989).

3) Transport Canada square survey file. This file contains the section centroid latitude and longitude for all the prairie provinces. Its function in this study was to locate yields within individual ARA boundaries.

Individual wheat yields were assigned to ARAs in three steps. The latitudes and longitudes of the section centroids from the Transport Canada file were converted to coordinates that were compatible with the ARA map information. Then the section centroids were placed into individual ARAs using computerized ARC/INFO procedures. Finally, the legal descriptions within each ARA were matched to the legal descriptions of each yield record

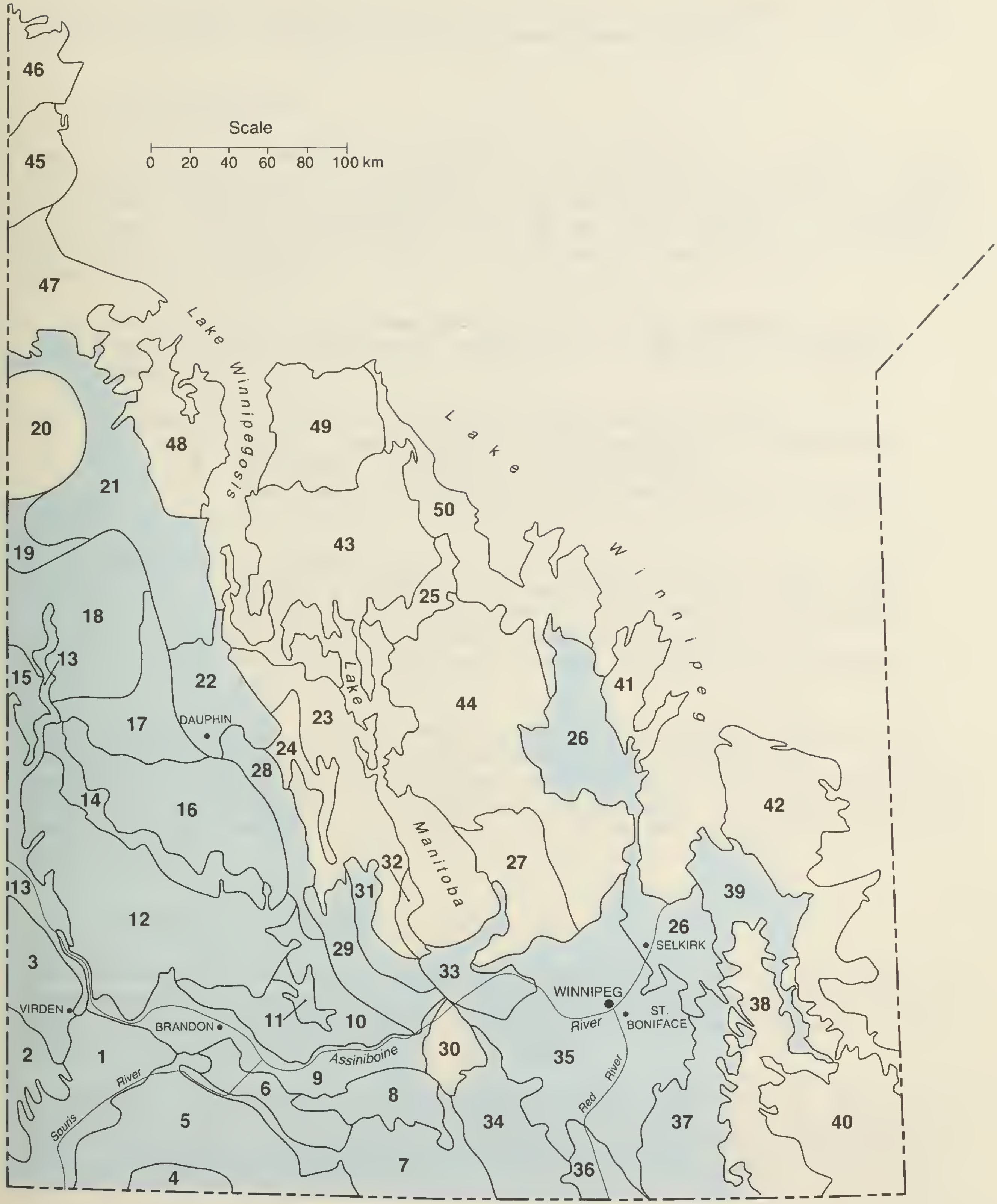

Fig. 2. Qualifying Agroecological Resource Areas (ARAs) used in this study (shaded areas).

extracted from the MCIC database. Appendix 1 is a flow chart which outlines these and all other file management steps.

2.3. DATA SELECTION

The data were selected to minimize the effects of extraneous or irrelevant sources of variation so that the variability being measured would be due to natural effects rather than to management practices. Sample sizes also had to be large enough to produce statistically reliable results. Three data selection criteria were used in this study:

1) Spring wheat was chosen as the test crop because 70 per cent of crop insurance contracts in Manitoba involve wheat production.

2) Management practices were standardized such that
   - only wheat yields defined as continuous (stubble) cropping were included;
   - the level of nitrogen application was at least 44.8 kg/ha (40 lb/ac).

3) ARAs were included in the analysis only if:
   - wheat yields were reported for at least ten years within the time period 1960 to 1988 (not necessarily consecutive years);
   - each year had to include yields in at least ten locations.

These restrictions in the data selection process resulted in a wheat yield file containing approximately 125,000 records. Only 31 ARAs out of the 50 ARAs in Manitoba had at least 10 reported yields in 10 different years. No reported yields were included from the years 1960 to 1963 due to a lack of management information during this period.

2.4. STATISTICAL DESCRIPTIONS FOR ARAs

The evaluation of risk in crop production was based upon an investigation of both spatial and temporal crop yield variability. Both of these dimensions were considered in the development of all statistical tests employed in the study.

A series of parametric statistics were calculated for each qualifying ARA including mean wheat yield and standard deviation from the mean for the period of analysis, coefficient of variation, maximum reported yield, kurtosis (peakedness), skewness (symmetry), annual mean yields and standard deviations of annual mean yields. All statistical analyses were done using the statistics package SAS (Release 5.18).

The number of observations ranged from 269 in ARA 37 to 18,478 in ARA 35. Most of the distributions exhibited some skewness towards the lower yields, which indicated some slight degree of bias towards crop failure.

Table 1. Descriptive statistics for each qualifying ARA

ARA	No. of obs.	No. of yrs.[1]	Mean yield kg/ha (bu/ac)	S.D.[2] kg/ha	C.V.[3] %	Max. yield kg/ha	Kurt.[4]	Skew.[5]
1	2297	16	1518 (22.6)	735	48.5	3699	-0.64	-0.06
2	1210	14	1527 (22.7)	766	50.2	4573	-0.18	0.06
3	1439	16	1615 (24.0)	755	46.7	4035	-0.18	0.18
4	573	14	1789 (26.6)	673	37.6	3699	0.28	-0.05
5	16278	23	1891 (28.1)	766	40.5	5380	0.12	0.07
6	2633	16	1961 (29.2)	715	36.5	6053	0.66	0.10
7	9780	23	2217 (33.0)	866	39.1	6053	0.18	-0.02
8	5305	22	2114 (31.4)	781	36.9	5716	0.11	-0.12
9	7933	23	1984 (29.5)	779	39.3	5716	0.25	-0.25
10	2366	21	1726 (25.7)	776	44.9	5044	-0.07	-0.09
11	2147	23	2116 (31.5)	697	32.9	5380	0.87	-0.13
12	15967	23	2015 (30.0)	712	35.3	6053	0.52	-0.21
13	662	11	1711 (25.4)	720	42.1	4371	0.02	-0.03
14	878	12	1847 (27.5)	773	41.8	4035	-0.12	-0.17
15	767	12	2098 (31.2)	747	35.6	4170	-0.06	-0.10
16	958	12	2035 (30.3)	653	32.1	4035	0.40	-0.14
17	3208	16	2217 (33.0)	637	28.7	5380	0.93	-0.09
18	657	12	1948 (29.0)	764	39.2	4035	-0.02	-0.33
19	2108	15	2272 (33.8)	701	30.9	4371	0.96	-0.43
21	3063	19	2128 (31.6)	689	32.4	5044	0.51	-0.36
22	1083	14	1935 (28.8)	695	35.9	4237	0.22	-0.26
26	1560	18	2032 (30.2)	775	38.1	6053	0.75	-0.38
28	1190	15	1946 (28.9)	889	45.7	4708	-0.33	-0.28
29	2388	19	1859 (27.7)	780	42.0	4035	-0.32	-0.14
31	1497	21	2106 (31.3)	843	40.0	5716	0.34	-0.10
33	1965	22	2366 (35.2)	781	33.0	5918	0.70	-0.40
34	10821	24	2274 (33.8)	910	40.0	5380	0.03	-0.42
35	18478	23	2034 (30.3)	888	43.6	6053	-0.23	-0.37
36	3263	23	2383 (35.4)	900	37.8	5044	0.17	-0.44
37	269	12	2075 (30.9)	902	43.5	4708	-0.28	-0.08
39	654	13	2180 (32.4)	655	30.0	4371	0.48	-0.05

[1] at least 10 reported yields per year
[2] standard deviation
[3] coefficient of variation (S.D./mean x 100)
[4] kurtosis
[5] skewness

Table 1 lists the descriptive statistics for each ARA. Yields reported as zero were included in all calculations. The frequency of zero yields was less than 2 per cent, on average, of the total population in almost all ARAs. Some highlights of this table include:

1) mean yields varied from 1518 kg/ha (22.6 bu/ac) in ARA 1

to 2383 kg/ha (35.4 bu/ac) in ARA 36;

2) a minimum yield of zero was reported in each ARA in at least one of the years, indicating that the crop on that quarter section was not harvested during the period of study, for whatever reason;

3) 6053 kg/ha (90 bu/ac) was the highest reported yield. This was reported in ARA 6, ARA 7, ARA 12, ARA 26 and ARA 35 (the reliability of this figure could not be confirmed by the Manitoba Crop Insurance Corporation);

0.637 — 0.910

4) standard deviations ranged from 637 kg/ha (9.5 bu/ac) in ARA 17 to 910 kg/ha (13.5 bu/ac) in ARA 34;

5) the coefficient of variation ranged from 28.7 per cent in ARA 17 to 50.2 per cent in ARA 2;

6) there was no evident relationship between the means and the standard deviations;

7) skewness was slightly negative in 27 of the 31 ARAs reflecting a higher probability of low (or zero) yields during the study period.

Appendix 2 shows the graphical representations of some of these statistics for each qualifying ARA. These include a wheat yield frequency histogram, a cumulative probability distribution, a plot of the annual mean yield over time and a plot of the annual standard deviation from the mean.

The histograms were plotted using the SAS procedure PROC GCHART. The class interval width was 336 kg/ha (5 bu/ac), resulting in a maximum of 17 discrete yield classes. The frequency of each yield class was expressed as a percent of the total number of observations. These histograms (Appendix 2, Figs. 1 and 2) were visually compared to a normal distribution. Although most of the yield distributions exhibited some differences from normality, these differences were not deemed to be severe. Bimodality, for example, was not evident. Consequently the use of parametric statistical tests in the ARA classification procedures seemed to be reasonable.

The SAS procedure PROC GPLOT was used to plot the annual mean and the annual standard deviation (Appendix 2, Figs 3 and 4). The number of years varied from ARA to ARA, because of the exclusion of years with less than 10 reported yields (years were not always consecutive). The least number of years were included in an ARA was 11 years (ARA 13) and the greatest number of years included was 25 years (ARA 34). The average number of years included was 18. The range of years included in the analysis of each ARA was noted at the bottom of the standard deviation plot.

The plots of the annual means and standard deviations illustrate the following:

1) 1980 and 1988 were the lowest producing years for a majority (83.9 per cent) of ARAs. These were years of severe drought, with 1988 being the worst of the two years. (Manitoba Agriculture Yearbook, 1980, 1988);

2) the highest annual yields occurred in 1985 in 87.1 per cent of the ARAs and the lowest annual yields occurred in 1988;

3) yield variability, as estimated by annual standard deviations, ranged from a low of 202 kg/ha (3 bu/ac) in ARA 3 in 1968 to 1071 kg/ha (15.9 bu/ac) in ARA 26 in 1985;

4) stresses that negatively affected annual mean yields did not exhibit the same influence over the annual standard deviations. Drought, for example, did not generally appear to result in increases in annual standard deviations.

The plots of the annual statistics describe the temporal patterns of yield distributions of a particular ARA and assist in the development of risk areas. It is significant that the plots of the mean yield did not clearly indicate either increasing or decreasing average yields for most ARAs. However, the plots of the standard deviations indicated a tendency towards increases in magnitude over time, particularly in many of the southern, drier ARAs. This may indicate that yield variability has been increasing over time in these areas. Regression analysis would help to quantify these trends, in regards to the direction and magnitude of the changes, but this analysis was not within the scope of this study.

2.5. DEVELOPING NEW RISK AREAS

2.5.1. Testing for Differences Between ARAs

The process of developing new risk areas involved grouping ARAs which had similar yield populations. Three parametric statistics were used for this purpose, namely the mean wheat yields for the period of analysis, the standard deviations from the mean and the patterns in mean wheat yields.

The SAS procedure PROC GLM was used to assess differences between mean yields of each ARA and the corresponding standard deviations. The mean and the standard deviations were examined using an analysis of variance (ANOVA) with year and ARA as the terms of the model. Each annual ARA parameter was weighted by the number of observations in that year to avoid distortion of the effects due to comparatively small sample sizes, and to reflect the precision associated with unequal numbers of observations.

For both parameters the Least Squared Means (LSMs) were used in conjunction with the t-test to evaluate differences between pairs of ARAs. The LSMs for each ARA was an adjustment of the original mean to account for the different number of observations in each year.

Table 2 contains the GLM results for both the mean and standard deviation comparisons. Each value in this table is the probability (p) that a difference in LSMs (of the observed magnitude) occurs by chance. Differences were considered significant at the 5 per cent level whenever $p<=0.05$. For example, in comparing ARA 1 to all other ARAs, the mean yield was not significantly different from ARA 2 ($p=0.39$), ARA 3 ($p=0.21$), ARA 4 ($p=0.20$), ARA 10 ($p=0.06$) and ARA 13 ($p=0.32$), but was different ($p<=0.05$) from all others.

The patterns in annual mean yields were compared using the Pearson product-moment correlation (SAS procedure PROC CORR). The top half of Table 3 lists the significant ($p<=0.05$) correlation coefficients (R) that resulted from comparisons between patterns in annual mean yield. The number of years compared for each pair of ARAs is listed in the lower half of the table.

2.5.2. The Process of Grouping Statistically Similar ARAs

The procedure used to group ARAs involved systematically comparing each ARA against all other qualifying ARAs in the province. Any two (or more) ARAs were grouped if their yield populations were identified to be similar, i.e. there were no significant differences between them.

To be considered in the same group (Risk Area) the two ARAs had to satisfy four criterion, following the procedure below:

1) no significant difference between mean yields, i.e. the probability of the observed difference between LSMs (Table 2) exceeded 0.05. IF NOT THEN

2) no significant differences between standard deviations, i.e. the probability of the observed differences between the LSMs (Table 2) exceeded 0.05. IF NOT THEN

3) a significantly similar pattern in annual mean yields, i.e. the correlations (Table 3) are different from zero and positive. AND

4) the correlations exceeded 0.79 (Table 3).

Figure 3 illustrates this process for identifying statistically similar groups. This procedure is further explained by the

Table 2. Probability of a difference between ARA least square means for mean yields and standard deviations.

Mean yield probabilities

Std. dev. probabilities

ARA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	21	22	26	28	29	31	33	34	35	36	37	39
1	–	0.39	0.21	0.20	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.32	0.10	0.00	0.00	0.00	0.04	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
2	0.14	–	0.75	0.56	0.05	0.05	0.00	0.00	0.00	0.48	0.00	0.18	0.79	0.42	0.05	0.04	0.00	0.21	0.00	0.00	0.18	0.04	0.07	0.13	0.00	0.00	0.00	0.00	0.00	0.14	0.01
3	0.91	0.21	–	0.73	0.09	0.09	0.00	0.00	0.01	0.71	0.00	0.01	0.99	0.59	0.08	0.07	0.00	0.30	0.00	0.00	0.27	0.06	0.11	0.23	0.00	0.00	0.00	0.00	0.00	0.19	0.01
4	0.86	0.39	0.93	–	0.48	0.41	0.01	0.05	0.15	0.92	0.07	0.18	0.77	0.91	0.26	0.27	0.03	0.59	0.01	0.06	0.60	0.30	0.37	0.62	0.04	0.00	0.00	0.10	0.00	0.34	0.08
5	0.50	0.02	0.49	0.58	–	0.70	0.00	0.00	0.02	0.11	0.02	0.01	0.24	0.49	0.38	0.40	0.00	0.98	0.00	0.00	0.92	0.44	0.60	0.75	0.01	0.00	0.00	0.00	0.00	0.52	0.08
6	0.97	0.14	0.93	0.87	0.45	–	0.00	0.04	0.27	0.13	0.12	0.37	0.21	0.41	0.56	0.60	0.02	0.87	0.00	0.07	0.76	0.70	0.83	0.59	0.06	0.00	0.00	0.12	0.00	0.62	0.16
7	0.01	0.00	0.02	0.09	0.00	0.00	–	0.12	0.00	0.00	0.20	0.00	0.00	0.00	0.17	0.10	0.46	0.04	0.65	0.19	0.01	0.02	0.03	0.00	0.61	0.04	0.03	0.00	0.01	0.47	0.71
8	0.00	0.00	0.01	0.07	0.00	0.00	0.67	–	0.17	0.00	0.89	0.06	0.01	0.03	0.51	0.40	0.60	0.17	0.14	0.97	0.07	0.20	0.19	0.01	0.67	0.00	0.00	0.28	0.00	0.78	0.78
9	0.00	0.00	0.01	0.06	0.00	0.00	0.56	0.93	–	0.00	0.39	0.69	0.05	0.11	0.99	0.89	0.08	0.43	0.01	0.26	0.27	0.66	0.58	0.09	0.19	0.00	0.00	0.56	0.00	0.91	0.37
10	0.01	0.00	0.02	0.08	0.01	0.01	0.71	0.96	0.99	–	0.00	0.01	0.79	0.79	0.11	0.10	0.00	0.42	0.00	0.00	0.39	0.09	0.16	0.34	0.00	0.00	0.00	0.00	0.00	0.25	0.02
11	0.62	0.06	0.58	0.62	0.99	0.58	0.04	0.03	0.02	0.05	–	0.25	0.02	0.05	0.61	0.51	0.59	0.24	0.18	0.92	0.13	0.32	0.29	0.04	0.64	0.01	0.01	0.56	0.00	0.83	0.73
12	0.10	0.00	0.14	0.29	0.06	0.08	0.03	0.02	0.01	0.10	0.36	–	0.06	0.14	0.89	0.98	0.03	0.51	0.00	0.14	0.34	0.80	0.70	0.12	0.12	0.00	0.00	0.22	0.00	0.84	0.29
13	0.28	0.04	0.27	0.32	0.40	0.26	0.68	0.56	0.53	0.57	0.46	0.77	–	0.66	0.14	0.14	0.01	0.39	0.00	0.02	0.38	0.15	0.20	0.36	0.01	0.00	0.00	0.03	0.00	0.23	0.04
14	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.04	0.06	0.00	0.00	0.05	–	0.26	0.27	0.01	0.63	0.00	0.04	0.64	0.29	0.37	0.66	0.03	0.00	0.00	0.06	0.00	0.36	0.07
15	0.72	0.42	0.80	0.90	0.42	0.73	0.03	0.02	0.02	0.03	0.47	0.16	0.23	0.00	–	0.93	0.36	0.56	0.14	0.54	0.46	0.79	0.72	0.35	0.40	0.02	0.03	0.82	0.01	0.92	0.49
16	0.12	0.01	0.13	0.20	0.18	0.11	0.88	0.72	0.68	0.72	0.25	0.49	0.82	0.06	0.12	–	0.26	0.59	0.09	0.44	0.48	0.86	0.77	0.36	0.31	0.01	0.01	0.70	0.00	0.86	0.42
17	0.76	0.07	0.70	0.71	0.73	0.72	0.01	0.00	0.00	0.02	0.81	0.15	0.35	0.00	0.56	0.16	–	0.11	0.35	0.62	0.04	0.12	0.12	0.01	0.98	0.02	0.03	0.14	0.01	0.64	0.99
18	0.00	0.00	0.00	0.01	0.00	0.00	0.09	0.14	0.14	0.17	0.01	0.02	0.12	0.78	0.01	0.15	0.00	–	0.04	0.20	0.94	0.67	0.76	0.86	0.14	0.00	0.01	0.32	0.00	0.59	0.22
19	0.01	0.00	0.01	0.05	0.00	0.00	0.45	0.68	0.71	0.75	0.03	0.05	0.44	0.11	0.02	0.55	0.01	0.26	–	0.17	0.01	0.03	0.03	0.00	0.45	0.19	0.43	0.02	0.15	0.39	0.56
21	0.01	0.00	0.01	0.06	0.00	0.00	0.55	0.82	0.86	0.88	0.03	0.04	0.50	0.07	0.02	0.63	0.01	0.19	0.84	–	0.09	0.24	0.23	0.02	0.68	0.01	0.01	0.41	0.00	0.79	0.77
22	0.02	0.00	0.03	0.08	0.03	0.02	0.56	0.74	0.77	0.78	0.07	0.14	0.48	0.16	0.04	0.59	0.03	0.31	0.99	0.86	–	0.55	0.66	0.92	0.07	0.00	0.00	0.16	0.00	0.53	0.15
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.84	0.00	0.02	0.00	0.62	0.03	0.01	0.07	–	0.90	0.40	0.17	0.00	0.00	0.45	0.00	0.77	0.30
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.63	0.00	0.01	0.00	0.46	0.02	0.01	0.04	0.74	–	0.53	0.16	0.00	0.00	0.40	0.00	0.72	0.27
29	0.00	0.00	0.00	0.01	0.00	0.00	0.06	0.15	0.15	0.24	0.00	0.00	0.18	0.31	0.00	0.21	0.00	0.56	0.41	0.27	0.51	0.13	0.08	–	0.02	0.00	0.00	0.03	0.00	0.47	0.09
31	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.03	0.07	0.00	0.00	0.07	0.75	0.00	0.07	0.00	0.99	0.13	0.07	0.21	0.54	0.37	0.42	–	0.05	0.11	0.28	0.04	0.65	0.99
33	0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.07	0.06	0.13	0.00	0.00	0.11	0.49	0.00	0.13	0.00	0.76	0.25	0.15	0.34	0.28	0.18	0.70	0.67	–	0.37	0.00	0.99	0.14	0.14
34	0.00	0.00	0.00	0.04	0.00	0.00	0.30	0.66	0.69	0.78	0.01	0.00	0.43	0.05	0.01	0.56	0.00	0.18	0.89	0.91	0.91	0.01	0.00	0.22	0.05	0.11	–	0.00	0.28	0.23	0.27
35	0.00	0.00	0.00	0.03	0.00	0.00	0.17	0.53	0.54	0.69	0.00	0.00	0.39	0.06	0.01	0.50	0.00	0.20	0.97	0.82	0.96	0.01	0.00	0.24	0.05	0.12	0.85	–	0.00	0.99	0.47
36	0.36	0.02	0.36	0.46	0.59	0.32	0.05	0.04	0.02	0.08	0.72	0.57	0.59	0.00	0.31	0.35	0.50	0.01	0.04	0.04	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–	0.13	0.12
37	0.33	0.09	0.32	0.34	0.44	0.32	0.97	0.88	0.86	0.87	0.47	0.67	0.84	0.22	0.27	0.97	0.39	0.33	0.75	0.82	0.76	0.16	0.12	0.49	0.28	0.38	0.78	0.75	0.56	–	0.68
39	0.18	0.02	0.18	0.24	0.26	0.17	0.90	0.76	0.73	0.76	0.32	0.56	0.84	0.09	0.16	0.99	0.23	0.18	0.60	0.68	0.63	0.04	0.03	0.28	0.11	0.19	0.62	0.58	0.42	0.97	–

Table 3. Significant correlations (p<0.05) between patterns of mean yields[1,2]

		Correlation coefficients																													
	ARA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	21	22	26	28	29	31	33	34	35	36	37	39
	1		0.92	0.74	0.81	0.81	0.64	0.65	0.64	0.78	0.82	--	0.76	0.69	--	--	0.60	--	0.65	0.73	0.64	0.70	--	0.83	0.66	0.63	--	--	--	--	--	--
	2	14		0.88	0.83	0.80	0.79	0.75	0.74	0.80	0.80	--	0.94	0.84	--	--	--	--	--	0.61	0.63	0.64	0.53	0.82	0.77	0.63	0.64	--	--	0.68	--	0.64
n	3	15	14		0.64	--	0.72	--	0.49	0.68	0.61	--	--	0.81	--	--	--	--	--	--	0.55	--	--	0.65	0.60	0.52	0.53	--	--	--	--	0.56
u	4	14	13	14		0.92	0.72	0.84	0.84	0.83	0.84	--	0.88	0.69	--	--	0.81	0.56	--	0.76	0.64	0.70	--	0.84	0.90	0.70	0.56	--	--	0.73	--	--
m	5	16	14	16	14		0.75	0.84	0.81	0.87	--	--	--	0.60	--	--	0.76	0.74	0.70	0.83	0.51	0.89	--	0.69	0.82	0.82	--	--	--	0.61	--	0.56
b	6	16	14	15	14	16		0.89	0.81	0.81	0.74	--	0.82	0.79	--	--	0.73	0.70	--	0.54	0.71	0.66	0.72	0.81	0.72	0.69	0.88	--	--	0.82	--	0.70
e	7	16	14	16	14	23	16		0.87	0.83	--	--	0.51	0.60	--	--	0.81	0.77	--	0.74	0.64	0.79	0.55	0.76	0.83	0.83	0.54	--	--	0.79	--	0.62
r	8	16	14	16	14	22	16	22		0.84	--	--	--	--	--	--	0.82	0.80	0.60	0.74	0.64	0.86	0.50	0.88	0.87	0.82	--	--	--	0.81	--	--
	9	16	14	16	14	23	16	23	22		--	--	--	0.69	--	--	0.75	0.80	0.63	0.81	0.76	0.83	--	0.84	0.88	0.89	--	--	--	0.67	--	0.60
o	10	16	14	16	14	21	16	21	21	21		--	--	--	--	--	0.67	0.67	0.67	0.88	0.74	0.79	--	0.79	--	--	--	--	--	--	--	--
f	11	16	14	16	14	23	16	23	22	23	21		--	--	--	--	--	0.50	--	--	--	--	--	--	--	0.47	--	--	0.42	--	0.96	--
	12	16	14	16	14	23	16	23	22	23	21	23		0.82	--	--	0.60	0.64	--	0.70	--	0.72	--	--	--	--	0.66	--	--	--	--	0.63
y	13	11	11	11	11	11	11	11	11	11	11	11	11		--	0.60	0.67	--	--	--	--	--	--	0.69	--	--	--	--	--	--	--	--
e	14	12	12	12	12	12	12	12	12	12	12	12	12	11		--	--	--	--	--	--	0.61	--	--	--	--	--	--	--	--	--	--
a	15	12	12	12	12	12	12	12	12	12	12	12	12	11	12		0.61	0.67	0.70	--	--	--	--	--	--	--	--	--	--	--	--	--
r	16	12	12	12	11	12	12	12	12	12	12	12	12	11	11	11		0.79	--	0.57	0.57	0.70	--	0.80	0.64	0.57	0.59	--	--	0.69	--	--
s	17	15	13	14	13	16	15	16	16	16	16	16	16	11	12	12	12		0.72	0.69	0.70	0.84	--	0.59	0.69	0.79	0.74	--	--	0.69	--	0.70
	18	12	12	12	11	12	12	12	12	12	12	12	12	11	11	11	12	12		0.77	0.69	0.74	--	--	--	0.66	--	--	--	--	--	--
c	19	15	14	15	14	15	15	15	15	15	15	15	15	11	12	12	12	14	12		0.87	0.74	--	0.57	0.77	0.77	0.58	--	--	0.71	--	--
o	21	16	14	16	14	19	16	19	18	19	18	19	19	11	12	12	12	15	12	15		0.72	--	0.64	0.65	0.67	0.72	--	--	0.70	--	--
m	22	14	13	14	13	14	14	14	14	14	14	14	14	11	12	12	12	14	12	14	14		--	0.77	0.82	0.81	0.62	--	--	0.64	--	0.62
p	26	16	14	16	14	18	16	18	18	18	18	18	18	11	12	12	12	15	12	15	17	14		0.58	--	--	0.77	--	--	0.58	--	0.65
a	28	14	14	15	13	16	14	15	15	16	15	15	15	11	12	12	12	13	12	14	15	13	15		0.83	0.63	0.69	--	--	0.67	--	0.62
r	29	16	14	16	14	19	16	19	19	19	19	19	19	11	12	12	12	16	12	15	17	14	18	15		0.83	0.72	--	--	0.69	--	--
e	31	16	14	16	14	21	16	21	21	21	20	21	21	11	12	12	12	16	12	15	18	14	18	15	19		0.67	--	--	0.65	--	--
d	33	16	14	16	14	22	16	22	22	22	21	22	22	11	12	12	12	16	12	15	18	14	18	15	19	21		--	--	--	--	0.56
	34	16	14	16	14	23	16	23	22	23	21	23	23	11	12	12	12	16	12	15	15	14	18	15	19	21	22		0.84	--	--	--
	35	16	14	16	14	23	16	23	22	23	21	23	23	11	12	12	12	16	12	15	19	14	18	15	19	21	22	23		--	--	--
	36	16	14	16	14	23	16	23	22	23	21	23	23	11	12	12	12	16	12	15	19	14	18	15	19	21	22	23	23		--	0.57
	37	12	11	12	11	12	12	12	12	12	12	12	12	11	10	10	11	12	11	12	12	12	12	11	12	12	12	12	12	12		--
	39	13	13	13	12	13	13	13	13	13	13	13	13	11	12	12	12	13	12	13	13	13	13	13	13	13	13	13	13	13	11	

1 -- indicates pairs of ARAs which were not significantly correlated (p>0.05)

2 number of years in which both ARAs in the comparison had at least 10 observations

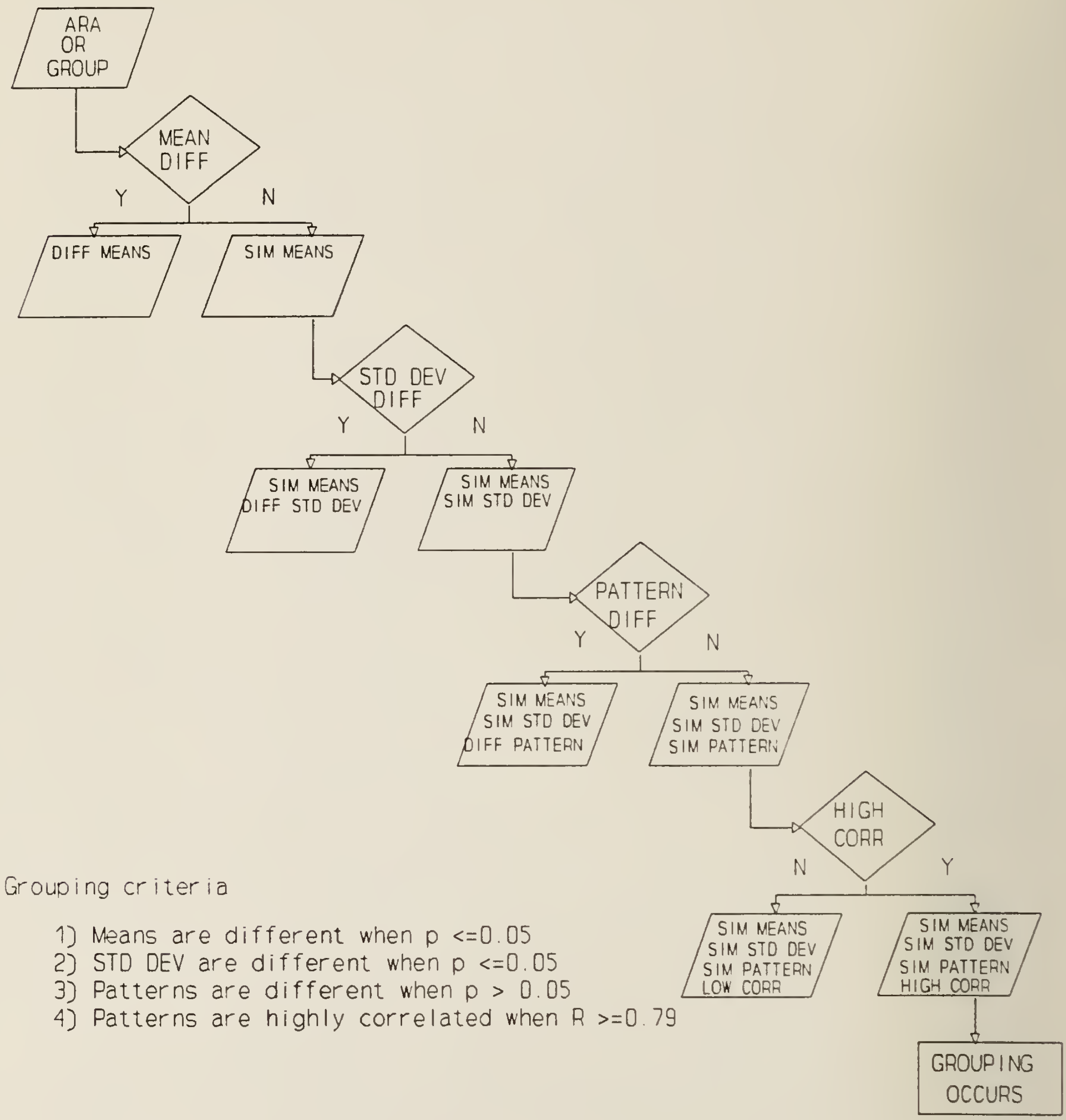

Fig. 3. Grouping criteria for pairs of ARAs and interim groups

following example for ARA 1. The GLM results of the mean yield comparisons (Table 2) indicate that ARA 1 had a mean yield that was not significantly different from the mean yields of ARAs 2, 3, 4, 10 and 13. These ARAs passed the first criterion. The standard deviation of ARA 1 was then compared only to the standard deviations of the 5 ARAs with similar mean yields; ARA 10 was statistically differentiated from ARA 1 at the second step, leaving 4 ARAs to be examined at the next level (ARAs 2,3,4 and 13). Step 3 indicates that there were significant correlations between the pattern of annual mean yield for ARA 1 and the four remaining ARAs. The final grouping criteria identified three possible grouping of ARAs. ARAs 1 and 2 had patterns of mean yields that were highly correlated (R=0.92) and could be grouped. ARAs 1 and 4 also could have been joined with ARA 1 (R=0.81). Lastly, all three of these ARAs could have been in a group as ARA 2 and 4 have highly correlated mean yield patterns (R=0.83). In this first iteration ARA 1 and 2 were grouped because the patterns of their mean yields were most similar. ARA 4 was not grouped with ARAs 1 and 2 because it was compatible with other ARAs, particularly ARA 5 (similar means, similar standard deviations, and significantly and highly correlated mean yield patterns; R=0.92). Whenever conflicting groupings were possible, the grouping with the largest correlation value was chosen.

There were a total of 465 possible ARA comparisons in this study. Table 4 lists the rate of statistical differentiation at each step of this process. Because of the order in which the criteria were applied, the mean yield criteria differentiated a higher percent of ARAs than did the standard deviation or the pattern of the annual mean yields.

Table 4. Frequency of dissimilar comparisons for each step of the grouping criteria.

Step	Step differentiation % (no.)[1]	Cumulative differentiation % (no.)
1 - MEAN	41.7 (194)	41.7 (194)
2 - S.D.	23.9 (111)	65.6 (305)
3 - PATTERN	17.4 (81)	83.0 (386)
4 - R VALUE	10.8 (50)	93.8 (436)

[1] the step differentiation is the proportion of the total number of possible comparisons (465) that were eliminated in that step.

The cumulative contribution of each step in the process is also shown in Table 4. Only 29 (6.2 per cent) of the ARA comparisons passed all four levels of criteria. Appendix 3. lists the frequency of dissimilar comparisons for each ARA.

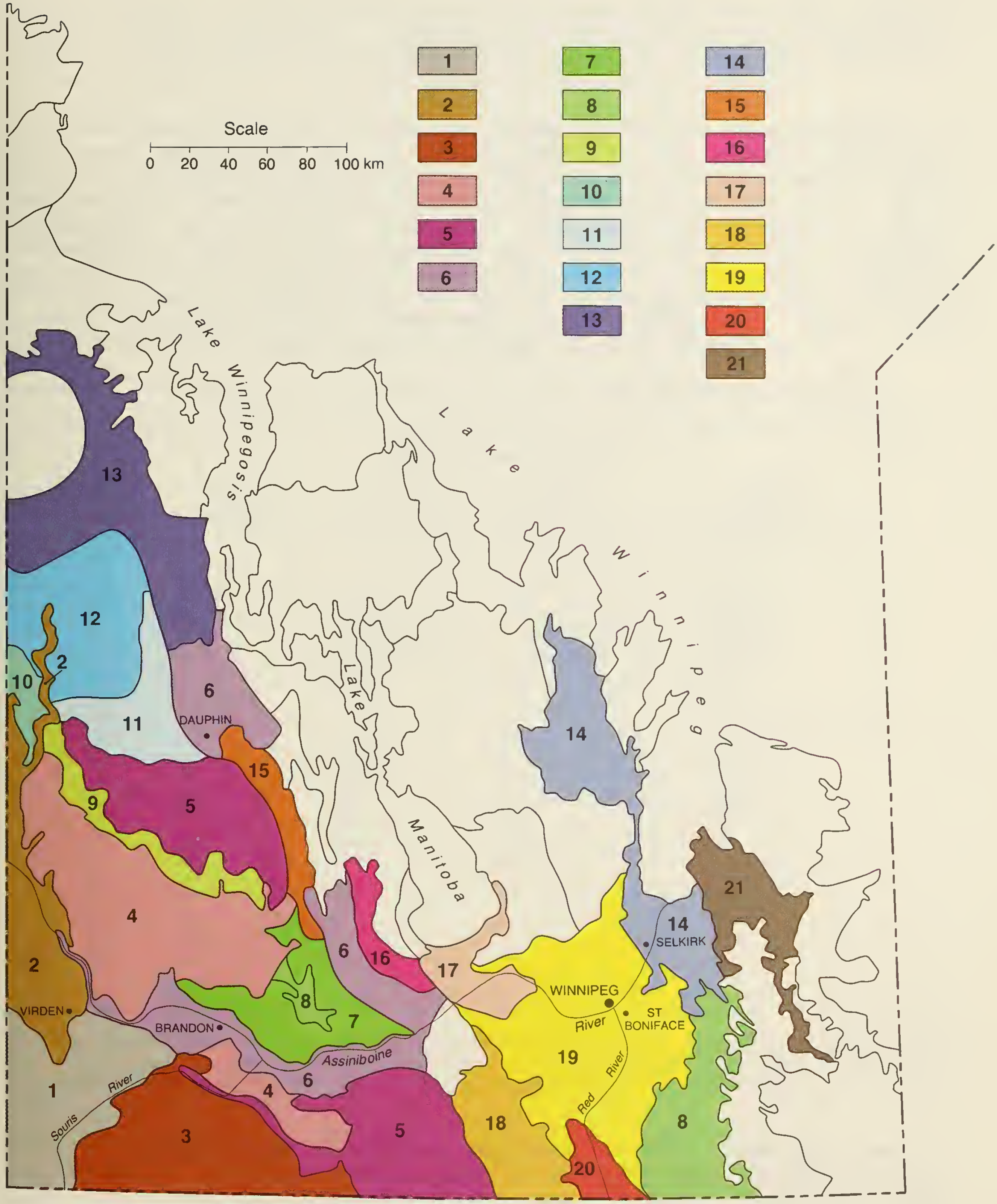

Fig. 4. First interim grouping of ARAs (21 groups).

This process of statistical differentiation resulted in 21 interim groups of ARAs (Table 5). Figure 4 illustrates the distribution of these groups across the agricultural area of Manitoba. It is an interim product in the development of new risk areas.

To investigate further groupings, these 21 groups were examined in the same manner as the original ARAs. The ANOVA (LSMs) and correlation coefficients were calculated and then the groups were subjected to the grouping criteria (Appendices 4.1 and 4.2). This identified groups that were not statistically unique. As a consequence the set of 21 groups were consolidated into 17 groups as shown in Table 5 (second iteration). Note that ARAs 33 and 34 were grouped in this iteration rather than in the first, due to slight changes in the group population statistics, which were reflected in the least squared means of each iteration.

Table 5. Results of the iterative application of the grouping criteria[1]

	ARAs in each group			
Group Number	First iteration	Second iteration	Third iteration	Fourth iteration
1	1,2	1,2,3,13	1,2,3,10,13	1,2,3
2	3,13	4,5	4,5	10,13
3	4,5	6,11,12,37	6,11,12,37	4,5,6
4	6,12	7,8,16	7,8,16	11,12
5	7,8,16	9,22,29,31	9,22,28,29,31	37,39
6	9,22,29	10	14	7,8
7	10	14	15	16
8	11,37	15	17	9,14,22,28,29,31
9	14	17	18	15,17
10	15	18	19,21	18,19,21
11	17	19,21	26	26
12	18	26	33,34	33,34
13	19,21	28	35	35
14	26	33,34	36	36
15	28	35	39	
16	31	36		
17	33	39		
18	34			
19	35			
20	36			
21	39			

[1] the first three sets of groups were determined by the grouping criteria. The fourth set of groups were formed as a result of inclusion of biophysical and geographic information to the groups from the third iteration.

This grouping process was then repeated on the 17 groups, and it was found that further consolidation was possible (Appendices 4.3 and 4.4). Fifteen interim groups were formed, using the same differentiation process. These groups are also shown in Table 5 (third iteration).

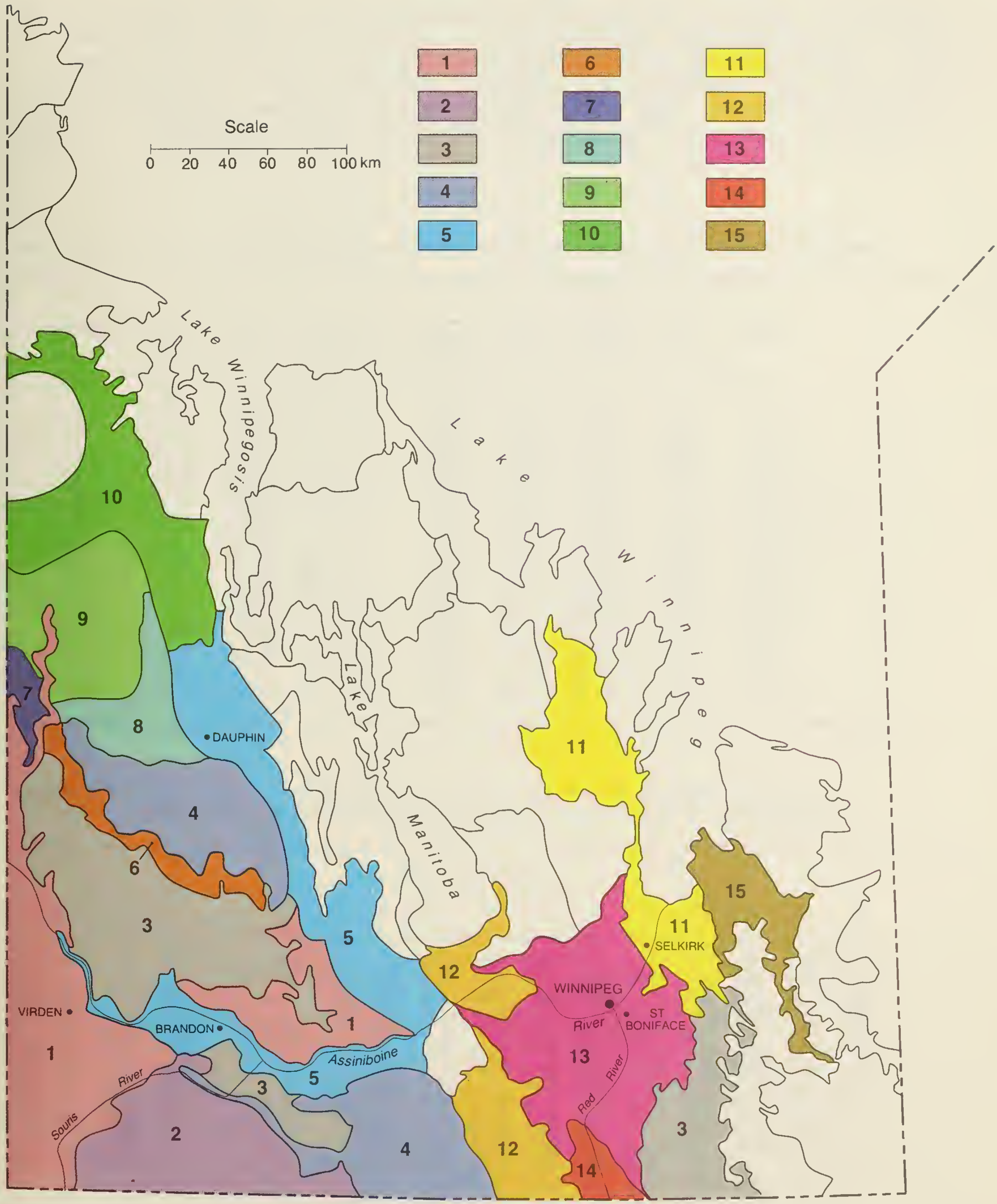

Fig. 5. Third interim grouping of ARAs (15 groups). These groups represent the statistical grouping of ARAs without considering any soil landscape characteristics.

When the differentiation procedure was applied to these 15 groups, it was found that no further consolidation was possible. The groups were all statistically differentiated from each other. The distribution of these groups across the province is shown in Figure 5 and the descriptive statistics for each group are found in Table 6. Results of the statistical testing are shown in Tables 7 and 8.

Table 6. Descriptive statistics for the third interim grouping of ARAs

Group	No. of obs.	Mean yield kg/ha (bu/ac)	S.D. kg/ha	C.V. %	Max. yield kg/ha	Kurt.	Skew.
1	7994	1613 (23.99)	760	47.1	5044	-0.25	0.01
2	16851	1888 (28.07)	763	40.4	5380	0.13	0.07
3	21016	2020 (30.03)	715	35.4	6053	0.55	-0.16
4	16043	2172 (32.29)	829	38.2	6053	0.23	-0.20
5	14091	1969 (29.28)	793	40.3	5716	0.13	-0.21
6	878	1847 (27.47)	771	41.7	4035	-0.12	-0.17
7	767	2098 (31.19)	747	35.6	4170	-0.06	-0.10
8	3208	2217 (32.97)	637	28.7	5380	0.92	-0.09
9	657	1948 (28.96)	764	39.2	4035	-0.02	-0.33
10	5171	2186 (32.51)	698	31.9	5044	0.67	-0.38
11	1560	2032 (30.22)	775	38.1	6053	0.75	-0.38
12	12786	2288 (34.02)	892	40.0	5918	0.13	-0.43
13	18478	2034 (30.25)	888	43.7	6053	-0.23	-0.37
14	3263	2383 (35.44)	900	37.8	5044	0.17	-0.44
15	654	2180 (32.42)	655	30.0	4371	0.48	-0.05

Table 7. Probability of a difference between third interim grouping least square means for mean yields and standard deviations

		Mean yield prob.														
	Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	1	--	0.00	0.00	0.00	0.00	0.42	0.06	0.00	0.23	0.00	0.02	0.00	0.00	0.00	0.01
S	2	0.03	--	0.03	0.00	0.08	0.62	0.48	0.00	0.94	0.00	0.53	0.00	0.00	0.00	0.17
t	3	0.61	0.02	--	0.00	0.84	0.25	0.91	0.09	0.62	0.03	0.82	0.00	0.35	0.00	0.41
d	4	0.05	0.00	0.00	--	0.00	0.03	0.42	0.94	0.18	0.94	0.13	0.00	0.02	0.01	0.97
	5	0.00	0.00	0.00	0.04	--	0.28	0.87	0.08	0.66	0.03	0.89	0.00	0.29	0.00	0.38
D	6	0.03	0.00	0.01	0.14	0.43	--	0.38	0.06	0.70	0.05	0.42	0.00	0.15	0.00	0.16
e	7	0.14	0.49	0.18	0.03	0.00	0.01	--	0.48	0.66	0.46	0.82	0.08	0.88	0.05	0.59
v	8	0.10	0.83	0.15	0.00	0.00	0.00	0.59	--	0.22	0.99	0.21	0.07	0.23	0.04	0.99
	9	0.09	0.01	0.06	0.30	0.65	0.85	0.02	0.02	--	0.21	0.77	0.03	0.47	0.02	0.34
p	10	0.06	0.00	0.01	0.67	0.29	0.22	0.02	0.00	0.40	--	0.18	0.03	0.14	0.02	0.99
r	11	0.00	0.00	0.00	0.01	0.12	0.74	0.00	0.00	0.62	0.04	--	0.00	0.56	0.00	0.41
o	12	0.00	0.00	0.00	0.24	0.42	0.28	0.01	0.00	0.49	0.66	0.06	--	0.00	0.47	0.37
b	13	0.05	0.00	0.00	0.97	0.03	0.14	0.03	0.00	0.29	0.65	0.01	0.22	--	0.00	0.56
.	14	0.36	0.57	0.51	0.02	0.00	0.01	0.36	0.55	0.04	0.02	0.00	0.00	0.02	--	0.24
	15	0.90	0.38	0.77	0.59	0.26	0.16	0.26	0.36	0.25	0.50	0.06	0.38	0.59	0.58	--

Table 8. Significant correlations ($p<0.05$) between patterns of mean yields for the third interim grouping of ARAs[1,2]

		Correlation coefficients														
	Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
N	1		0.84	0.91	0.76	0.88	--	--	--	--	0.60	--	0.71	0.65	0.62	--
o	2	21		0.87	0.94	0.94	--	--	0.72	0.64	0.70	0.53	0.84	0.76	0.76	--
.	3	21	23		0.84	0.93	--	--	0.62	--	0.69	0.46	0.77	0.77	0.74	0.57
	4	21	23	23		0.91	--	--	0.71	--	0.62	0.63	0.90	0.84	0.85	--
o	5	21	23	23	23		--	--	0.60	--	0.61	0.63	0.85	0.82	0.78	0.56
f	6	12	12	12	12	12		--	--	--	--	--	--	--	--	--
	7	12	12	12	12	12	12		0.68	0.70	--	--	--	--	--	--
Y	8	16	16	16	16	16	12	12		0.73	0.73	--	0.52	0.52	--	0.57
e	9	12	12	12	12	12	11	11	12		0.75	--	--	--	--	--
a	10	18	19	19	19	19	12	12	15	12		--	0.56	0.53	0.53	--
r	11	18	18	18	18	18	12	12	15	12	17		0.62	0.67	0.59	0.55
s	12	21	23	23	23	23	12	12	16	12	19	18		0.89	0.96	--
	13	21	23	23	23	23	12	12	16	12	19	18	23		0.93	0.66
	14	21	23	23	23	23	12	12	16	12	19	18	23	23		--
	15	13	13	13	13	13	12	12	13	12	13	13	13	13	13	

1 -- indicates pairs of ARAs which were not significantly correlated ($p>0.05$)

2 number of years in which both ARAs in the comparison had at least 10 observations.

2.5.3. Physical Refinements to the Statistically Grouped ARAs

The next phase of risk area development involved the subjective comparison of the soil biophysical data for each defined group. This was done to ensure that the groups made sense physically. Soil landscape information was obtained from the legend of the Soil Landscape Map of Manitoba. The soil landscape information used included soil development, soil parent material, soil texture, deposition of parent material, surface form, degree of slope and average elevation.

Two types of group realignment occurred as a consequence of the reexamination. In some cases an ARA was judged physically incompatible with other ARAs in that group whereby it was split off; in other cases, ARAs had similar physical characteristics to groups of which they were not a member. Only the following adjustments were then made:

1) Group 1 (ARAs 1,2,3,10,13): This group was split into two parts. The first group contained ARAs 1,2 and 3 and the second group contained ARAs 10 and 13. This split was due to the following differences in soil development, parent materials, surface forms and slope:

	First group	Second group
Soil development	Black Chernozemic	Regosolic
Parent material	Morainal, lacustrine	Eolian, undiff.
Surface forms	Level, knoll/kettle	Hummocky, dissected
Slope	1 - 4 %	4 - 30 %

2) Group 2 (ARAs 4,5) and Group 3 (ARAs 6,11,12,37): ARA 6 was removed from Group 3 and joined with Group 2 because:

A) it was statistically similar to ARAs 4 and 5. All the grouping criteria were met except the correlation did not exceed 0.79 (ARA 4 vs 6: R=0.72, ARA 5 vs 6: R=0.75);
B) soil landscape features of ARA 6 were more consistent with ARAs 4 and 5;
C) ARA 6 was geographically close to ARAs 4 and 5.

3) Group 3 (ARAs 11,12,37) and Group 15 (ARA 39): ARA 39 was grouped with the ARAs in Group 3 because of similarities in soil development (Dark Gray Chernozemic), deposition methods (lacustrine) and range of slopes (1 - 3 per cent). Also the group statistics were similar to those of ARA 39 in all ways, except that patterns of annual mean yield were not highly correlated (R=0.57). Ultimately the ARAs in this group were segmented into two subgroups. The first consisted of ARAs 11 and 12, and the second ARAs 37 and 39. This was due to the geographic separations of these two areas.

4) Group 4 (ARAs 7,8,16): This group was divided into two subgroups; ARAs 7 and 8 in the first subgroup, and ARA 16 in the second. This was due to the following differences in soil landscapes:

	First group	Second group
Soil development	Black Chernozemic	Gray Luvisolic
Soil texture	Clay loam	Loam
Surface form	Undulating,hummocky	Knoll/kettle
Slope	1 - 15 %	16 - 30 %
Elevation	300 - 400 m	500 - 700 m

5) Group 5 (ARAs 9,22,28,29,31) and Group 6 (ARA 14): ARA 14 was joined to Group 5 due to similar soil landscape features, and it was statistically similarity to ARA 22 (passed all criteria except for a low correlation; R=0.61).

6) Group 7 (ARA 15) and Group 8 (ARA 17): The ARAs in these two groups were joined due to similar soil landscape features. Also these groups were statistically similar except that the correlation in mean yield patterns was only 0.68.

7) Group 9 (ARA 18) and Group 10 (ARAs 19 and 21): ARA 18 was statistically similar to the ARAs in Group 10, except that the correlation in annual mean yields was only 0.75. The two groups had similar soil textures (clay loam), some similarity in deposition and they are geographically close together.

This phase of risk area development resulted in the evolution of 11 groups of ARAs, with three of these groups split into subgroups based on soil and geographic considerations. Table 5 lists the ARAs in each group (Fourth iteration). Again the grouping criteria was applied to these groups (Tables 9 and 10). The evidence showed that no further combining of groups was necessary.

Table 9. Probability of a difference between fourth interim grouping least square means for mean yields and standard deviations[1]

		Mean yield probabilities													
	Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	1	--	0.22	0.00	0.00	0.00	0.00	0.08	0.00	0.16	0.00	0.01	0.00	0.00	0.00
S	2	0.01	--	0.15	0.01	0.00	0.01	0.52	0.00	0.49	0.00	0.16	0.00	0.00	0.00
t	3	0.91	0.00	--	0.02	0.00	0.07	0.68	0.01	0.96	0.00	0.56	0.00	0.00	0.00
d	4	0.12	0.10	0.01	--	0.00	0.76	0.15	0.18	0.57	0.06	0.73	0.00	0.55	0.00
	5	0.00	0.92	0.00	0.01	--	0.00	0.01	0.69	0.18	0.94	0.14	0.00	0.03	0.01
D	6	0.00	0.41	0.00	0.00	0.12	--	0.21	0.14	0.64	0.05	0.84	0.00	0.39	0.00
e	7	0.00	0.26	0.00	0.01	0.15	0.51	--	0.04	0.80	0.02	0.46	0.00	0.09	0.00
v	8	0.65	0.05	0.52	0.39	0.01	0.00	0.00	--	0.28	0.78	0.28	0.02	0.33	0.02
	9	0.02	0.37	0.02	0.08	0.31	0.58	0.89	0.04	--	0.21	0.77	0.03	0.47	0.02
p	10	0.00	0.84	0.00	0.02	0.68	0.47	0.29	0.02	0.41	--	0.19	0.03	0.15	0.03
r	11	0.00	0.05	0.00	0.00	0.02	0.10	0.39	0.00	0.63	0.05	--	0.01	0.57	0.00
o	12	0.00	0.56	0.00	0.00	0.25	0.70	0.40	0.00	0.50	0.66	0.07	--	0.00	0.48
b	13	0.00	0.91	0.00	0.00	0.98	0.10	0.14	0.01	0.30	0.66	0.02	0.22	--	0.00
.	14	0.66	0.07	0.54	0.45	0.02	0.00	0.01	0.99	0.05	0.02	0.00	0.00	0.02	--

[1] these comparisons were done prior to the final ordering of groups into risk areas.

The final step in the process involved reordering the final set of groups by the magnitude of their mean yield, and designating the subgroups as subgroup A and subgroup B. This resulted in the final risk area designations. Table 11 lists the ARAs in each risk area and the corresponding descriptive statistics. Figure 6 is a map of the new risk areas that were developed in this study.

Table 10. Significant correlations ($p<0.05$) between patterns of mean yields for the fourth interim grouping of ARAs[1,2,3]

		Correlation coefficients													
	Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14
N	1		0.88	0.80	0.83	0.69	0.84	--	--	--	0.58	--	0.67	0.73	0.62
o	2	17		0.90	0.91	0.86	0.91	0.59	0.56	--	0.66	0.47	0.80	0.71	0.72
.	3	17	21		0.85	0.94	0.93	0.72	0.71	0.64	0.70	0.54	0.84	0.76	0.76
o	4	17	21	23		0.82	0.92	0.61	0.59	--	0.68	--	0.76	0.77	0.74
f	5	17	21	23	23		0.91	0.72	0.66	--	0.62	0.63	0.90	0.84	0.85
	6	17	21	23	23	23		0.63	0.54	--	0.60	0.61	0.85	0.83	0.78
Y	7	14	14	14	14	14	14		0.78	0.59	0.60	0.61	--	0.53	--
e	8	15	16	16	16	16	16	14		0.78	0.70	--	--	--	--
a	9	12	12	12	12	12	12	12	12		0.75	--	--	--	--
r	10	17	18	19	19	19	19	14	15	12		--	0.56	0.53	0.53
s	11	17	18	18	18	18	18	14	15	12	17		0.62	0.67	0.59
	12	17	21	23	23	23	23	14	16	12	19	18		0.89	0.96
	13	17	21	23	23	23	23	14	16	12	19	18	24		0.92
	14	17	21	23	23	23	23	14	16	12	19	18	23	23	

1 -- indicates pairs of ARAs which were not significantly correlated
2 number of years in which both ARAs in the comparison had at least 10 observations.
3 these comparisons were done prior to the final ordering of groups into risk areas.

Table 11. Descriptive statistics for the risk areas[1,2].

Risk area	ARAs	No. of obs.	Mean yield kg/ha (bu/ac)	S.D. kg/ha	C.V. %	Max. yield kg/ha	Kurt.	Skew.
1A	1,2,3	4946	1549 (23.0)	751	48.5	4573	-0.34	0.05
1B	10,13	3028	1723 (25.6)	764	44.3	5044	-0.05	-0.07
2	4,5,6	19484	1898 (28.2)	757	39.9	6053	0.19	0.07
3	9,14,22, 28,29,31	14969	1962 (29.2)	792	40.4	5716	0.11	-0.21
4	26	1560	2032 (30.2)	775	38.1	6053	0.75	-0.38
5A	11,12	18114	2027 (30.1)	711	35.1	6053	0.56	-0.21
5B	37,39	923	2149 (32.0)	738	34.3	4708	0.34	-0.13
6	35	18478	2034 (30.3)	888	43.7	6053	-0.23	-0.37
7	18,19,21	5828	2159 (32.1)	709	32.8	4573	0.58	-0.39
8A	7,8	15085	2180 (32.4)	838	38.4	6053	0.20	-0.03
8B	16	958	2035 (30.3)	653	32.1	4053	0.40	-0.14
9	15,17	3975	2194 (32.6)	661	30.1	5380	0.70	-0.12
10	33,34	12786	2288 (34.0)	892	39.0	5918	0.13	-0.43
11	36	3263	2363 (35.4)	900	37.8	4578	0.17	-0.44

1 the total risk area mean yields for Risk Areas 1, 5 and 8 can be found in the detailed descriptions of these risk areas in the text
2 these are the same ARA groupings as the fourth set of interim groups but sorted by mean yield.

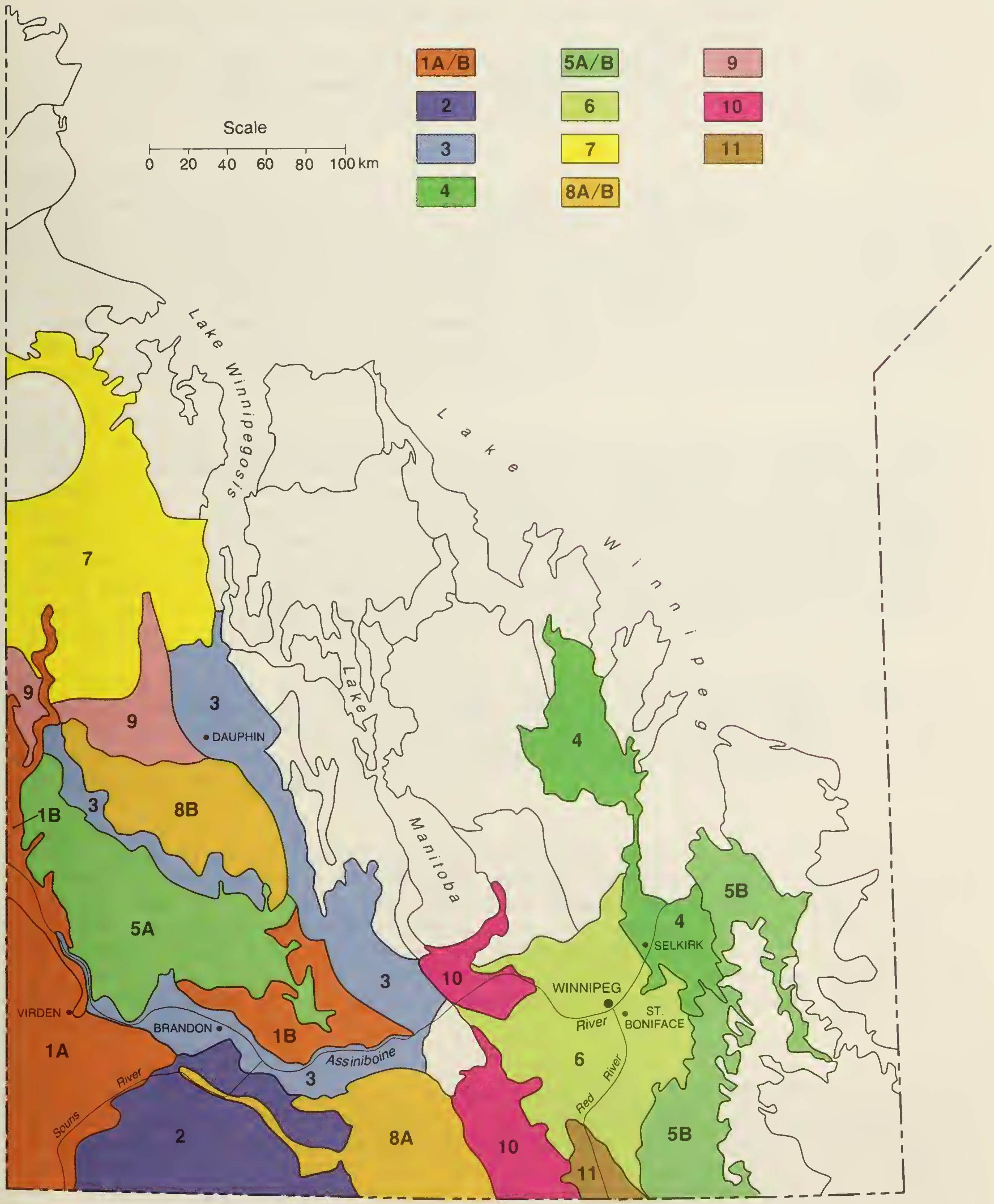

Fig. 6. The 11 new Risk Areas developed from the qualifying ARAs in Manitoba, based on statistical differentiation and soil landscape characteristics. The areas are arranged by increasing mean yields.

2.6. DESCRIPTIONS OF THE NEW RISK AREAS FOR MANITOBA

This section describes each risk area in terms of it's location, size and relative level of variability (C.V.). Soil landscape features and climatic conditions for each risk area are found in Table 12.

Risk Area 1A

This section of Risk Area 1 is located in the extreme south west corner of the province. It is bounded by the U.S. border to the south and the Saskatchewan border to the west. Area 1A includes the Souris River plain and the towns of Melita and Souris. It is 0.649 million hectares (1.604 million acres) in size. The mean yield (area average) for this part of Risk Area 1 is the lowest of all the risk areas in the study (1549 kg/ha) but the variability of yield is the highest (C.V.=48.5 per cent).

Risk Area 1B

This section of Risk Area 1 is split into two portions. The western segment consists of the flood plains of the Shell, South Saskatchewan and Assiniboine Rivers, including the towns of Miniota and Virden. The Eastern segment includes the areas around Neepawa, Brandon and Shilo, but not the areas surrounding Carberry and Melbourne. The mean yield for this part of Risk Area 1 is 1723 kg/ha and the measure of variability (C.V.) is 44.4 per cent. This is one of the smaller risk areas with only 0.446 million hectares (1.102 million acres).

The overall mean yield for Risk Area 1 is 1613 kg/ha and the relative variability is 47.1 per cent. The total area is 1.095 million hectares (2.707 million acres). The risk level in this area is the highest of all risk areas as shown by the high relative variability of yield.

Risk Area 2

This risk area is directly east of Risk Area 1 and includes the broad table lands surrounding Turtle Mountain Provincial Park except for the Souris and Pembina River valleys. Boissevain, Hilton, Belmont and Cartwright are all found within this area. The mean yield for this area is 1898 kg/ha. and the C.V. is 39.9 per cent, indicating a lower level of risk compared to Risk Area 1. There are 0.714 million hectares (1.765 million acres) in Risk Area 2.

Risk Area 3:

This risk area comprises three sections, all located in the western half of the province. The western section is located on the southern flank of Riding Mountain National Park. The central section is in the West Lake Region, extending to the area north of Dauphin Lake and west of Lake Winnipegosis including the Dauphin, Sifton and Fork River areas. It also includes the areas south of Gladstone and the regions west of Portage La Prairie. The third and most southerly section includes the Assiniboine

River valley from Brandon to Spruce Woods Provincial Park. The mean yield for this spatially diverse risk area is 1962 kg/ha, and the relative variability is fairly high (C.V.=40.4 per cent). This is the third largest risk area with 1.155 million hectares (2.853 million acres).

Risk Area 4

This risk area is made up of a section in the eastern part of the Interlake Region, from just south of Lake St. George to Lake Winnipeg, including Gimli and Beaconia and a section to the south that includes the area around Selkirk, Beausejour and Vivian. The mean yield for this risk area is 2032 kg/ha and the C.V. is the fifth lowest at 38.1 per cent. The risk area is one of the smaller areas with 0.529 million hectares (1.306 million acres).

Risk Area 5A

This area is the western section of Risk Area 5. It consists of the Newdale Plain, including the towns of Russell, Birtle, Minnedosa and Carberry. It is the largest of the two sections in Risk Area 5, with 0.888 million hectares (2.194 million acres). The mean yield for this section is 2027 kg/ha and the C.V. is fairly low at 35.1 per cent.

Risk Area 5B

The second part of Risk Area 5 is in the south eastern, sandy land region of the province. The northern extreme begins at the southeast shore of Lake Winnipeg (Grand Beach Provincial Park) and continues east to Great Falls. There are two southern areas, one to the south east including the Pinawa and Hadashville areas and the second is due south to the U.S. border. Risk Area 5B has a higher mean yield than Risk Area 5A (2149 kg/ha) and a lower C.V. (34.4 per cent). There are 0.627 million hectares (1.550 million acres) in this section of Risk Area 5.

Risk Area 5 has an overall mean yield of 2033 kg/ha, which is very similar to the mean yields of Risk Areas 4 and 6. The level of variability, however, is comparatively lower at 35.1 per cent. Risk Area 5 is one of the more favourable areas in terms of variability in that it has the third lowest C.V. It is the largest risk area with 1.515 million hectares (3.744 million acres).

Risk Area 6

This region consists of a large portion of the Winnipeg Plain. It includes most of the Red River Valley from Steinbach to the U.S. border. The mean yield is moderate at 2034 kg/ha, but the C.V. is the second highest at 43.7 per cent. It is the sixth largest risk area with 0.920 million hectares (2.273 million acres).

Risk Area 7

This is the most northern risk area included in this study. It extends from Red Deer Lake to Duck Mountain Provincial Park, excluding the Porcupine Hills, and from the Saskatchewan border to the western shores of Lake Winnipegosis. It includes the towns of Camperville, Cowan and Benito. The level of relative variability is the second lowest of all risk areas in this study (C.V.=32.1 per cent) and the mean yield is comparatively high (2210 kg/ha). The area is 1.167 million hectares (2.884 million acres).

Risk Area 8A
This is the south part of Risk Area 8 and it is located in the south central part of the province. It extends north from the U.S. border to Notre Dames de Lourdes and west to Morden. The mean yield of this risk area is 2180 kg/ha and the C.V. is 38.4 per cent. The relative variability and size of this risk area are average compared to other areas. The size is 0.483 million hectares (1.193 million acres).

Risk Area 8B
This north section of Risk Area 8 includes the Riding Mountain National Park area. The mean yield for this section of Risk Area 8 is 2035 kg/ha, which is lower than the mean yield in Risk Area 8A. The level of relative variability, however, is also lower at 32.1 per cent. This section is almost the same size as the southern section with 0.469 million hectares (1.160 million acres).

Risk Area 8 consists of 0.952 million hectares (2.352 million acres) with an overall mean yield of 2172 kg/ha, and a C.V. of 38.2 per cent.

Risk Area 9
The Shell River divides this risk area into two sections. The western section is the area from the Saskatchewan border to Roblin and south to Lake of the Prairie, and the eastern section includes the Grandview area north of Riding Mountain National Park up to Pine River. The mean yield for this small risk area is 2194 kg/ha, and the C.V. is the lowest of all areas at 30.1 per cent. This combination of minimum variability and fairly high production potential, identifies this risk area as one of the most favourable wheat production areas in the province. It is, however, the second smallest with only 0.289 million hectares (0.714 million acres).

Risk Area 10
This risk area consists of a southern and northern section. The southern section is located in the south west portion of the Winnipeg Plain extending south to the U.S. border, including the towns of Winkler, Carman and Altona. It is

Table 12. General soil landscape and climate data for each risk area

Risk area	Soil development[1]	Texture[2]	Deposition[3]	Surface form[4]	Slope (%)	Elevation (metres)	GSL[5] (days)	Degree days >5°C	Days to mature[6]	APPTN[7] (mm)
1A	Bl. Chern	S,SL	M,L	L,K/K	1-3	400-500	171.8	1741.7	90.7	306.2
1B	Regosolic	S,L	E	D,H	4-30	300-300	168.5	1632.5	91.4	303.0
2	Bl,G Chern	L,CL	M,L	L,K/K,H	4-15	400-600	175.2	1632.7	89.5	357.6
3	Bl,G Chern	L,CL	M,L	L,K/K	1-9	300-500	170.8	1626.2	90.7	324.0
4	G Chern	C	L	L	1-3	200-300	168.5	1573.0	89.5	321.3
5A	Bl Chern	L	M	L,K/K	1-3	400-500	167.9	1584.0	91.9	304.7
5B	G Chern	SL,C	L	L	1-3	200-300	172.4	1679.5	88.1	343.2
6	Bl Chern	C	L	L	1-3	200-300	175.1	1767.0	87.0	317.7
7	Chern,Luv	CL,L	M,L	L,K/K	1-30	400-800	163.5	1456.7	94.1	296.3
8A	Bl,G Chern	CL	M	H,U	1-15	200-300	173.9	1605.5	89.9	344.4
8B	Luv	L	M	K/K	16-30	400-700	157.2	1291.0	107.5	340.9
9	Bl,G Chern	L,CL	M,L	K/K,U	1-9	400-500	164.2	1497.0	92.8	302.8
10	Bl Chern	L,CL	L	L	1-3	200	176.3	1776.5	86.7	312.8
11	Bl Chern	CL	L	L	1-3	200-300	177.3	1906.0	85.6	334.5

[1] Bl Chern - Black Chernozemic, G Chern - Dark Gray Chernozemic, Chern - a mixture of Black And Dark Gray, Luv - Luvisolic
[2] S - sandy, SL - Sandy Loam, L - Loam, CL - Clay Loam, C - clay
[3] M - morainal, L - lacustrine, E - eolian
[4] L - level, K/K - knoll and kettle, H - hummocky, U - undulating, D - dissected
[5] growing season length - the number of days when mean daily temperature remains above 5°C.
[6] for spring wheat - number of days between seeding and harvest.
[7] accumulated precipitation during the growing season (May through September inclusive).

located between Risk Area 6 and Risk Area 8A. The smaller, northern section is situated at the south end of Lake Manitoba around the city of Portage La Prairie. The mean yield is 2288 kg/ha, which is the second highest in the province, but the C.V. is 39.0 per cent. The total area of this risk area is 0.398 million hectares (0.983 million acres).

Risk Area 11

This risk area has a total area of only 0.070 million hectares (0.173 million acres). It flanks the Red River, south of Risk Area 6 and east of Risk Area 9. The southern edge of this risk area is the U.S. border including the town of Emerson. The mean yield of 2383 kg/ha is the highest of all the areas, but the level of relative variability is fourth smallest (C.V.=37.8 per cent).

2.7. RELATIONSHIP OF THE NEW RISK AREAS TO THE FREQUENCY OF YIELD FAILURE

The data in each risk area were examined to identify the frequency of zero yields (harvest was not completed in a quarter section in a given year) and the frequency of yields that were less than a given level of production guarantee. Several levels of production guarantees were used because coverage levels are being increased under the new Crop Insurance legislation. Results are shown in Table 13.

The frequency of zero yields in all areas was low. Risk Areas 5B, 8B and 9 had the lowest frequency at about 0.5 percent, whereas Risk Areas 4 and 6 had frequencies of approximately 3.0 percent. The provincial average frequency of zero yields was 1.8 percent.

The production guarantee is the area average yield multiplied by a critical yield level. It is similar to coverage levels employed in crop insurance. The data in Table 13 show that these ranged widely, depending on the risk area mean yields and the critical levels chosen.

As would be expected, varying the level of critical yield from 60 per cent to 80 per cent had a large influence on the frequency of "production failure", i.e. the number of times that farm yields fell below the production guarantee. The average provincial failure rate at the 60 per cent yield level was 14.7 per cent, whereas it was 20.3 per cent at the 70 per cent level and 27.4 per cent at the 80 per cent level. Risk Areas 7 and 9 had failure rates as low as 9.7 per cent and 8.5 per cent, respectively, at the 60 per cent production guarantee, while only Risk Areas 1A and 1B had failure rates exceeding 21 per cent. These results were consistent with the expected frequencies based on a normal distribution, and the relative variabilities (C.V) reported in Table 11. At the 80 per cent critical yield level the rates of failure were approximately 25 per cent in Risk Areas 7 and 9, and

Table 13. Frequency of reported yields less than the yield guarantee for each risk area

Risk area	C.V. (%)	Production guarantee kg/ha (bu/ac)[1] Critical yield levels(%) 60	70	80	Frequency (%) < guarantee and > zero[2] Critical yield levels(%) 60	70	80	Total frequency[3] (%) Critical yield levels(%) 60	70	80
1A	48.5	929 (13.8)	1084 (16.1)	1239 (18.4)	19.1	26.2	30.8	21.6	28.7	33.3
1B	44.3	1034 (15.4)	1206 (17.9)	1379 (20.5)	18.7	20.2	31.8	21.4	22.9	34.5
2	39.9	1139 (16.9)	1328 (19.8)	1518 (22.6)	14.3	18.5	28.3	15.7	19.9	29.7
3	40.4	1177 (17.5)	1373 (20.4)	1570 (23.3)	13.2	22.5	26.0	15.3	24.6	28.1
4	38.1	1219 (18.1)	1422 (21.2)	1625 (24.2)	10.7	17.2	20.2	13.9	20.4	23.4
5A	35.1	1217 (18.1)	1419 (21.1)	1621 (24.1)	11.1	17.8	21.7	12.3	19.0	22.9
5B	34.3	1289 (19.2)	1504 (22.4)	1719 (25.6)	10.6	16.9	28.7	11.2	17.5	29.3
6	43.7	1221 (18.2)	1424 (21.2)	1627 (24.2)	16.0	21.1	24.1	18.9	24.1	27.0
7	32.8	1296 (19.3)	1512 (22.5)	1728 (25.7)	8.5	15.7	25.1	9.7	16.9	26.3
8A	38.4	1308 (19.5)	1527 (22.7)	1744 (25.9)	12.5	19.9	28.9	13.8	21.2	30.2
8B	32.1	1221 (18.2)	1424 (21.2)	1628 (24.2)	11.3	18.0	21.9	11.7	18.4	22.3
9	30.1	1316 (19.6)	1536 (22.8)	1755 (26.1)	8.1	13.9	24.0	8.5	14.3	24.4
10	39.0	1373 (20.4)	1601 (23.8)	1831 (27.2)	14.9	16.6	24.0	17.2	18.9	26.3
11	37.8	1444 (22.5)	1668 (24.8)	1907 (28.4)	11.6	14.1	22.7	14.3	16.8	25.4

[1] production guarantee = risk area mean yield x critical yield level.
[2] this is the proportion of the total number of records in a risk area which were greater than 0 and less than the production guarantee.
[3] total frequency = (% < production guarantee) + (% yields reported as 0)

34 per cent in Risk Areas 1A and 1B. Four areas had failure rates between 20 and 25 per cent, seven were between 25 and 30 per cent and three exceeded 30 per cent at the 80 per cent critical yield level.

Increasing critical yield levels would have significant impact on any future safety net programs and they would have to be carefully accommodated to ensure the actuarial soundness of these programs. Also each area would have to be assessed individually because the frequency of failure is dependent on the level of relative variability (C.V.). Assuming a normal distribution and a low C.V. (30 per cent) the expected frequency of failure would range from 11.6 per cent at the 60 per cent critical yield level to 25.1 per cent at 80 per cent critical yield level. Comparative frequencies at higher levels of relative variability (40 per cent) are from 18.7 to 33.0 per cent. These expected values are similar to the actual values reported in Table 13 at similar levels of relative variability.

3. SUMMARY AND CONCLUSIONS

The final risk areas identified in this study were developed from spring wheat yield data and soil biophysical information. They reflect natural yield variability that is often beyond the ability of the farmer to control. The effects of management were minimized by using only data from continuous or stubble rotations with nitrogen application rates of at least 44.8 kg/ha (40 lbs/ac).

Approximately 125,000 wheat yield records over a 25 year period (1964 to 1988) were extracted from the Manitoba Crop Insurance Corporation questionnaire files. These yield values were integrated into a geographic framework called Agroecological Resource Areas (ARAs), based on natural features that reflect production potentials. The yield data from each ARA were examined by a series of statistical procedures, to identify and compare the spatial and temporal variability of yields. ARAs were grouped together if they passed four statistical measures of similarity and possessed similar soil/geographic characteristics. Several conclusions can be drawn from the results of this study:

1) The 31 ARAs used in this study were initially grouped into 15 statistically distinct areas. However, by considering soil biophysical characteristics, these statistically defined areas were refined into 11 Risk Areas in which three were subdivided.

2) The risk areas derived from this study differ from the risk areas currently used in Manitoba in several ways. There is an increased use of natural features to define boundaries, because natural features are a characteristic of the original ARA boundaries. Also the areas are defined on the basis of means, standard deviations and the pattern of annual mean

yield. This adds new dimensions to the identification of risk areas, in that it incorporates the evaluation of yield variability as an integral component in defining levels of risk. The ARAs are required to have similar mean yields and standard deviations overall, as well as similar patterns in annual mean yield to be identified as areas of equal production risk.

3) The risk areas defined in this study are sometimes comprised of several non-contiguous units. Although this is to be expected, it differs from the traditional approach where each area was a continuous geographic region. The cause of the yield variability within each unit in a single risk area may be different, but all units react similarly in terms of yield variability. The size differentials between risk areas is also greater in the ARA-based risk areas than it is in the current risk areas in Manitoba.

4) The methodology that was developed to identify risk areas for this study can be used for other crops in the province, providing that there are adequate numbers of observations, spread over a sufficient number of years. This methodology can also be applied to other provinces, where similar data are available.

5) The risk areas developed in this study are specific to spring wheat. Although other spring seeded cereals (except maize) could be expected to perform somewhat similarly, this is not the case for other crops such as oilseeds or forages. Therefore other risk area maps would have to be developed for these crops.

6) Increasing the level of critical yield has dramatic effects on the frequency of yield failure, and this would have to be carefully accommodated in any new program. Each area would have to be treated separately due to the varying levels of mean yields and relative variability.

The results of this study provide a statistically and scientifically sound evaluation of yield variability and production risk throughout the agricultural area of Manitoba. It provides the basis for redefinition and refinement of risk areas for crop insurance, but at the same time provides fundamental guidance for all other safety net programs. Based on proper knowledge of yield levels, variability and risk, these programs can be more equitable, more financially self-sustaining and more easily administered.

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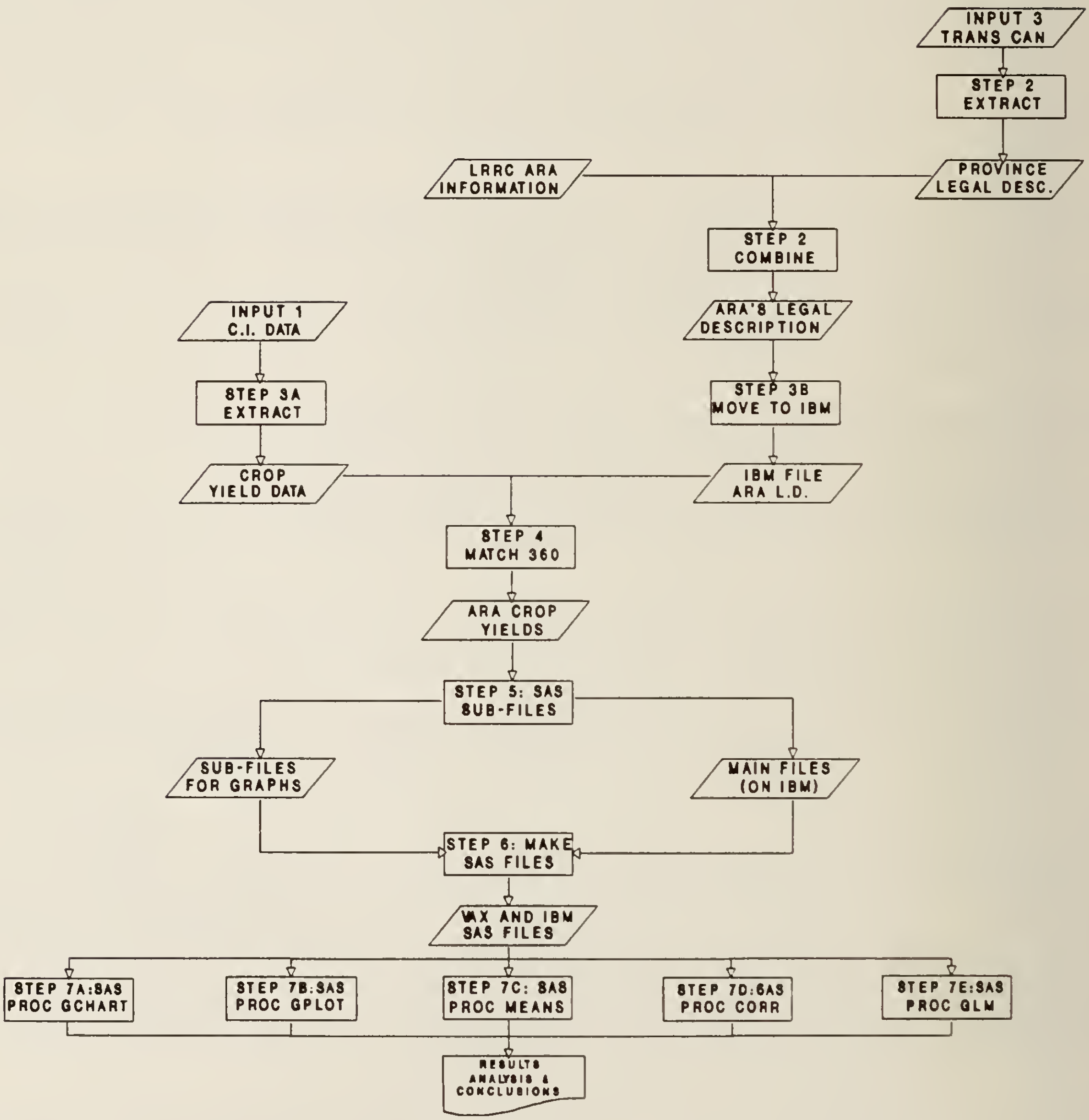
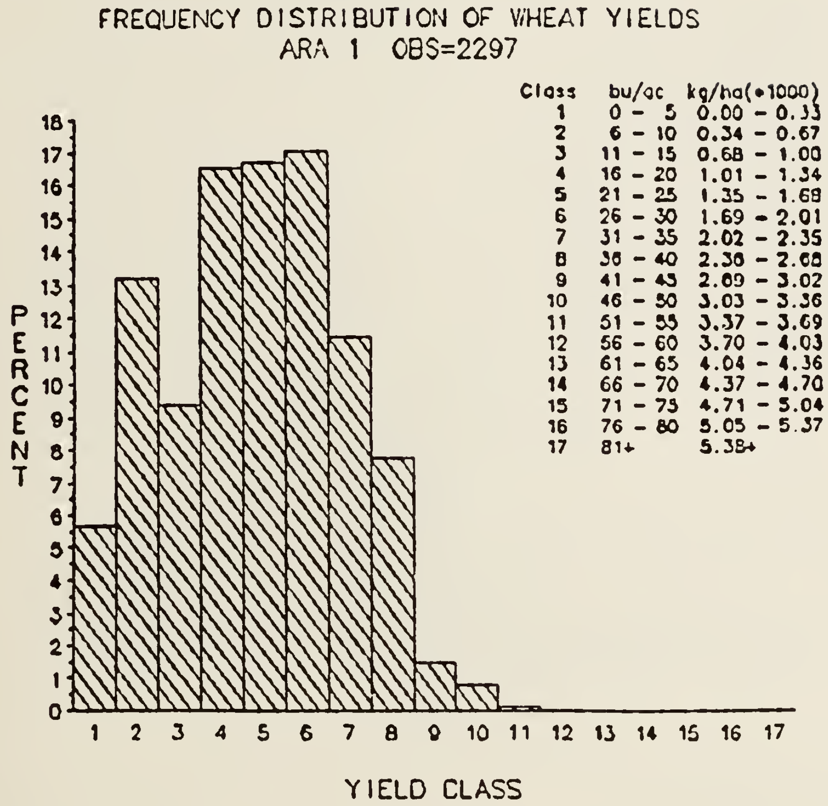
5. APPENDICES

APPENDIX 1. File preparation and data flow chart

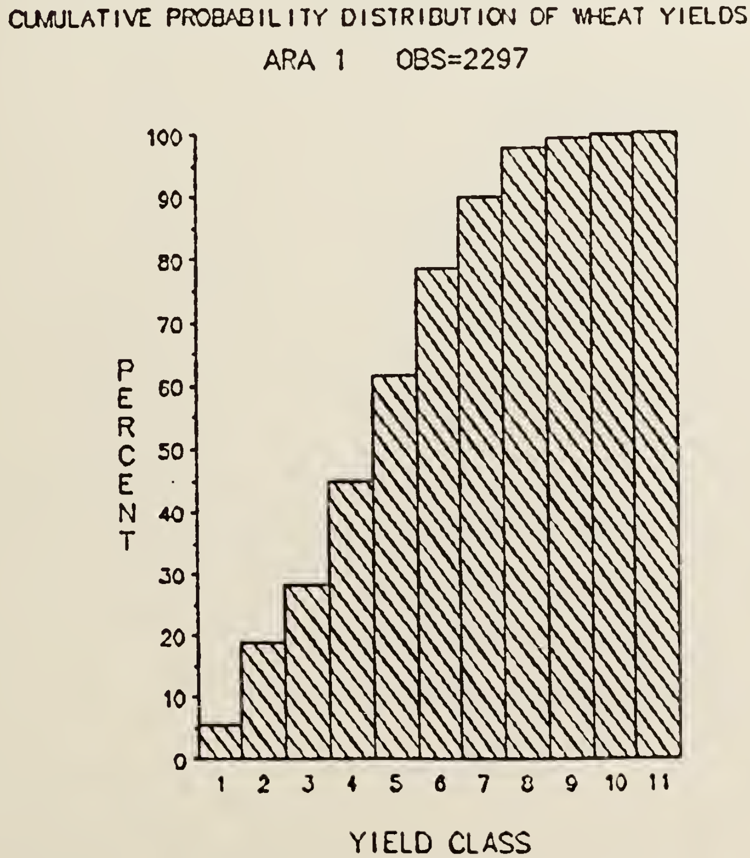


Appendix 2. Graphic descriptions of qualifying ARAs

ARA 1 Figure 1:

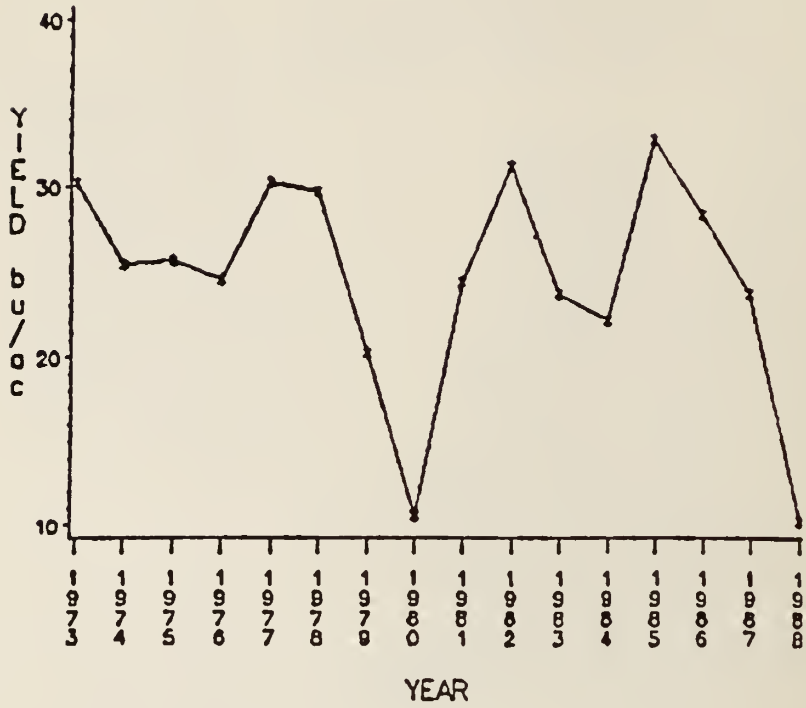


ARA 1 Figure 2:



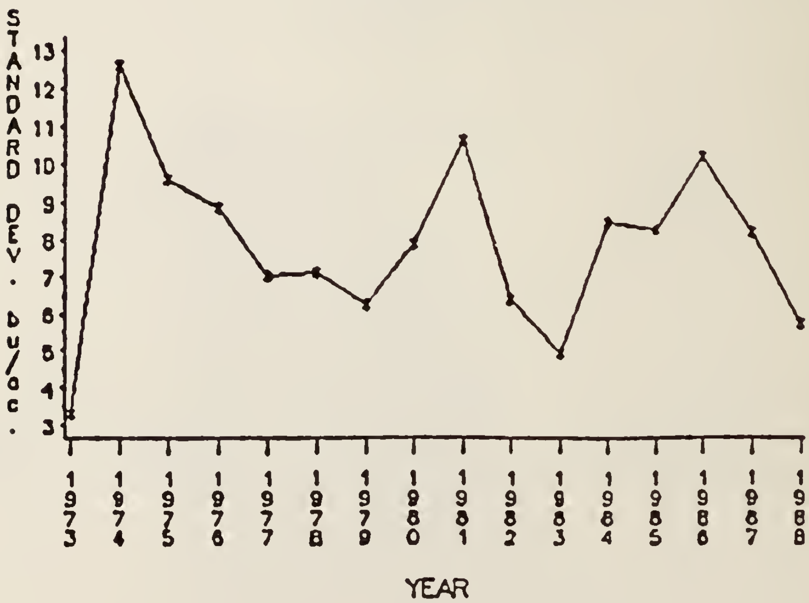
ARA 1 Figure 3:

AVERAGE WHEAT YIELDS FOR ARA 1



ARA 1 Figure 4:

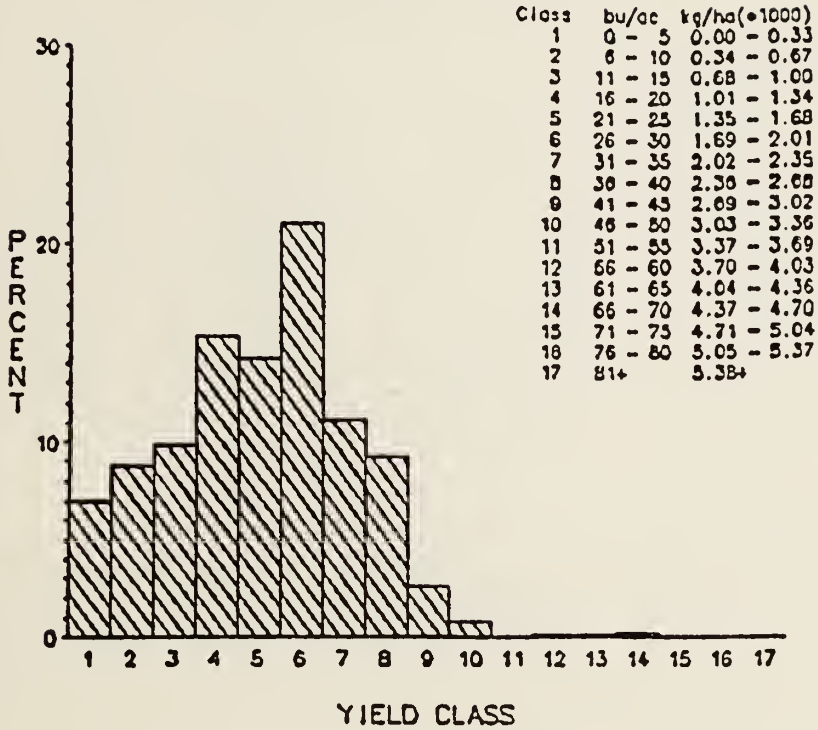
S.D. FROM THE MEAN WHEAT YIELDS
FOR ARA 1



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1973-1988
Nitrogen Level: 42kg/ha+

ARA 2 Figure 1:

FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 2 OBS=1210



ARA 2 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
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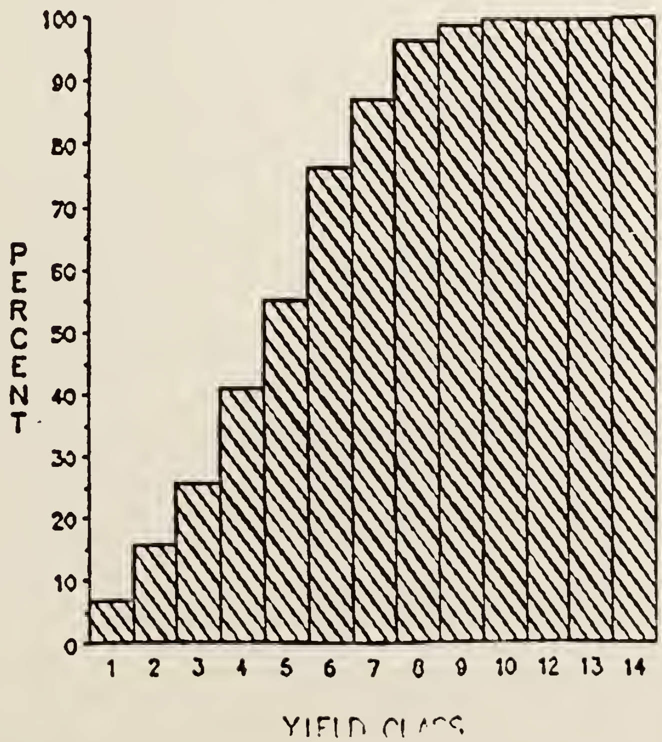
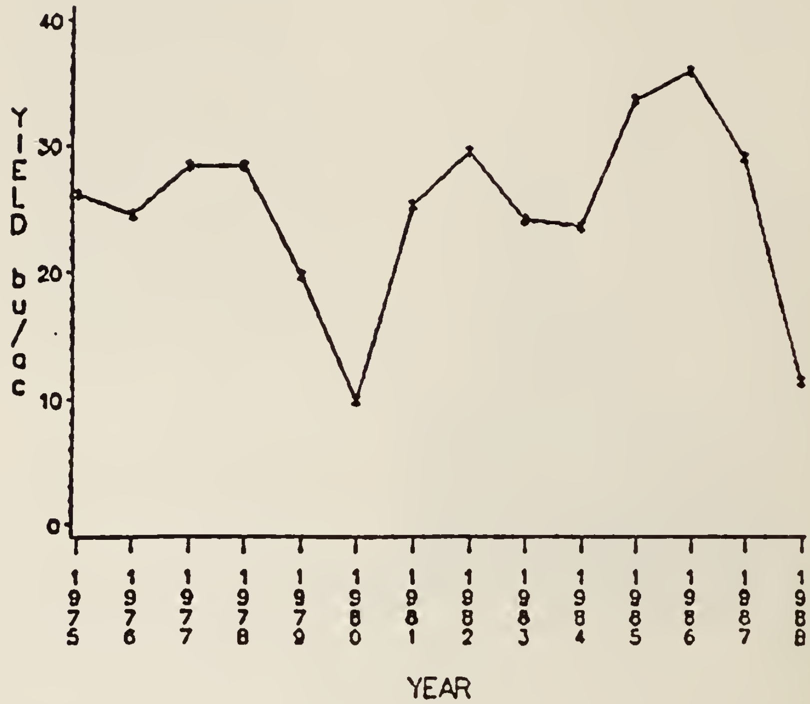


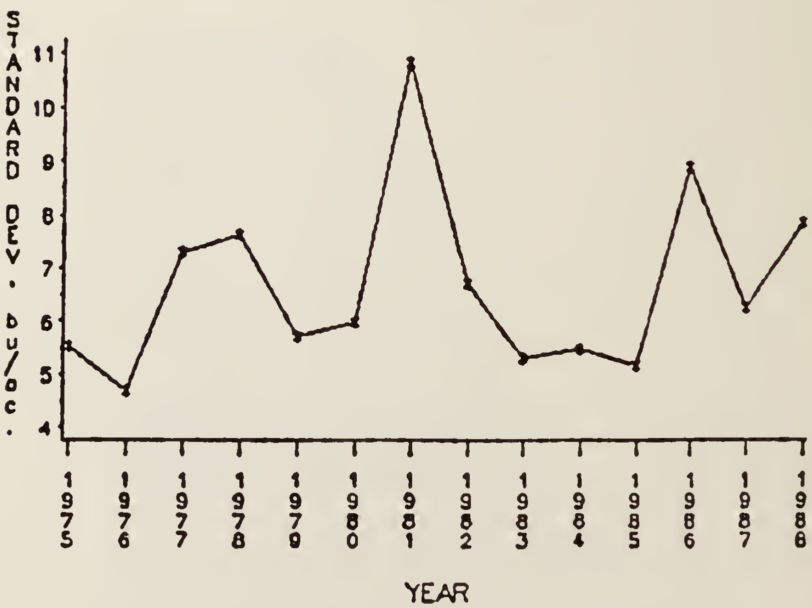
ARA 2 Figure 3:

AVERAGE WHEAT YIELDS FOR ARA 2



ARA 2 Figure 4:

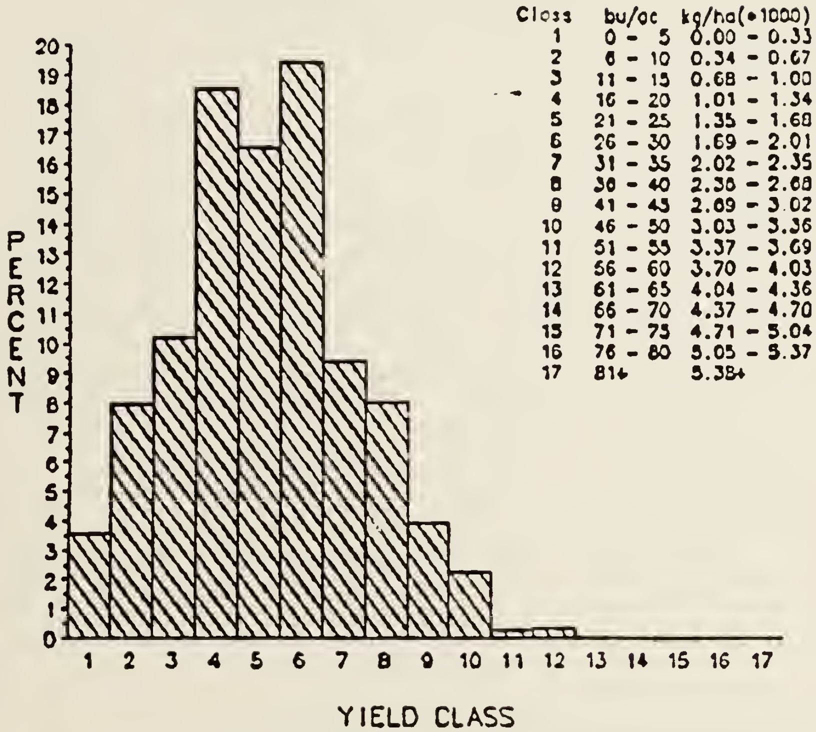
S.D. FROM THE MEAN WHEAT YIELDS
FOR ARA 2



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1975-1988
Nitrogen Level: 42kg/ha+

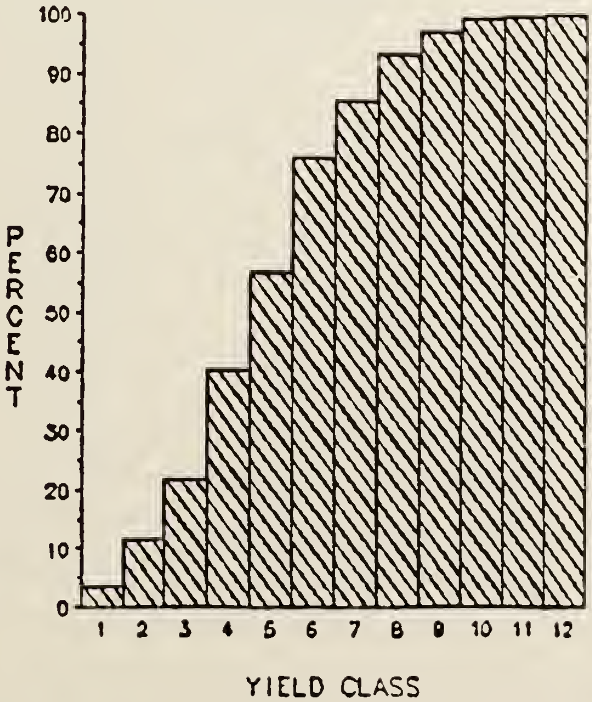
ARA 3 Figure 1:

FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 3 OBS=1439



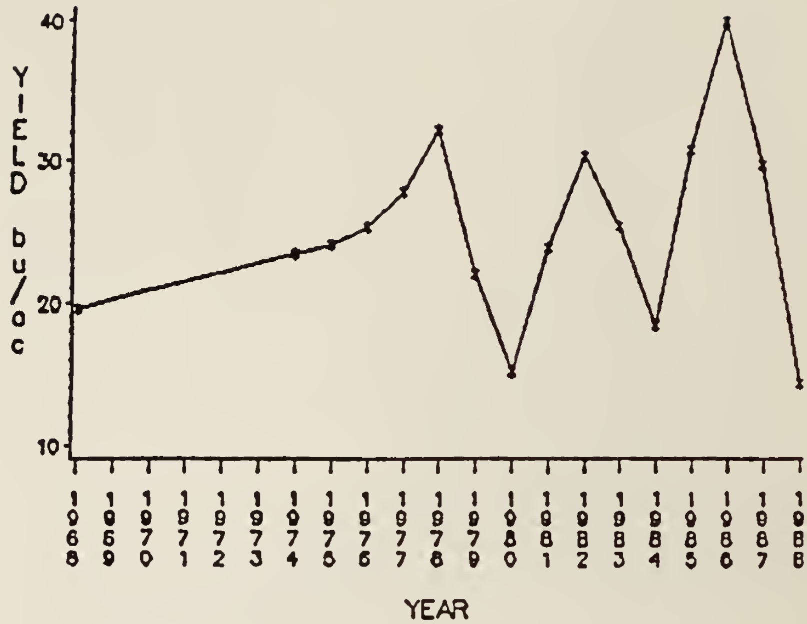
ARA 3 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 3 OBS=1439



ARA 3 Figure 3:

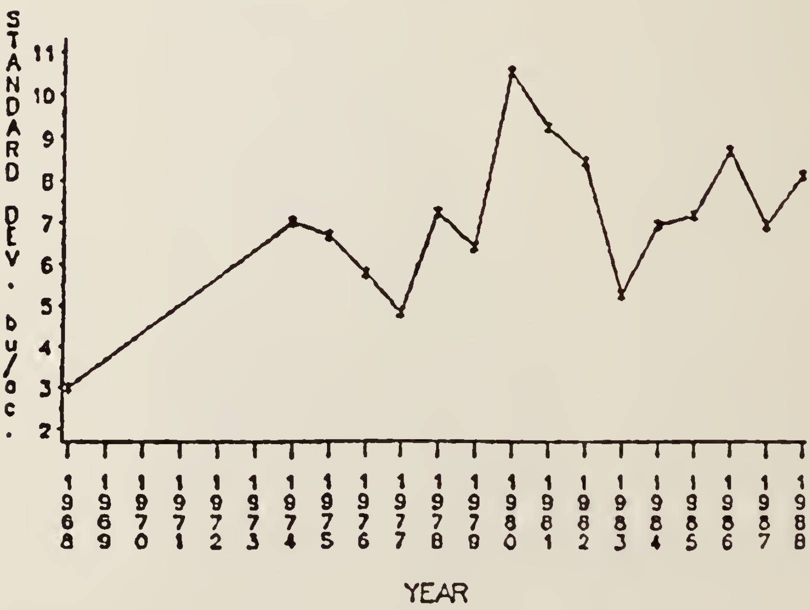
AVERAGE WHEAT YIELDS FOR ARA 3



• Represents years that have more than 10 reported yields
All other years are not included in the analysis

ARA 3 Figure 4:

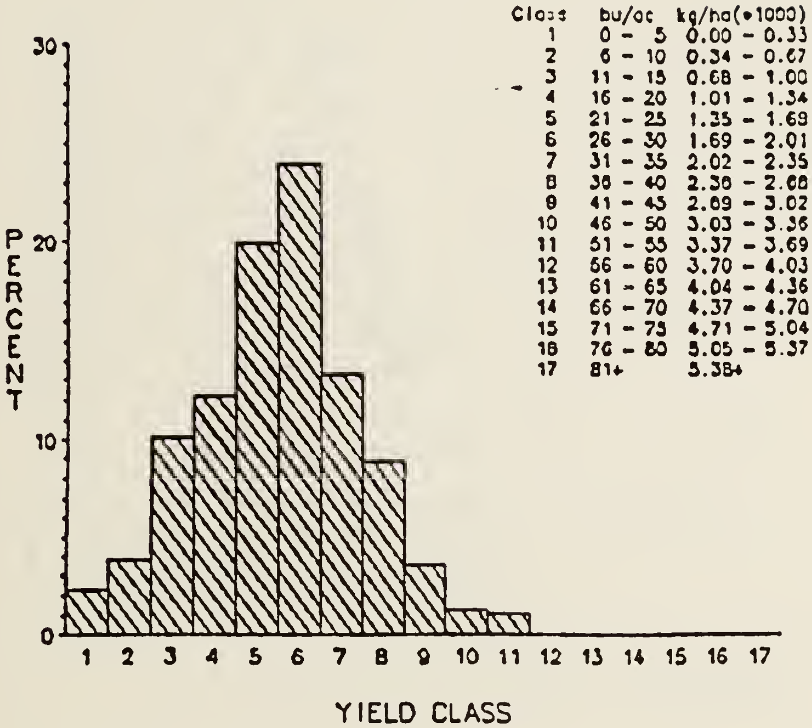
S.D. FROM THE MEAN WHEAT YIELDS
FOR ARA 3



Data Source: Manitoba Crop Insurance Corporation

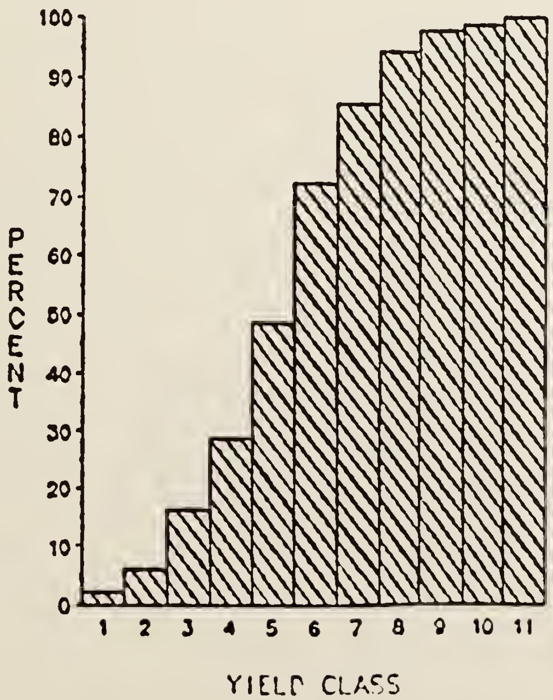
ARA 4 Figure 1:

FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 4 OBS=573



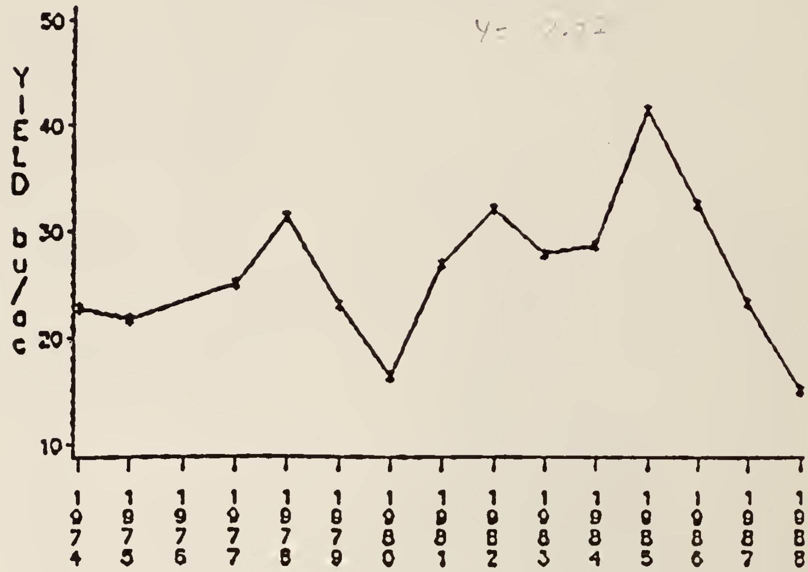
ARA 4 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 4 OBS=573



ARA 4 Figure 3:

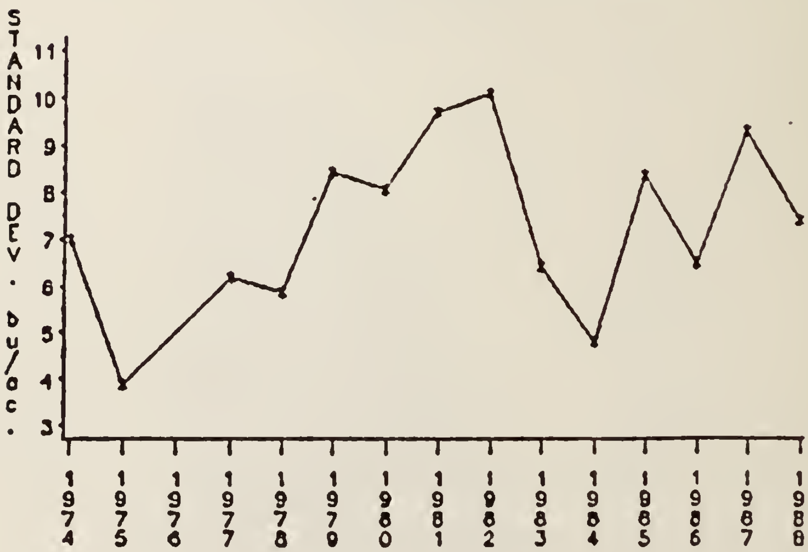
AVERAGE WHEAT YIELDS FOR ARA 4



• Represents years that have more than 10 reported yields
All other years are not included in the analysis

ARA 4 Figure 4:

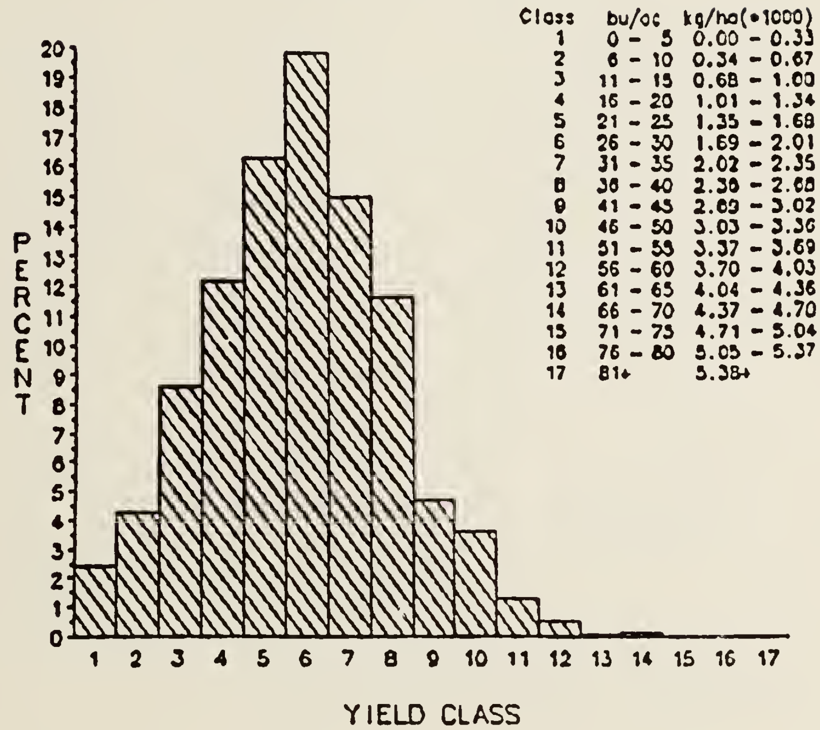
S.D. FROM THE MEAN WHEAT YIELDS
FOR ARA 4



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1974, 1975, 1977–1983
Nitrogen Level: 42kg/ha+

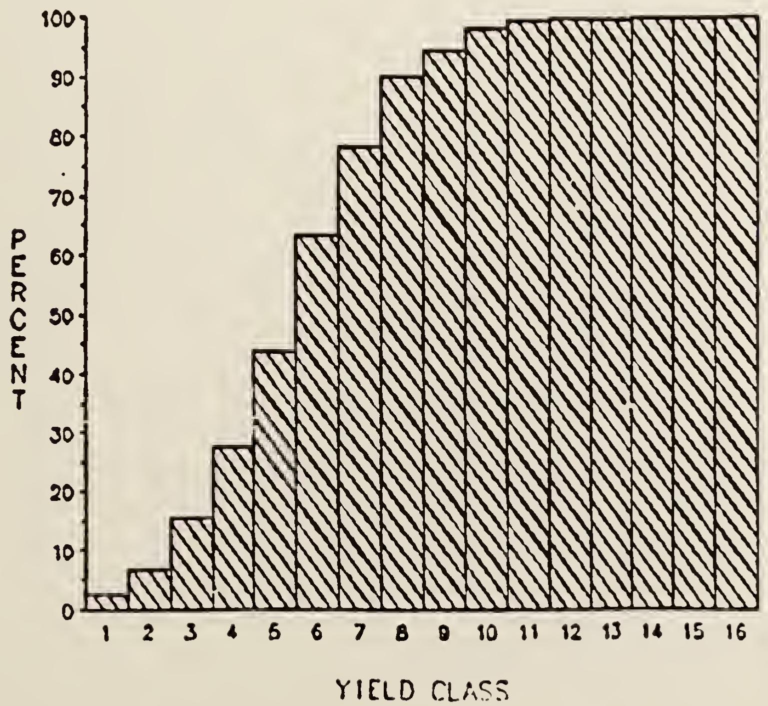
ARA 5 Figure 1:

FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 5 OBS=16278



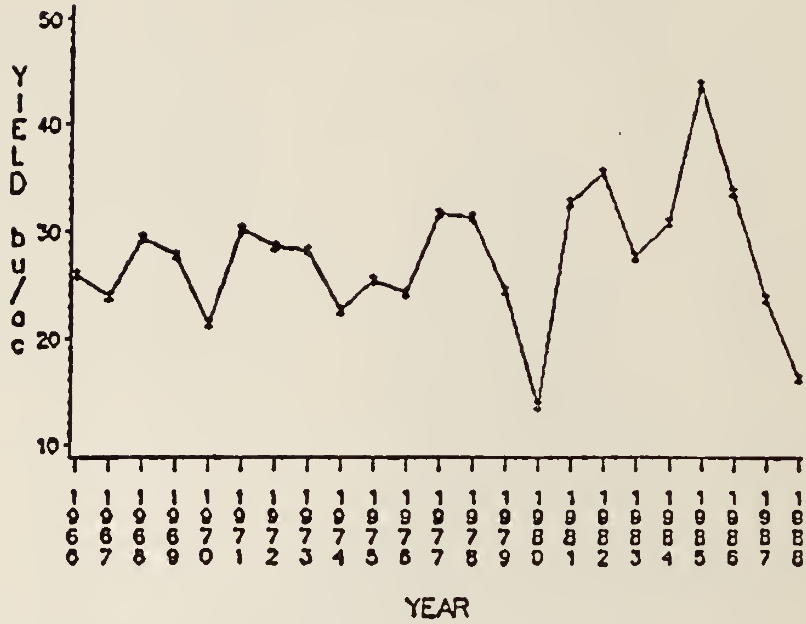
ARA 5 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 5 OBS=16278



ARA 5 Figure 3:

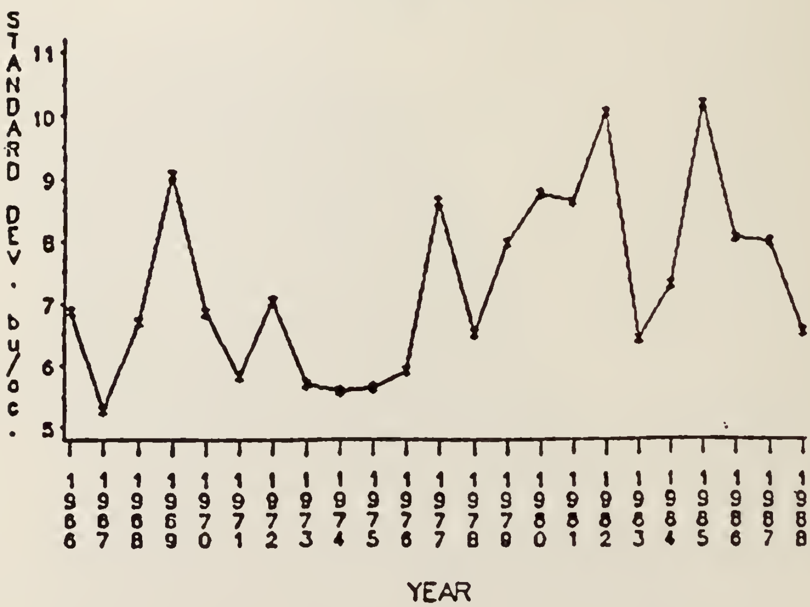
AVERAGE WHEAT YIELDS FOR ARA 5



* Represents years that have more than 10 reported yields
All other years are not included in the analysis

ARA 5 Figure 4:

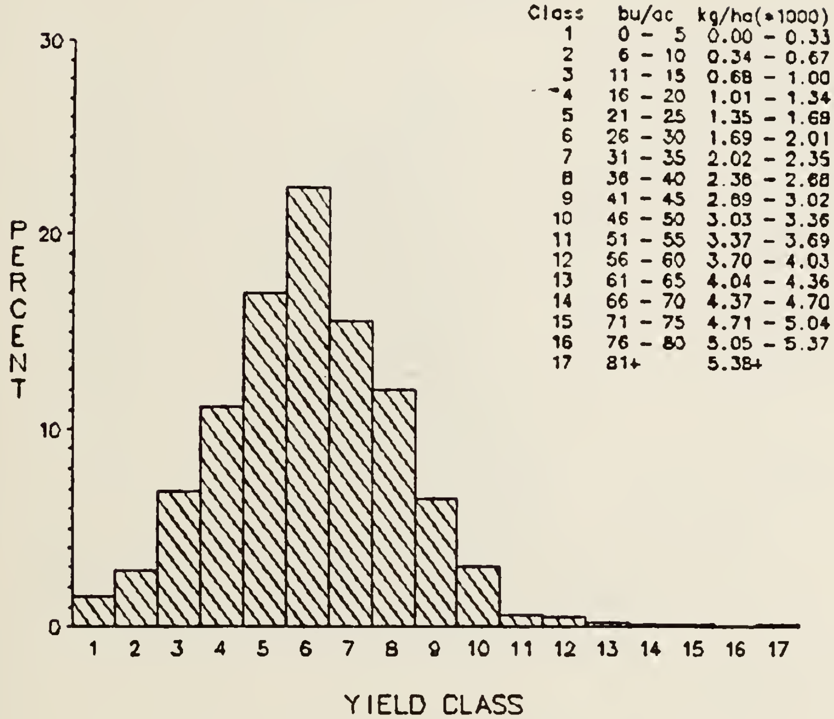
S.D. FROM THE MEAN WHEAT YIELDS
FOR ARA 5



Data Source:Manitoba Crop Insurance Corporation
Questionnaire 1966-1988
Nitrogen Level: 42kg/ha+

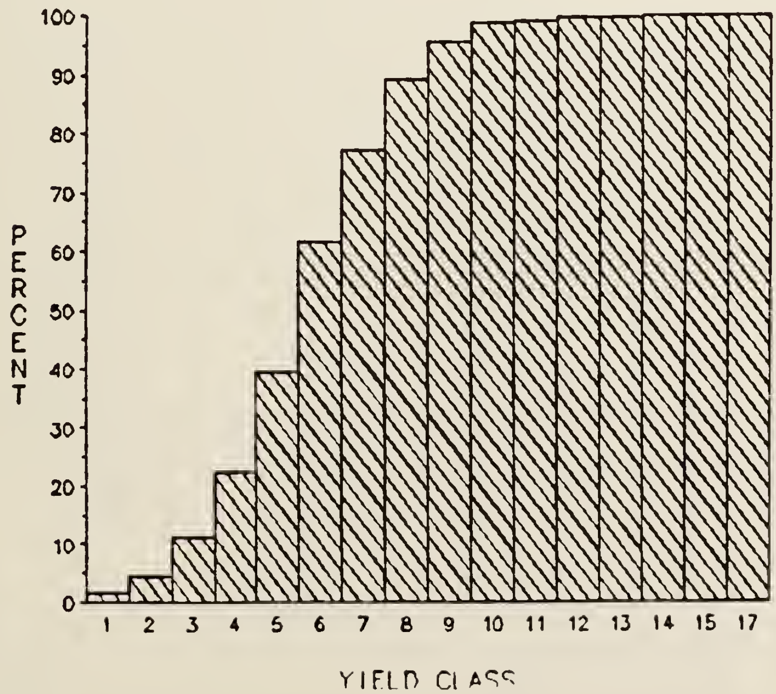
ARA 6 Figure 1:

FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 6 OBS=2633

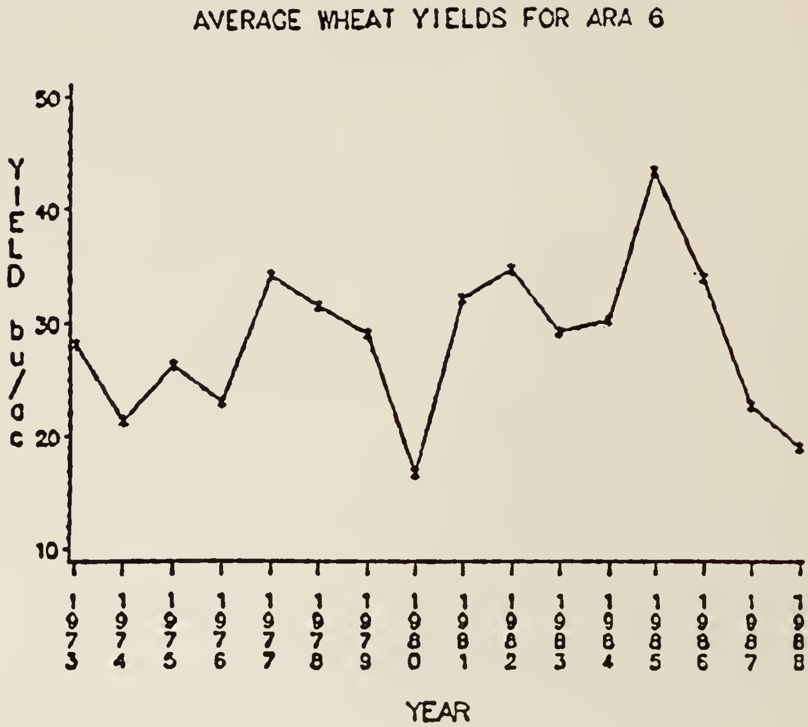


ARA 6 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 6 OBS=2633

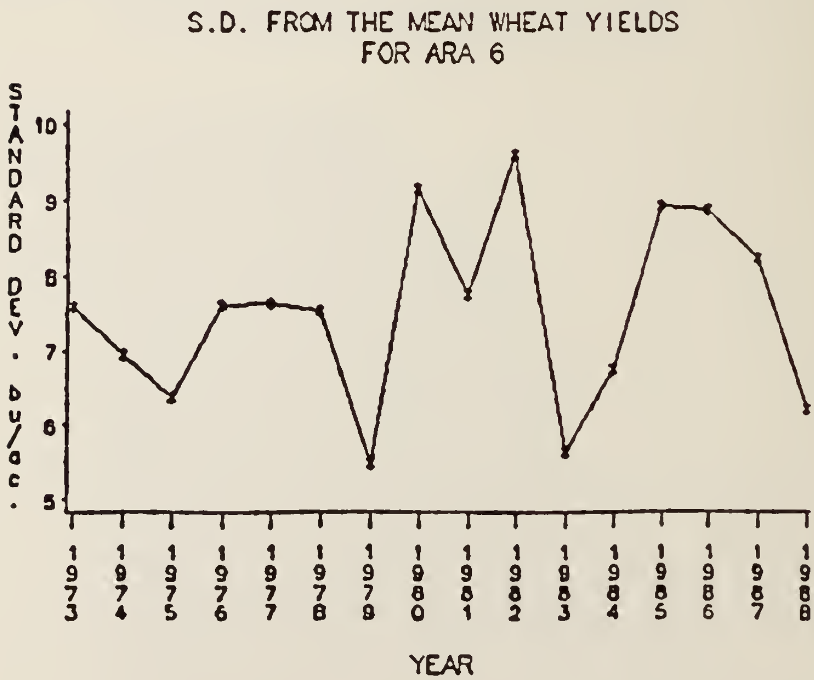


ARA 6 Figure 3:



• Represents years that have more than 10 reported yields

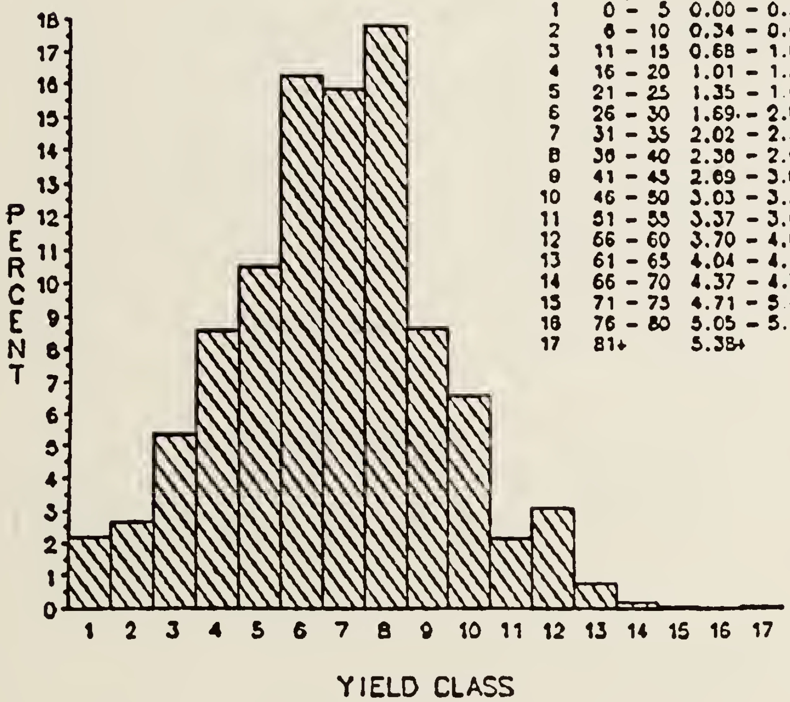
ARA 6 Figure 4:



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1973–1988
Nitrogen Level: 42kg/ha+

ARA 7 Figure 1:

FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 7 OBS=9780

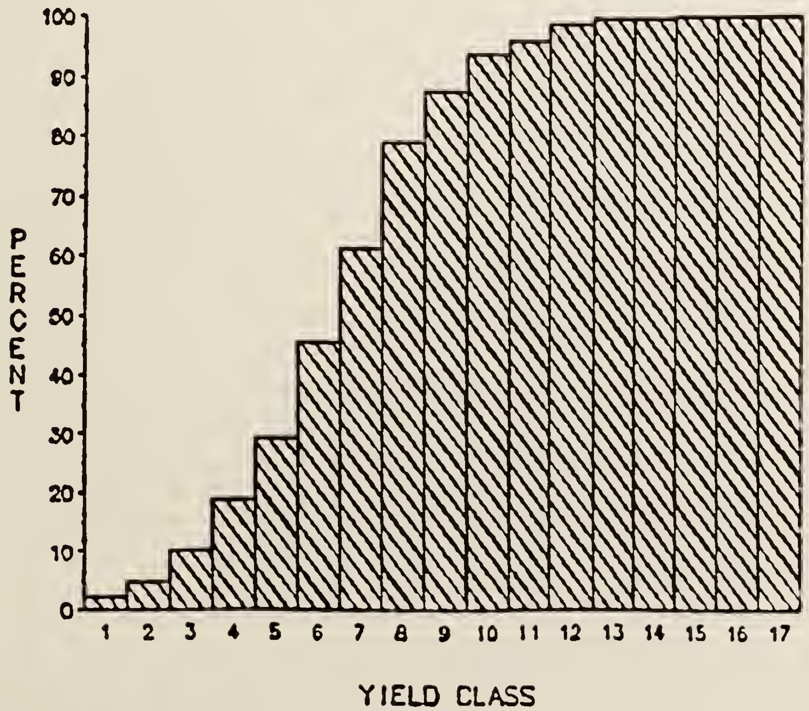


Class	bu/ac	kg/ha(*1000)
1	0 - 5	0.00 - 0.33
2	6 - 10	0.34 - 0.67
3	11 - 15	0.68 - 1.00
4	16 - 20	1.01 - 1.34
5	21 - 25	1.35 - 1.68
6	26 - 30	1.69 - 2.01
7	31 - 35	2.02 - 2.35
8	36 - 40	2.36 - 2.68
9	41 - 45	2.69 - 3.02
10	46 - 50	3.03 - 3.36
11	51 - 55	3.37 - 3.69
12	66 - 60	3.70 - 4.03
13	61 - 65	4.04 - 4.36
14	66 - 70	4.37 - 4.70
15	71 - 75	4.71 - 5.04
16	76 - 80	5.05 - 5.37
17	81+	5.38+

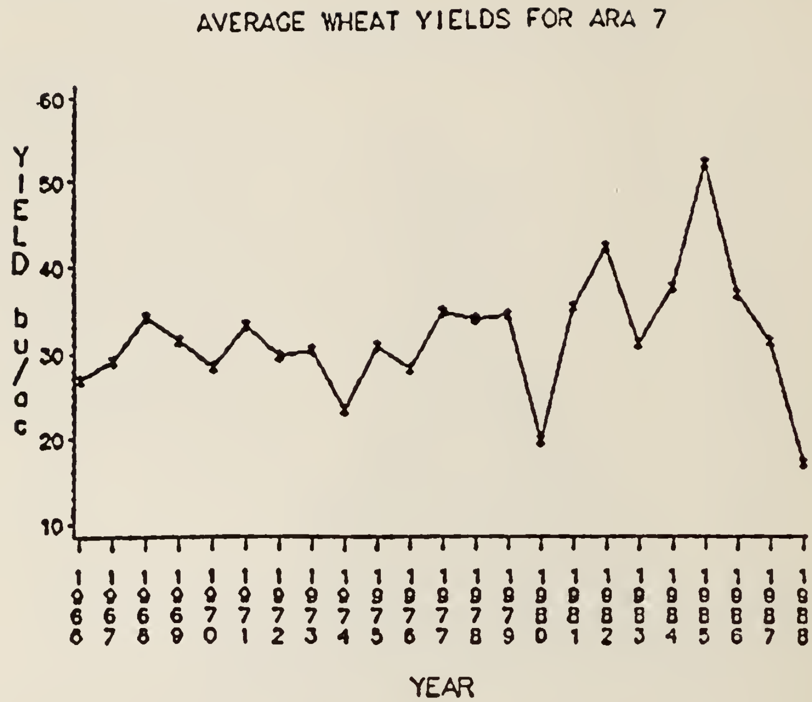
ARA 7 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS

ARA 7 OBS=9780

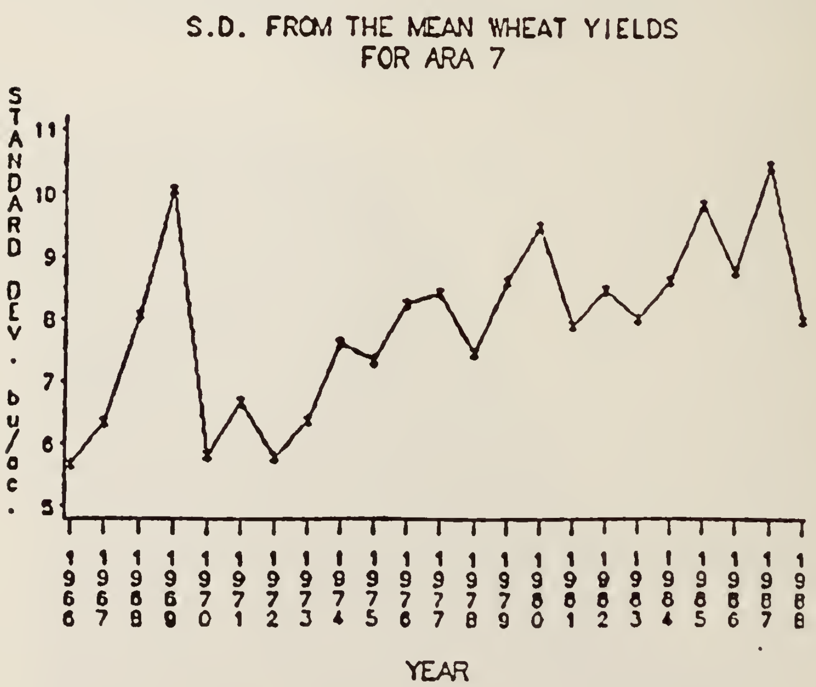


ARA 7 Figure 3:



* Represents years that have more than 10 reported yields
All other years are not included in the analysis

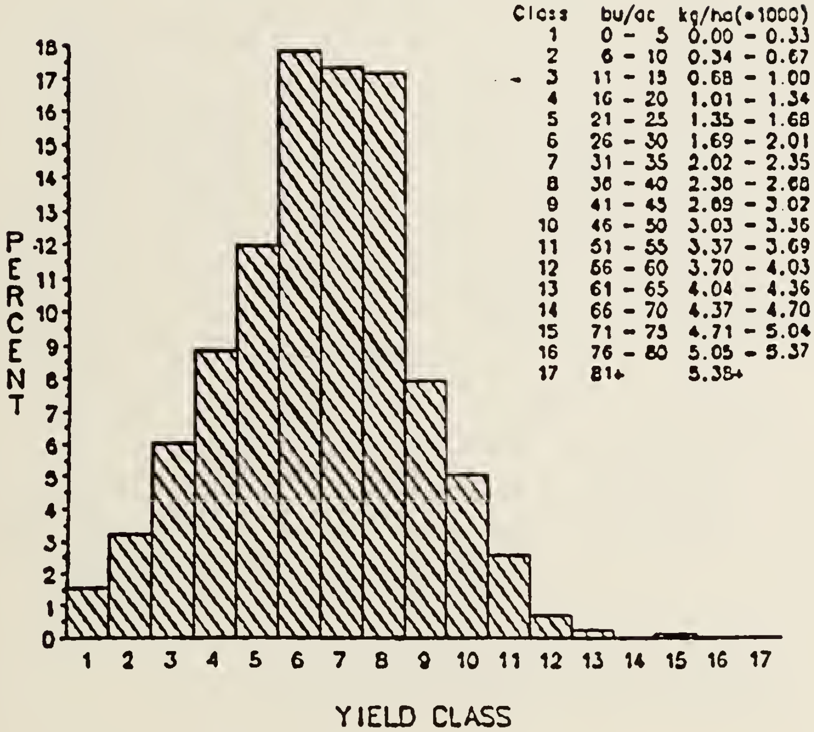
ARA 7 Figure 4:



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1966-1988

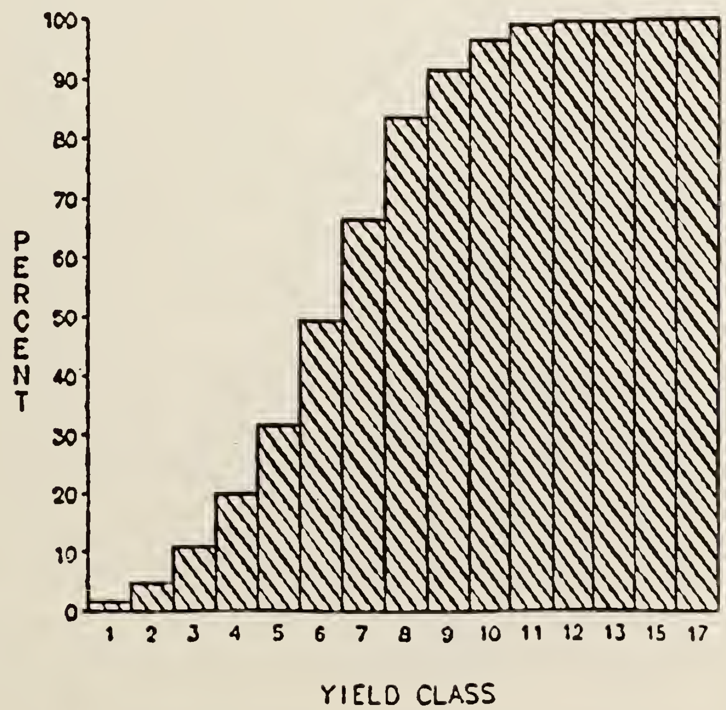
ARA 8 Figure 1:

FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 8 OBS=5305

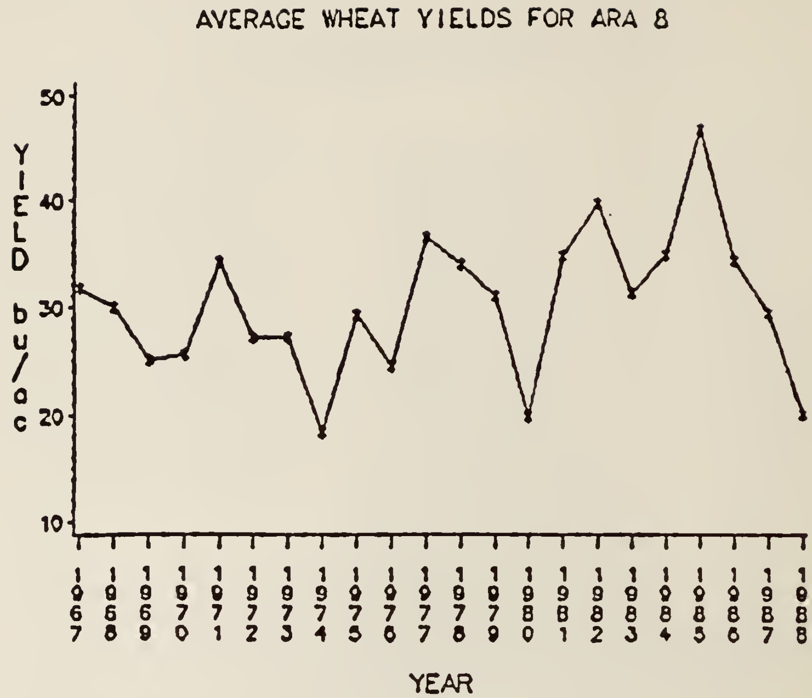


ARA 8 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 8 OBS=5305

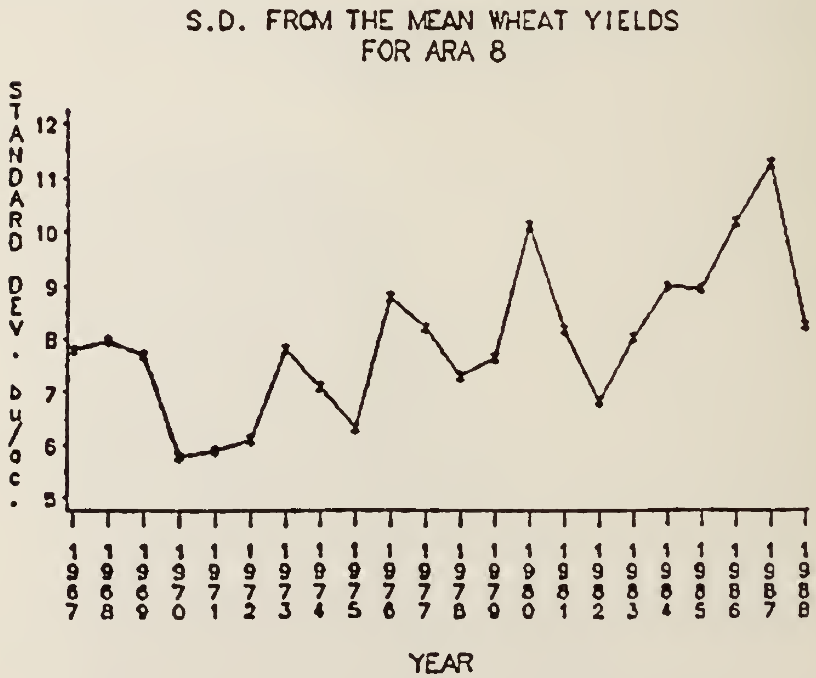


ARA 8 Figure 3:



• Represents years that have more than 10 reported yields
All other years are not included in the analysis

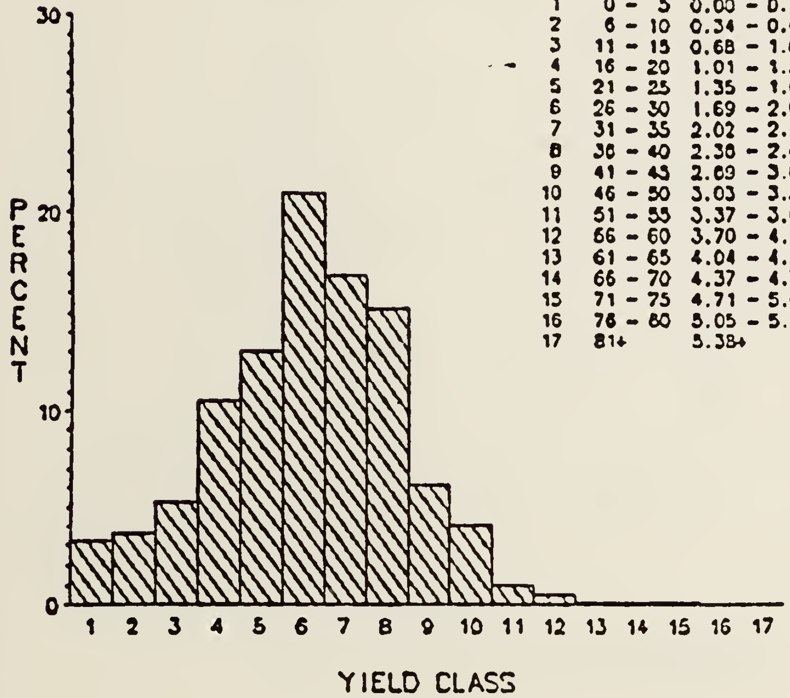
ARA 8 Figure 4:



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1967-1988
Nitrogen Level: 42kg/hae

ARA 9 Figure 1:

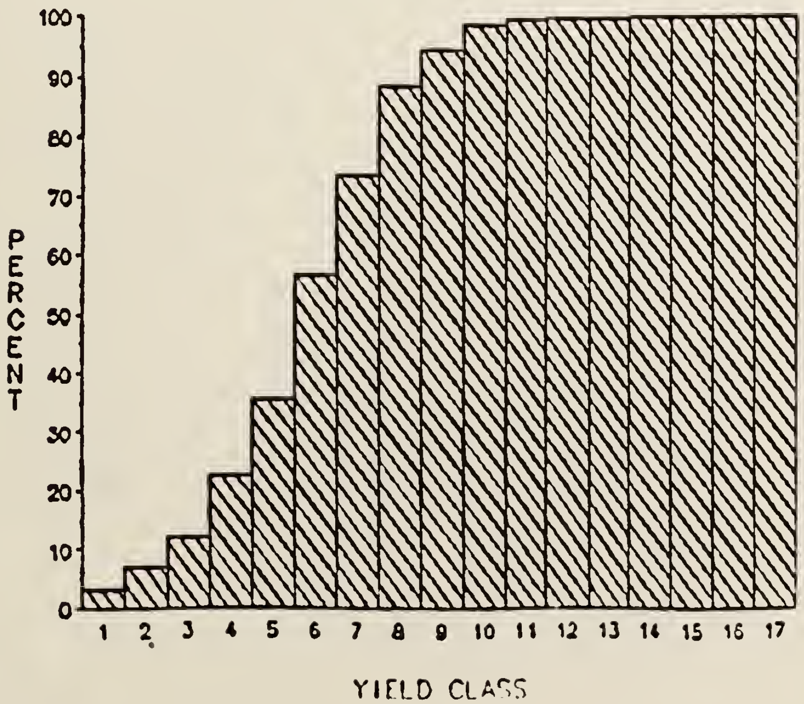
FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 9 OBS=7933



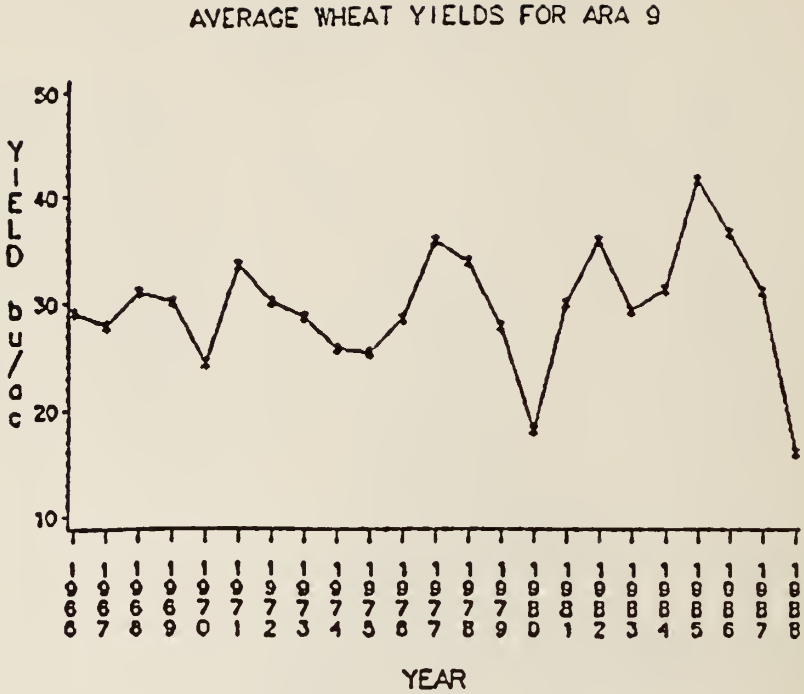
Class	bu/ac	kg/ha(*1000)
1	0 - 5	0.00 - 0.33
2	6 - 10	0.34 - 0.67
3	11 - 15	0.68 - 1.00
4	16 - 20	1.01 - 1.34
5	21 - 25	1.35 - 1.68
6	26 - 30	1.69 - 2.01
7	31 - 35	2.02 - 2.35
8	36 - 40	2.36 - 2.68
9	41 - 45	2.69 - 3.02
10	46 - 50	3.03 - 3.36
11	51 - 55	3.37 - 3.69
12	66 - 60	3.70 - 4.03
13	61 - 65	4.04 - 4.36
14	66 - 70	4.37 - 4.70
15	71 - 75	4.71 - 5.04
16	76 - 80	5.05 - 5.37
17	81+	5.38+

ARA 9 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 9 OBS=7933

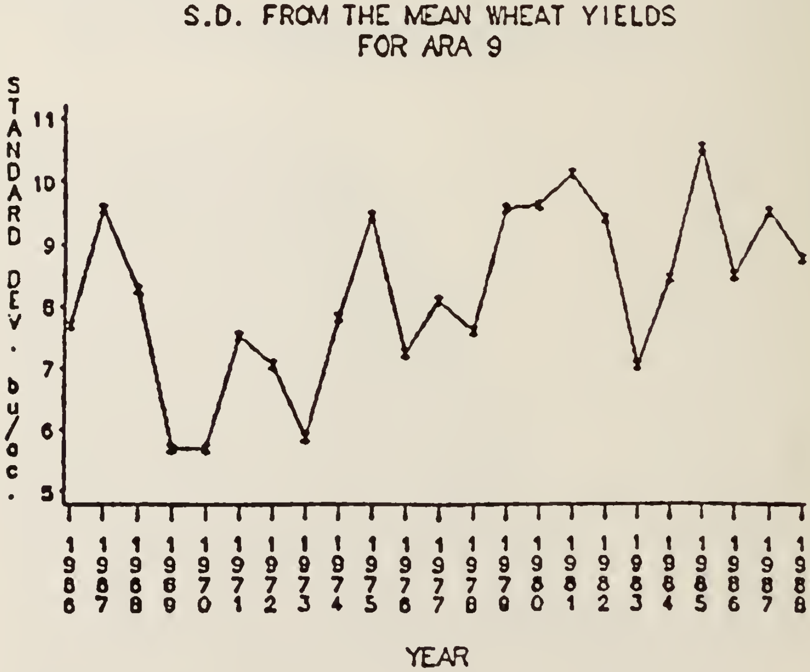


ARA 9 Figure 3:



* Represents years that have more than 10 reported yields
All other years are not included in the analysis

ARA 9 Figure 4:

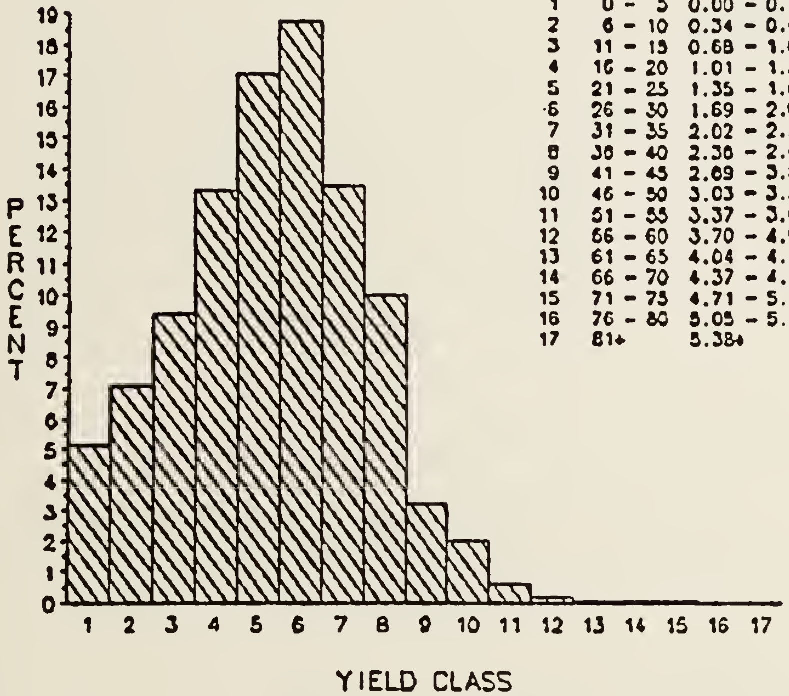


Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1966-1988
Nitrogen Level: 42kg/ha+

ARA 10 Figure 1:

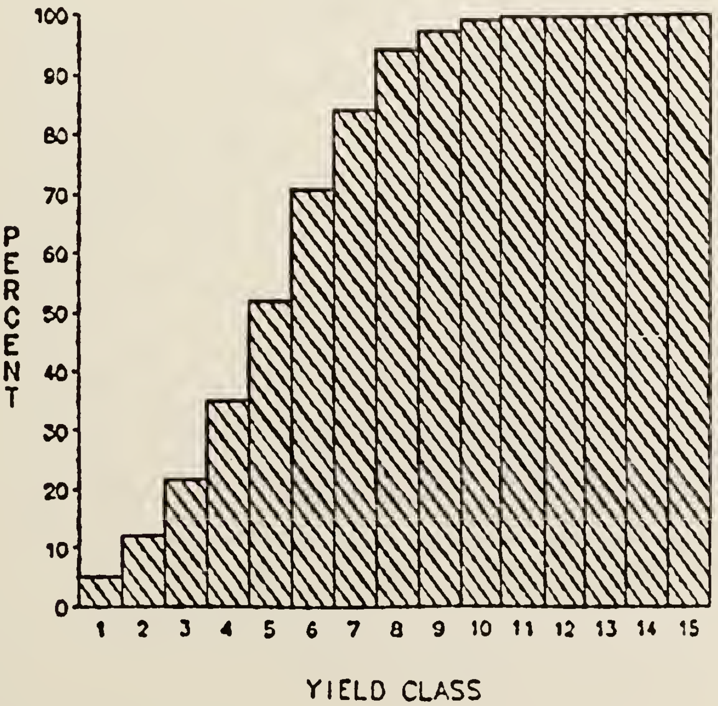
FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 10 OBS=2366

Class	bu/ac	kg/ha(*1000)
1	0 - 5	0.00 - 0.33
2	6 - 10	0.34 - 0.67
3	11 - 15	0.68 - 1.00
4	16 - 20	1.01 - 1.34
5	21 - 25	1.35 - 1.68
6	26 - 30	1.69 - 2.01
7	31 - 35	2.02 - 2.35
8	36 - 40	2.36 - 2.68
9	41 - 45	2.69 - 3.02
10	46 - 50	3.03 - 3.36
11	51 - 55	3.37 - 3.69
12	56 - 60	3.70 - 4.03
13	61 - 65	4.04 - 4.36
14	66 - 70	4.37 - 4.70
15	71 - 75	4.71 - 5.04
16	76 - 80	5.05 - 5.37
17	81+	5.38+

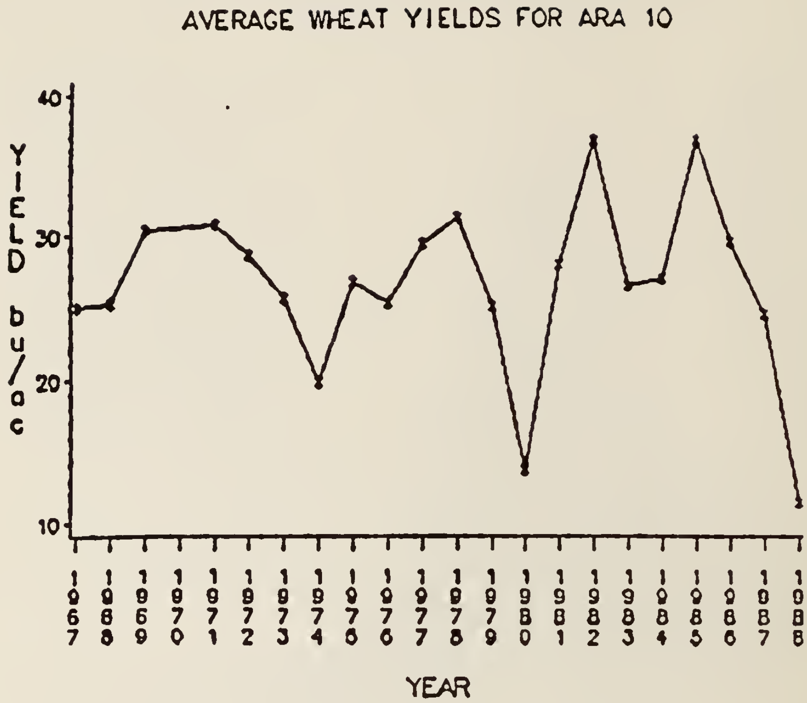


ARA 10 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 10 OBS=2366

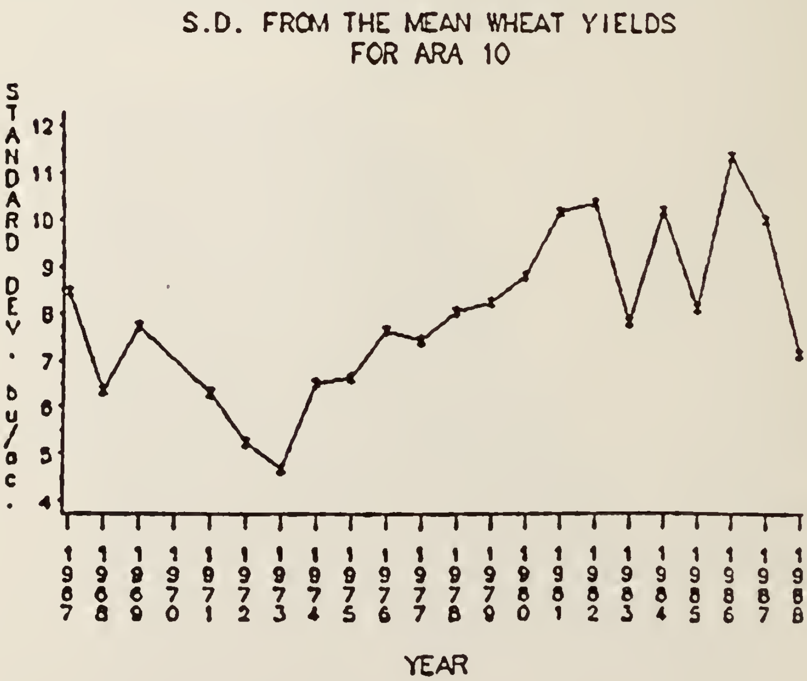


ARA 10 Figure 3:



• Represents years that have more than 10 reported yields
All other years are not included in the analysis

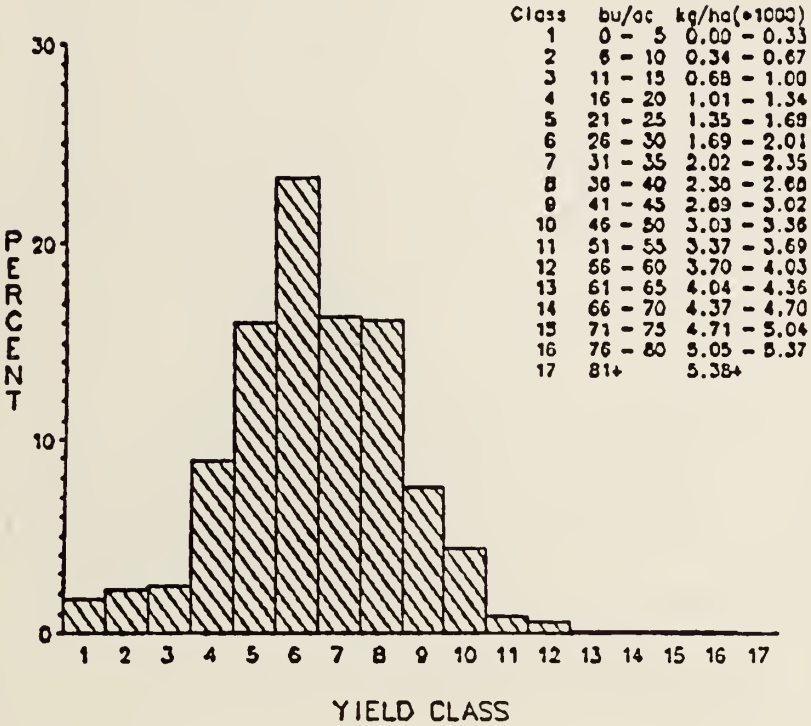
ARA 10 Figure 4:



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1967-1969, 1971-1988
Nitrogen Level: 42kg/ha+

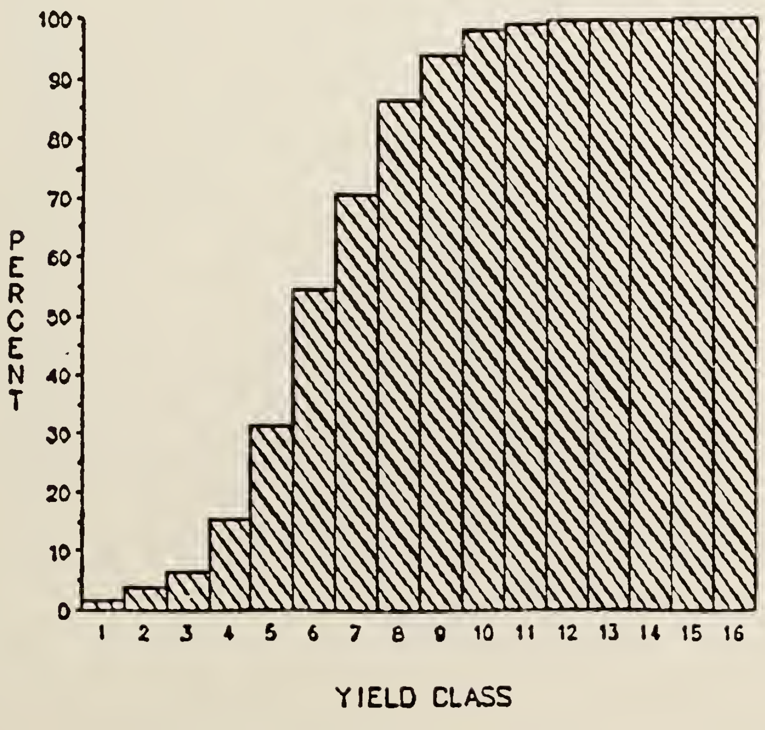
ARA 11 Figure 1:

FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 11 OBS=2147



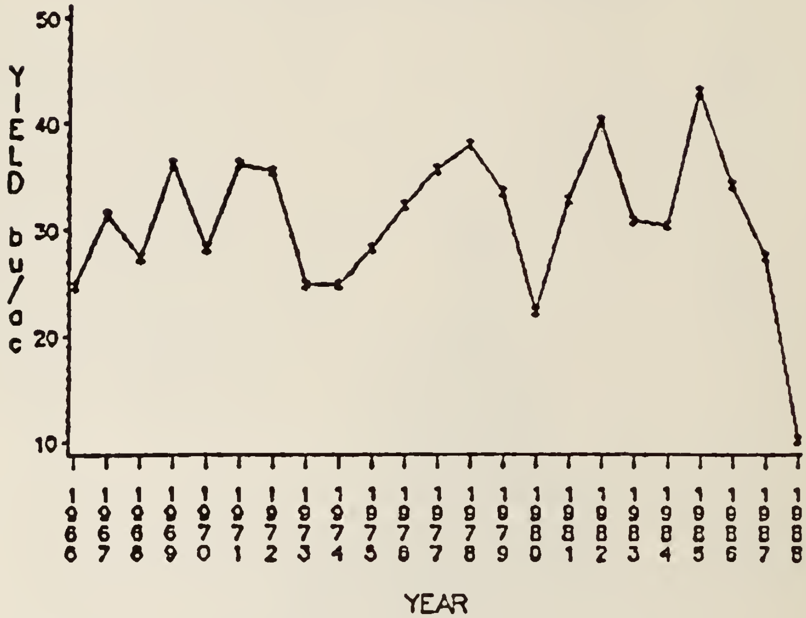
ARA 11 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 11 OBS=2147



ARA 11 Figure 3:

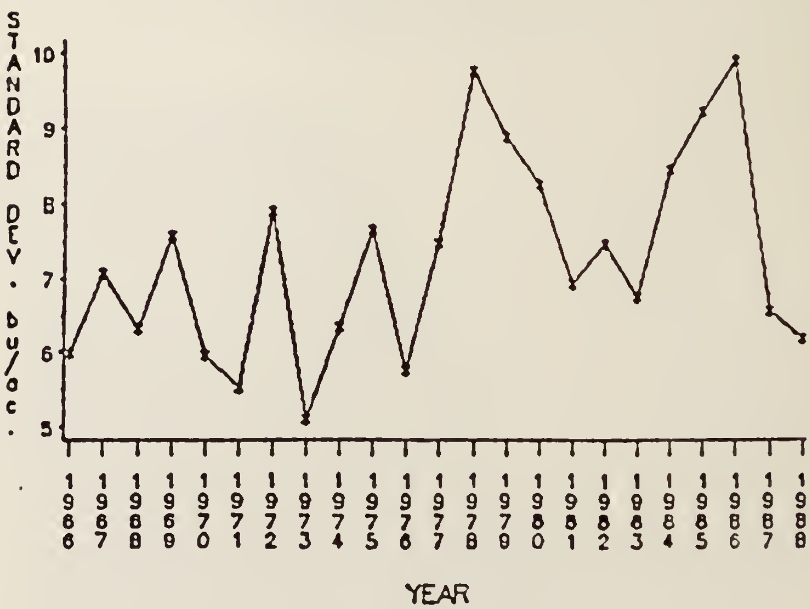
AVERAGE WHEAT YIELDS FOR ARA 11



* Represents years that have more than 10 reported yields
All other years are not included in the analysis

ARA 11 Figure 4:

S.D. FROM THE MEAN WHEAT YIELDS
FOR ARA 11

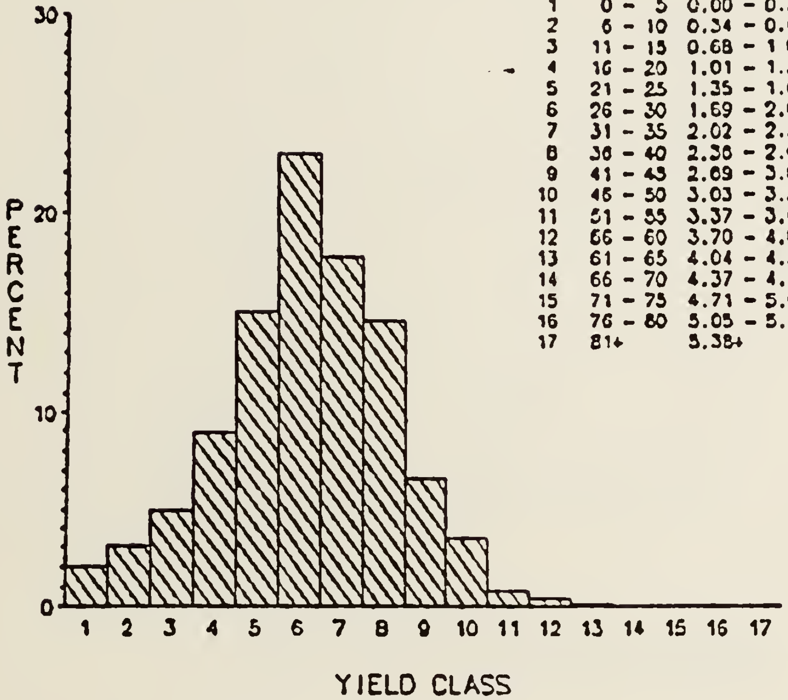


Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1966-1988
Nitrogen Level: 42kg/ha+

ARA 12 Figure 1:

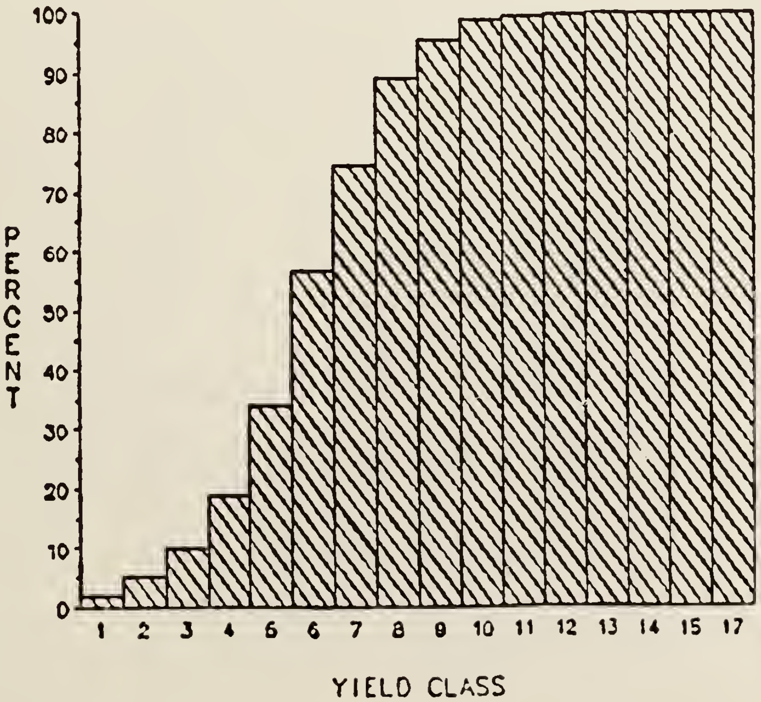
FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 12 OBS=15967

Class	bu/ac	kg/ha(*1000)
1	0 - 5	0.00 - 0.33
2	6 - 10	0.34 - 0.67
3	11 - 15	0.68 - 1.00
4	16 - 20	1.01 - 1.34
5	21 - 25	1.35 - 1.68
6	26 - 30	1.69 - 2.01
7	31 - 35	2.02 - 2.35
8	36 - 40	2.36 - 2.68
9	41 - 45	2.69 - 3.02
10	46 - 50	3.03 - 3.36
11	51 - 55	3.37 - 3.69
12	56 - 60	3.70 - 4.03
13	61 - 65	4.04 - 4.36
14	66 - 70	4.37 - 4.70
15	71 - 75	4.71 - 5.04
16	76 - 80	5.05 - 5.37
17	81+	5.38+



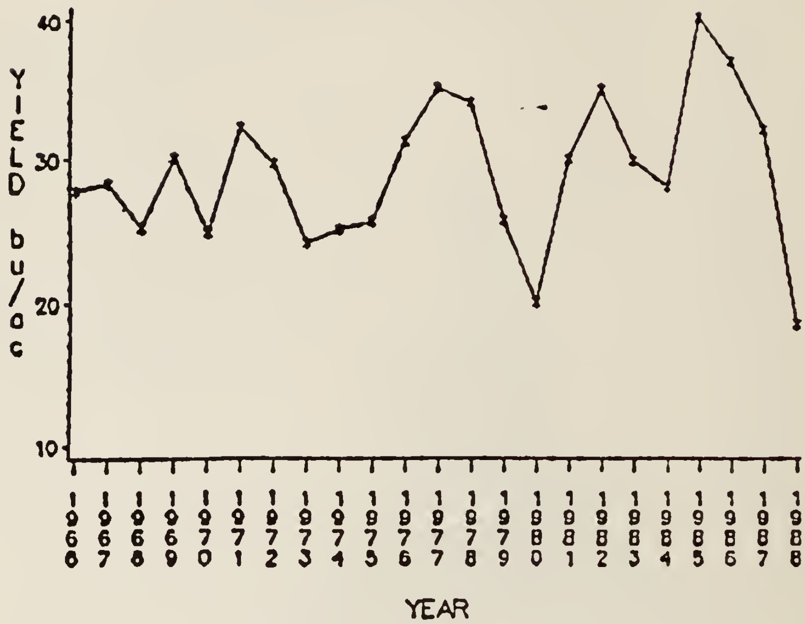
ARA12 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA12 OBS=15967



ARA 12 Figure 3:

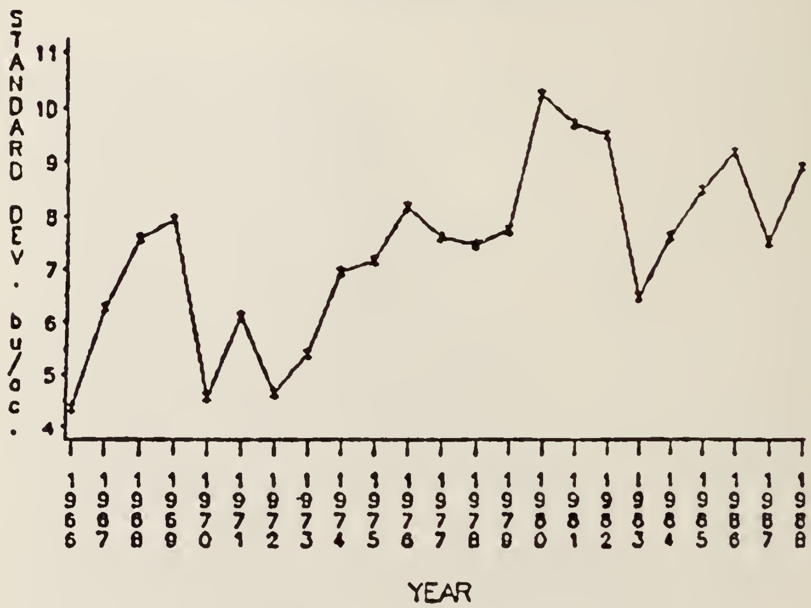
AVERAGE WHEAT YIELDS FOR ARA 12



• Represents years that have more than 10 reported yields
All other years are not included in the analysis

ARA 12 Figure 4:

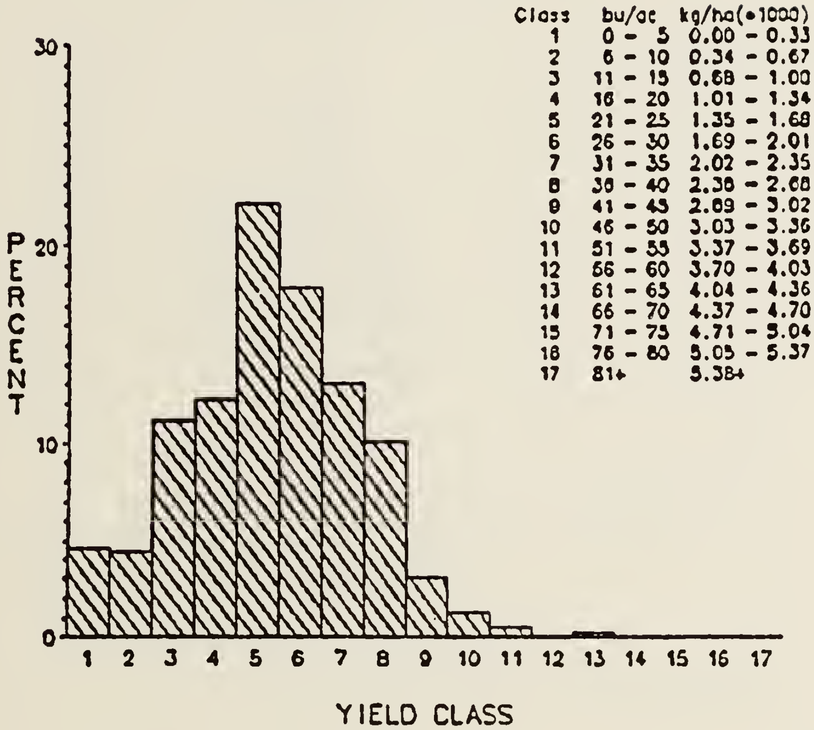
S.D. FROM THE MEAN WHEAT YIELDS
FOR ARA 12



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1966-1988
Nitrogen Level: 42kg/ha+

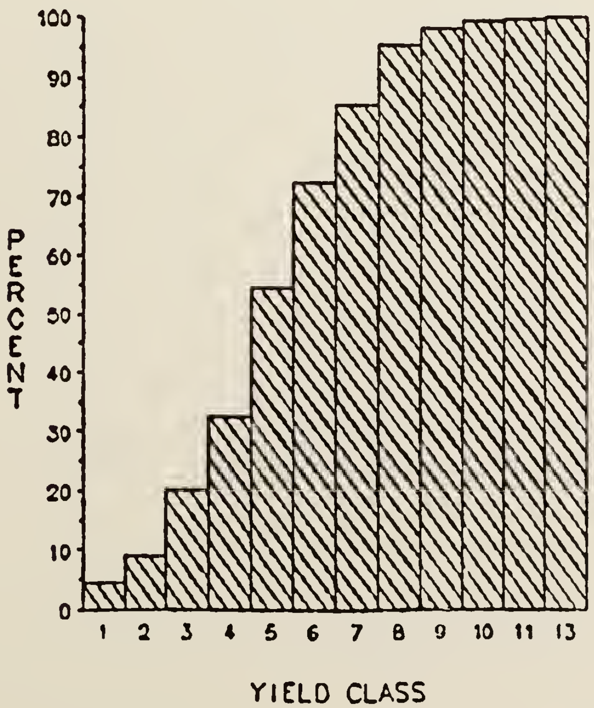
ARA 13 Figure 1:

FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 13 OBS=662

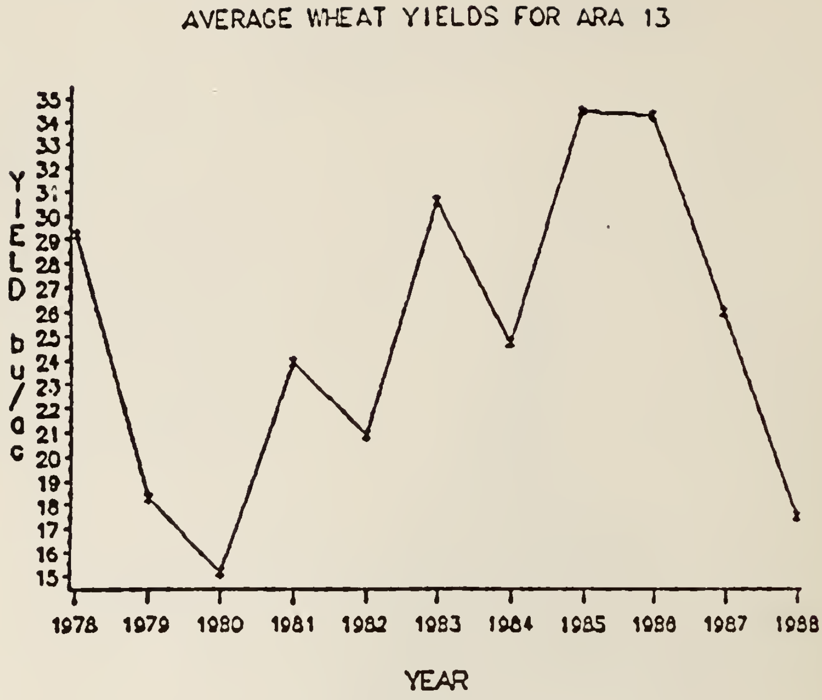


ARA 13 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 13 OBS=662

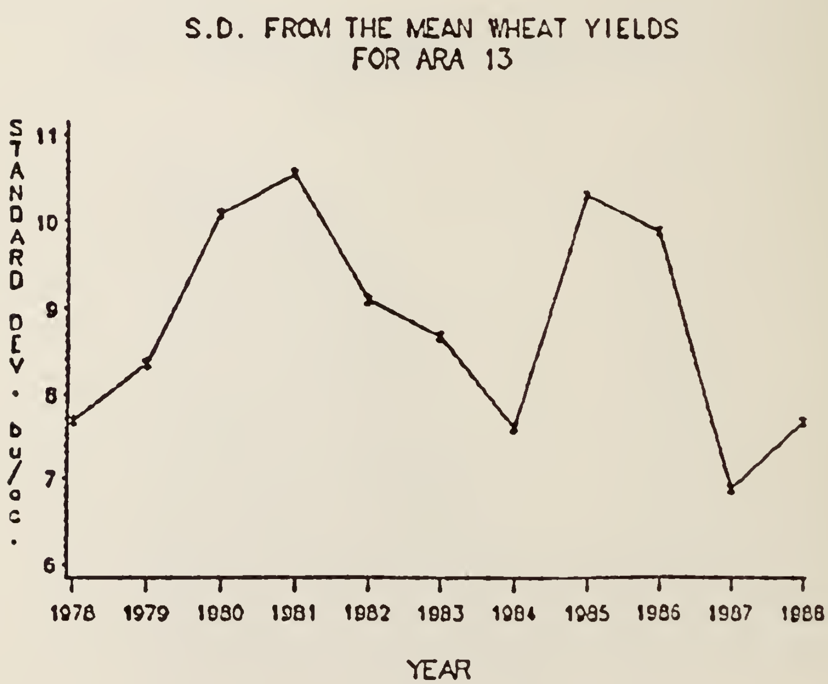


ARA 13 Figure 3:



• Represents years that have more than 10 reported yields
All other years are not included in the analysis

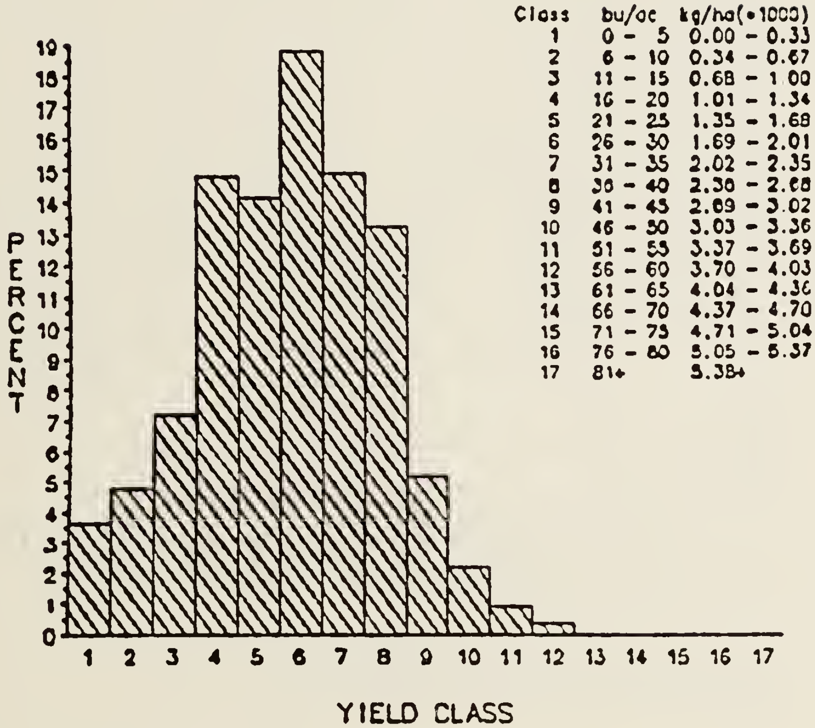
ARA 13 Figure 4:



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1978–1988
Nitrogen Level: 42kg/ha+

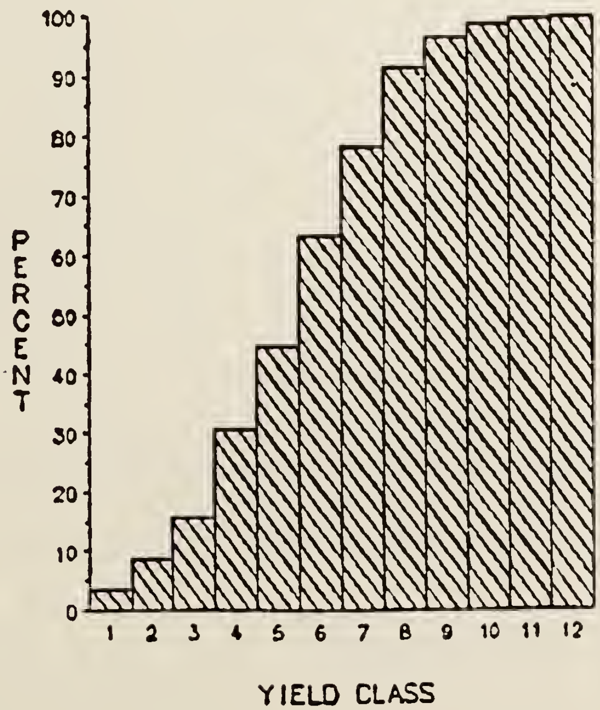
ARA 14 Figure 1:

FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 14 OBS=878



ARA 14 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 14 OBS=878



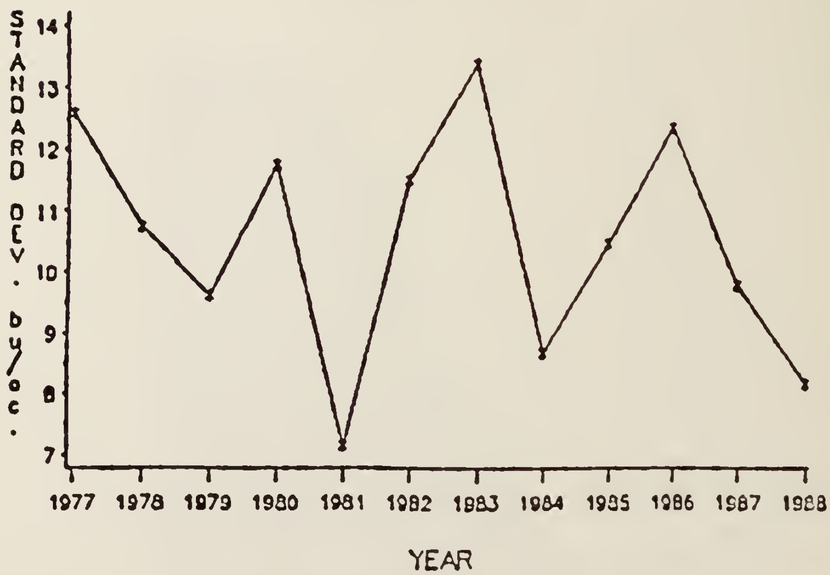
ARA 14 Figure 3:

AVERAGE WHEAT YIELDS FOR ARA 14

• Represents years that have more than 10 reported yields
All other years are not included in the analysis

ARA 14 Figure 4:

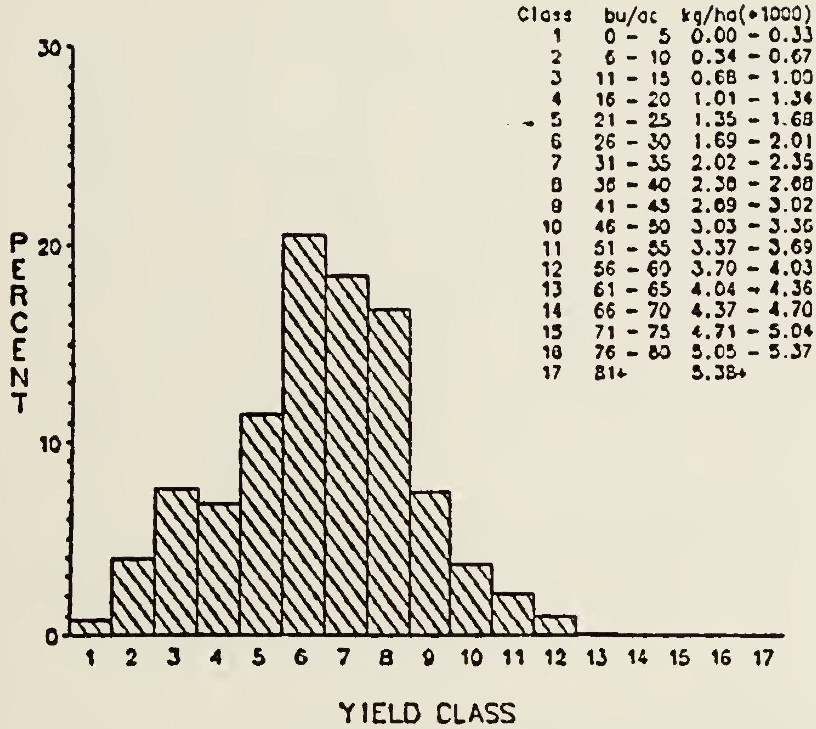
S.D. FROM THE MEAN WHEAT YIELDS
FOR ARA 14



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1977-1988
Nitrogen Level: 42kg/ha+

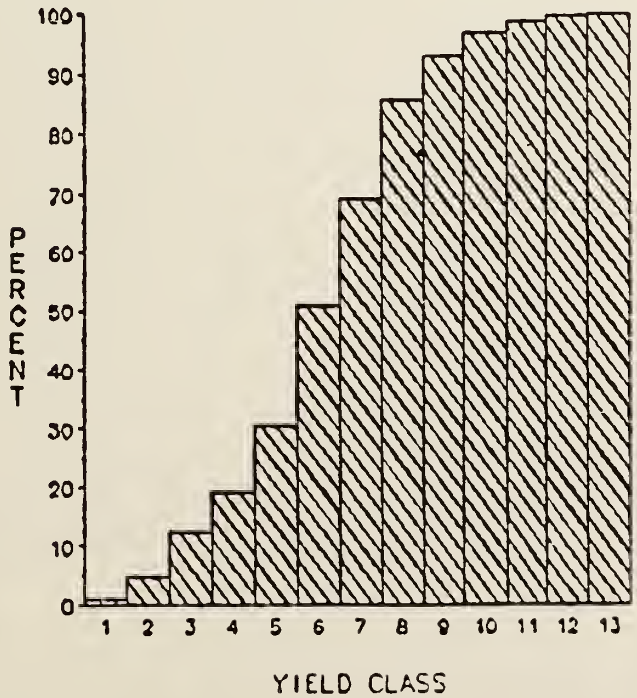
ARA 15 Figure 1:

FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 15 OBS=767



ARA 15 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 15 OBS=767



ARA 15 Figure 3:

AVERAGE WHEAT YIELDS FOR ARA 15

* Represents years that have more than 10 reported yields
All other years are not included in the analysis

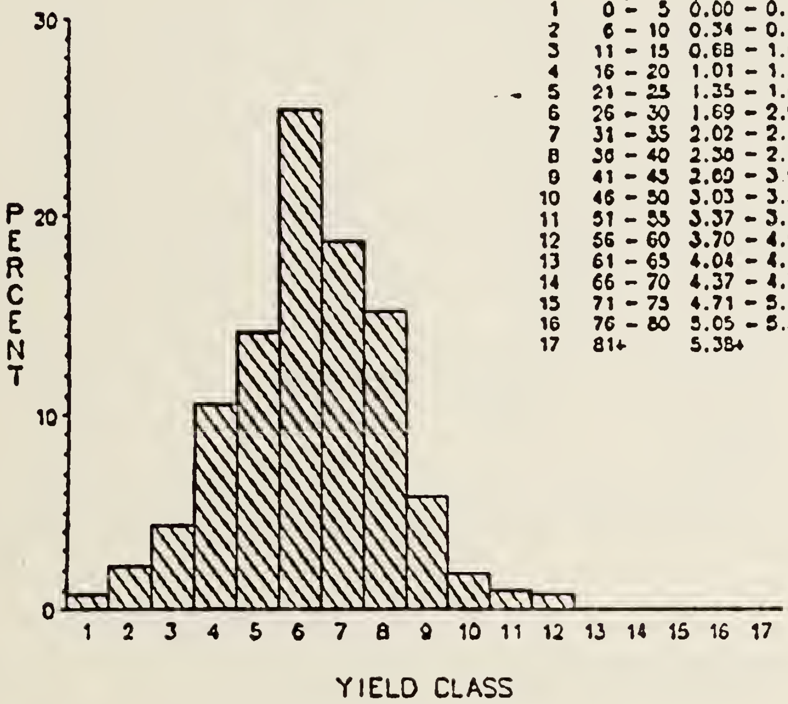
ARA 15 Figure 4:

S.D. FROM THE MEAN WHEAT YIELDS
FOR ARA 15

Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1977-1988
Nitrogen Level: 42kg/ha+

ARA 16 Figure 1:

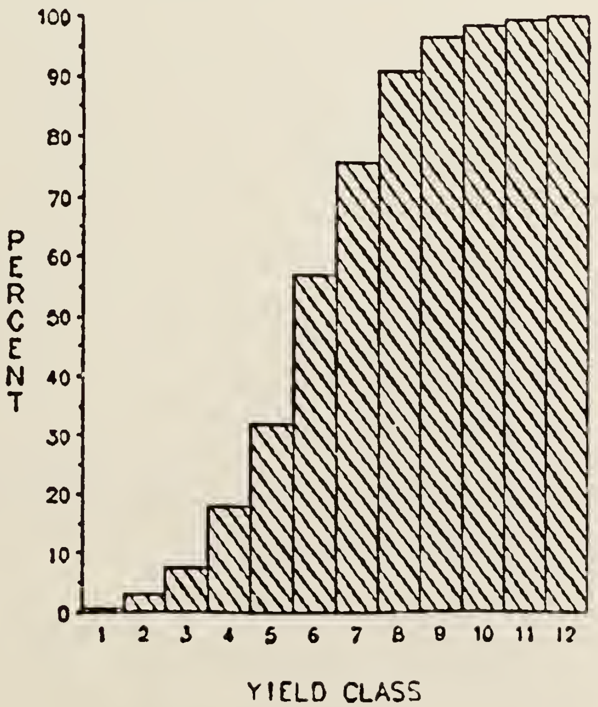
FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 16 OBS=958



Class	bu/ac	kg/ha(*1000)
1	0 - 5	0.00 - 0.33
2	6 - 10	0.34 - 0.67
3	11 - 15	0.68 - 1.00
4	16 - 20	1.01 - 1.34
5	21 - 25	1.35 - 1.68
6	26 - 30	1.69 - 2.01
7	31 - 35	2.02 - 2.35
8	36 - 40	2.36 - 2.68
9	41 - 45	2.69 - 3.02
10	46 - 50	3.03 - 3.36
11	51 - 55	3.37 - 3.69
12	56 - 60	3.70 - 4.03
13	61 - 65	4.04 - 4.36
14	66 - 70	4.37 - 4.70
15	71 - 75	4.71 - 5.04
16	76 - 80	5.05 - 5.37
17	81+	5.38+

ARA 16 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 16 OBS=958



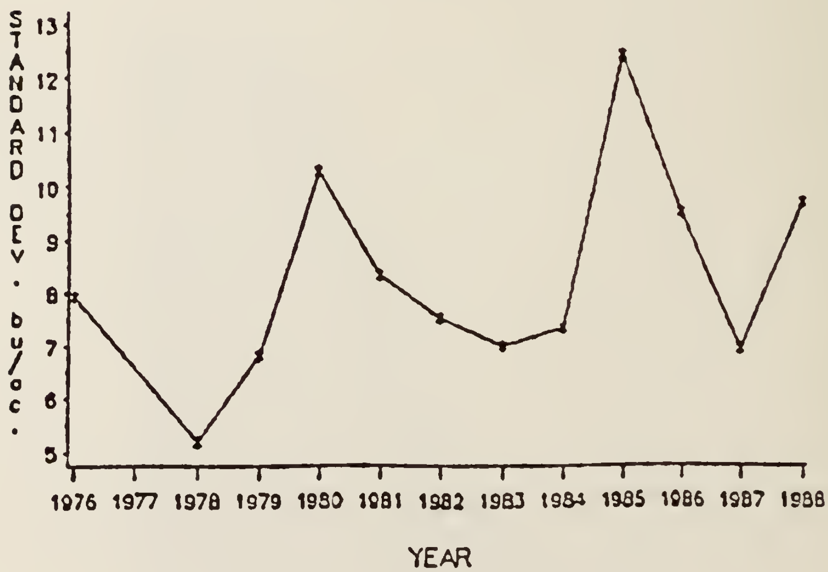
ARA 16 Figuro 3:

AVERAGE WHEAT YIELDS FOR ARA 16

* Represents years that have more than 10 reported yields
All other years are not included in the analysis

ARA 16 Figure 4:

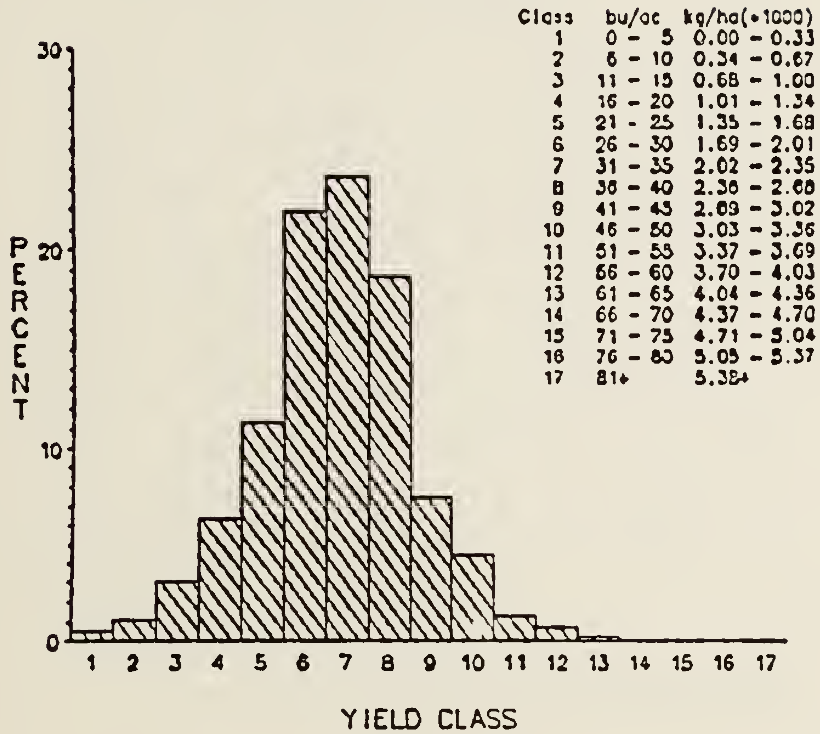
S.D. FROM THE MEAN WHEAT YIELDS
FOR ARA 16



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1976, 1978–1988
Nitrogen Level: 42kg/ha+

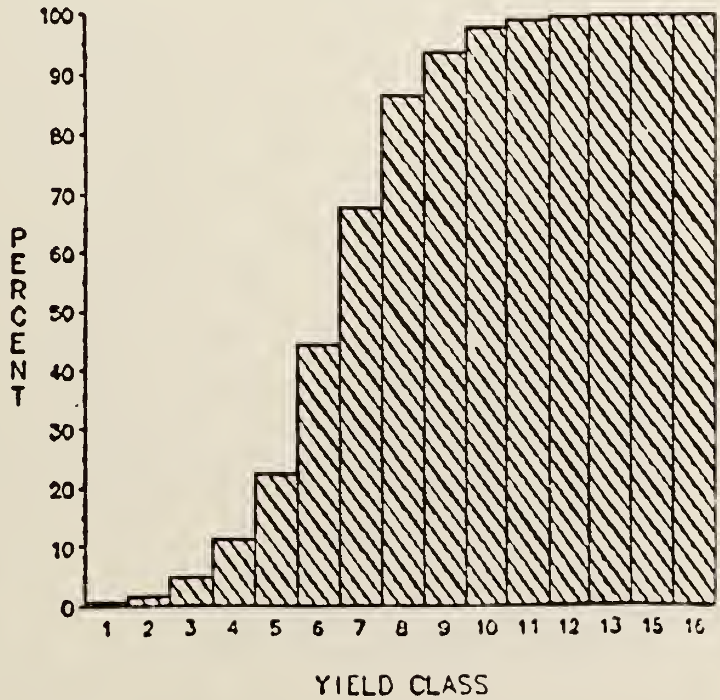
ARA 17 Figure 1:

FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 17 OBS=3208

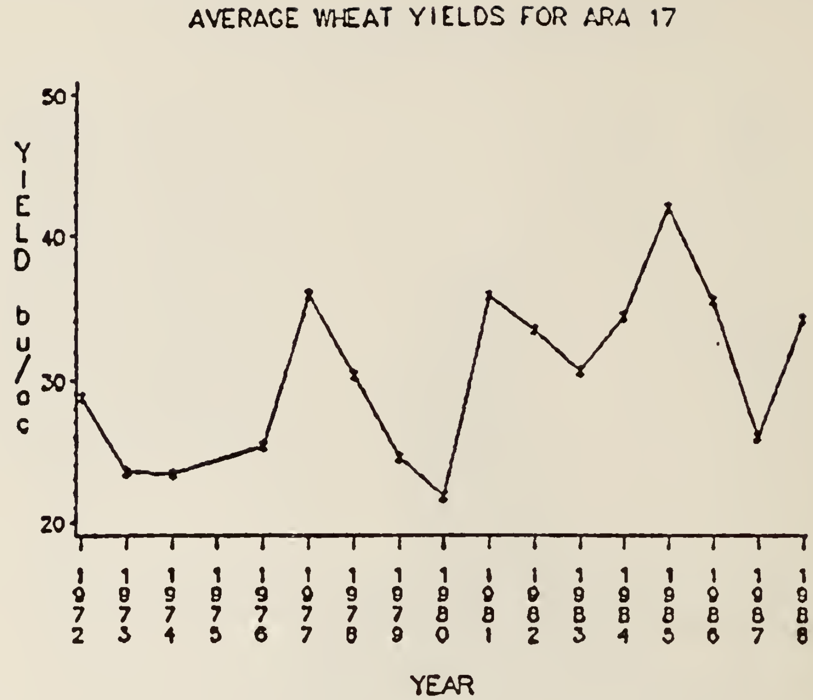


ARA 17 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 17 OBS=3208

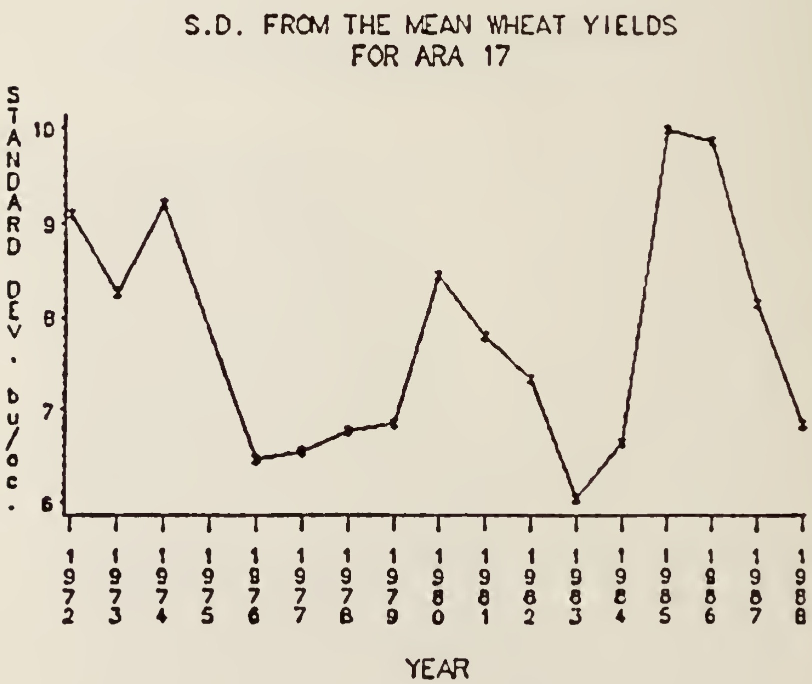


ARA 17 Figure 3:



• Represents years that have more than 10 reported yields
All other years are not included in the analysis

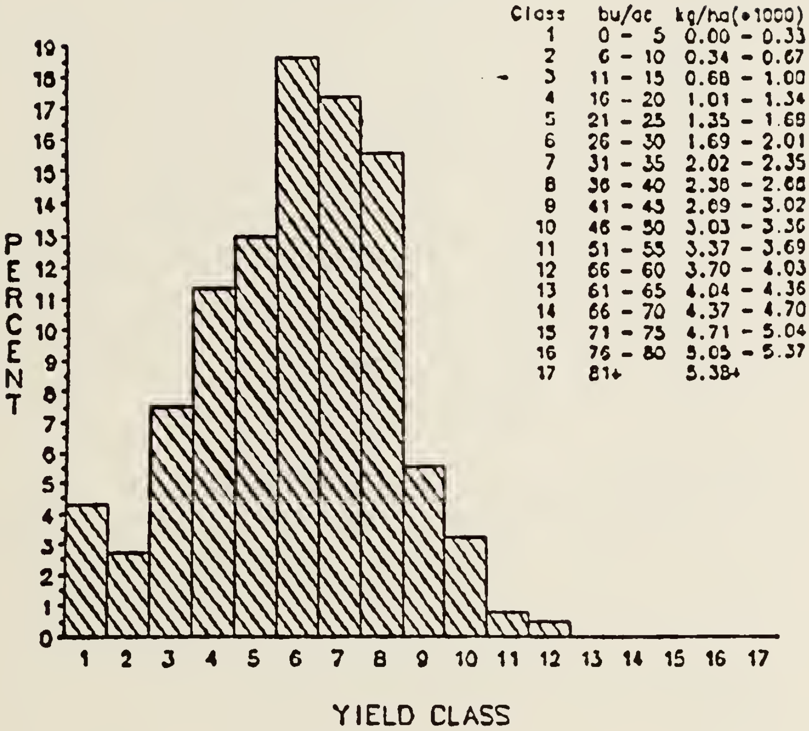
ARA 17 Figure 4:



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1972-1974, 1976-1988
Nitrogen Level: 42kg/ha+

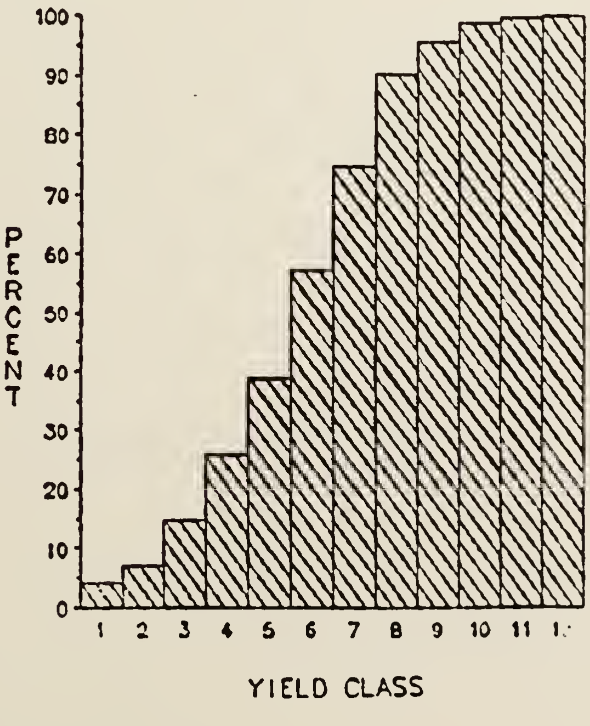
ARA 18 Figure 1:

FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 18 OBS=657

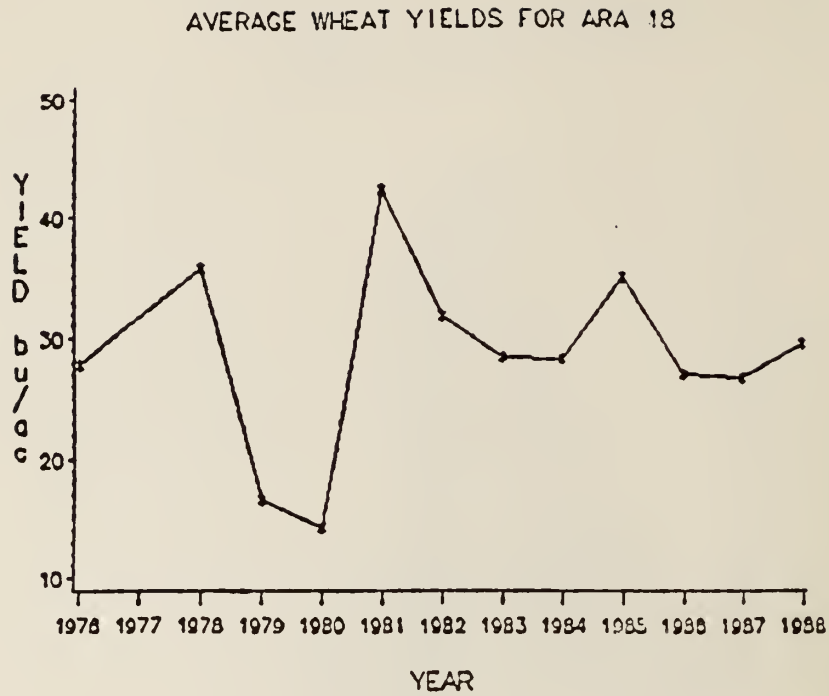


ARA 18 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 18 OBS=657

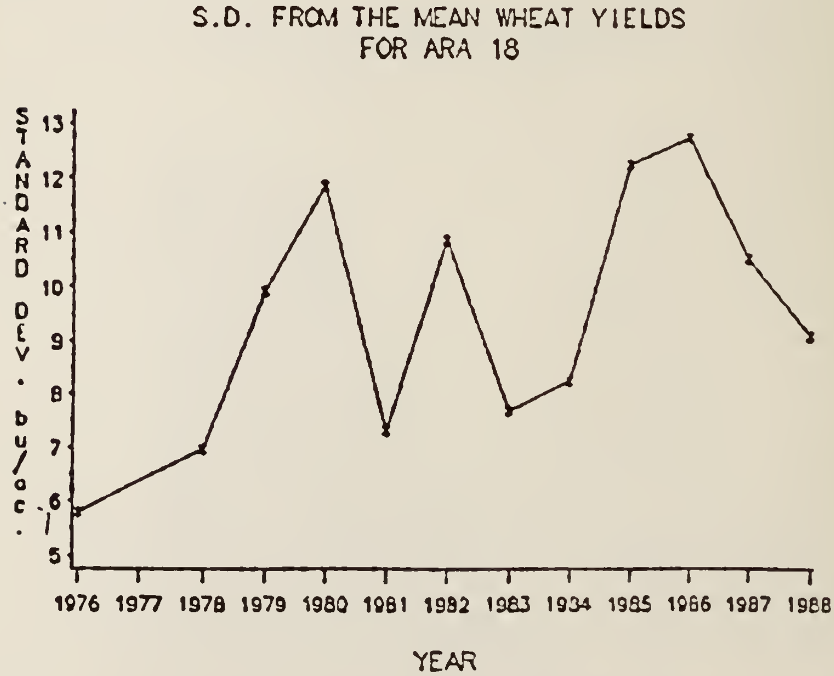


ARA 18 Figure 3:



• Represents years that have more than 10 reported yields
All other years are not included in the analysis

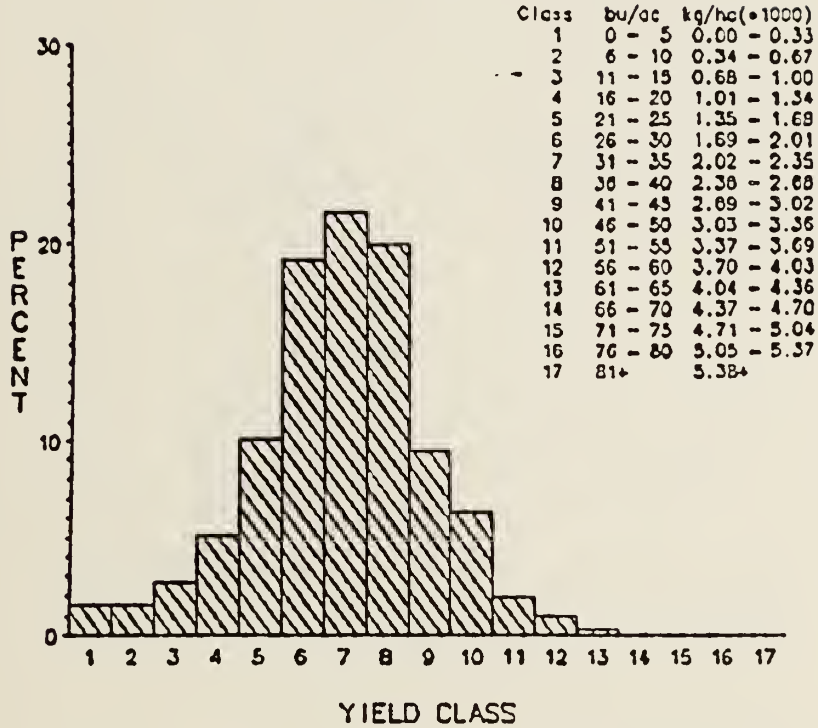
ARA 18 Figure 4:



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1976, 1978–1988
Nitrogen Level: 42kg/ha+

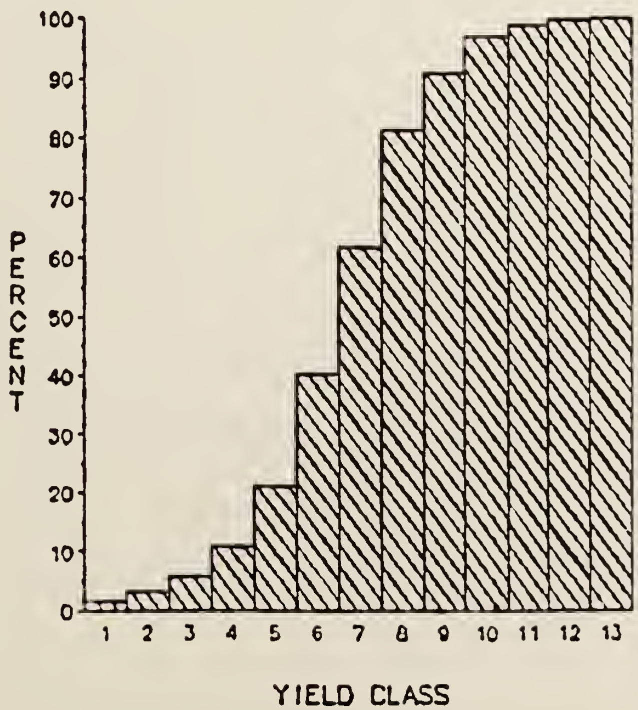
ARA 19 Figure 1:

FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 19 OBS=2108

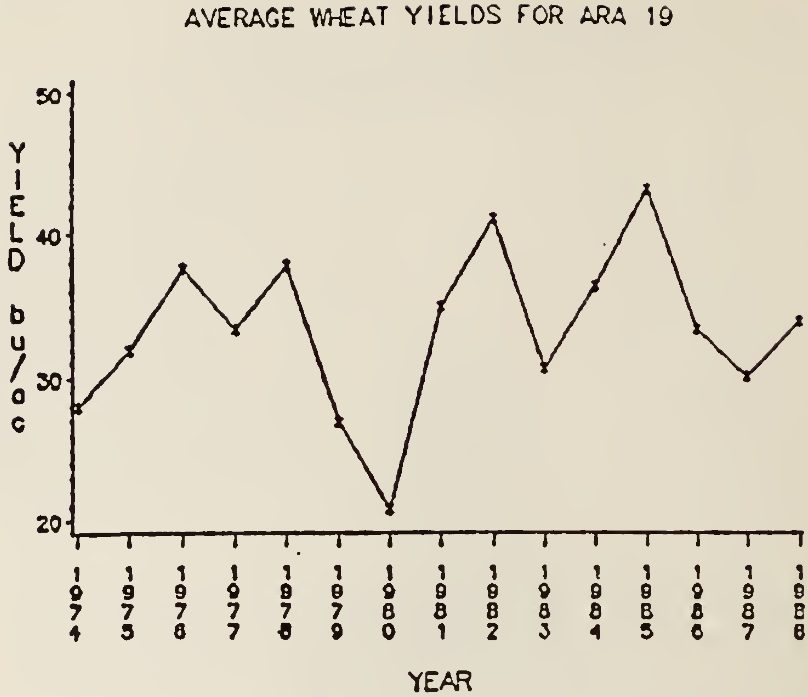


ARA 19 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 19 OBS=2108

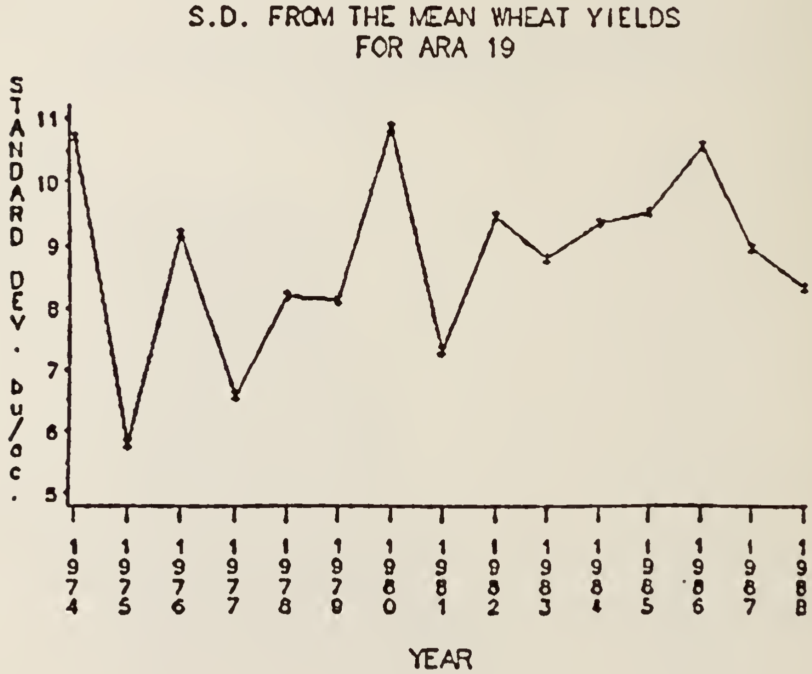


ARA 19 Figure 3:



• Represents years that have more than 10 reported yields
All other years are not included in the analysis

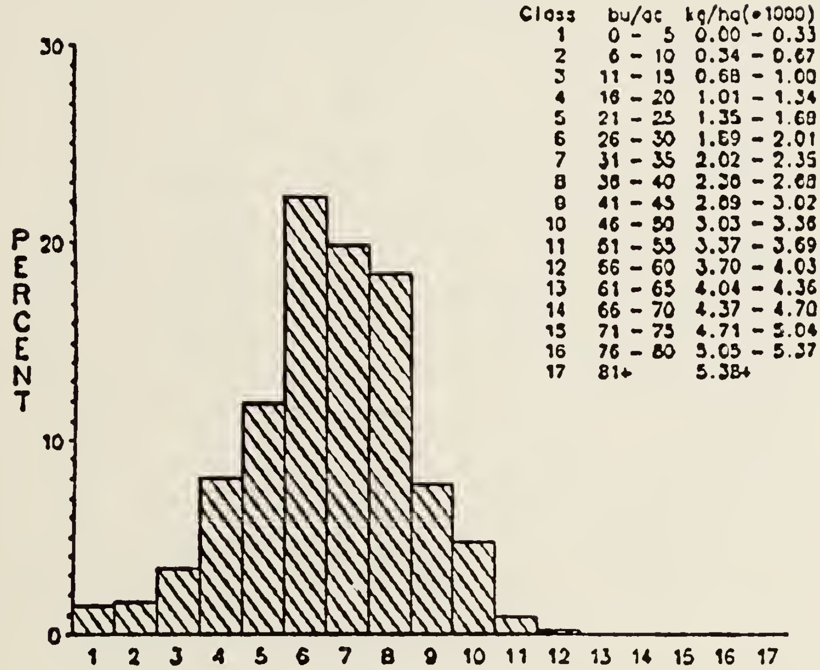
ARA 19 Figure 4:



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1974–1988
Nitrogen Level: 42kg/ha+

ARA 21 Figure 1:

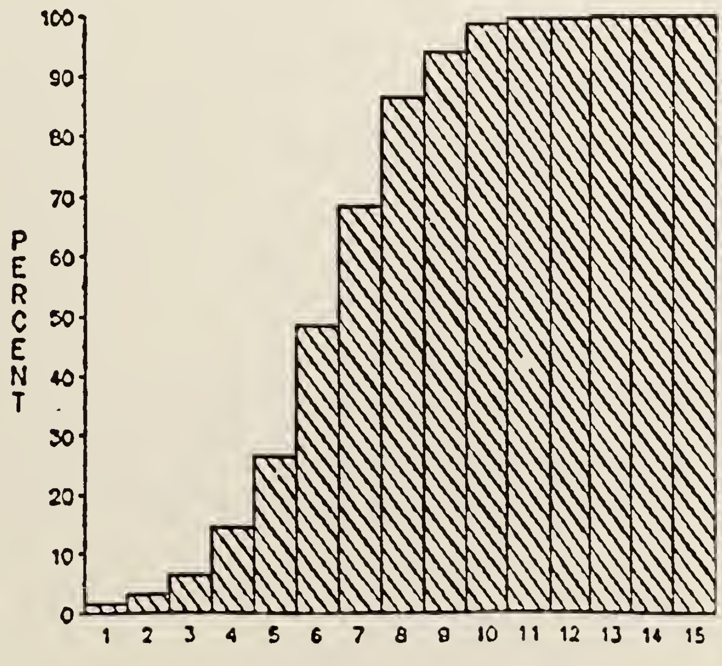
FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 21 OBS=3063



YIELD CLASS

ARA 21 Figure 2:

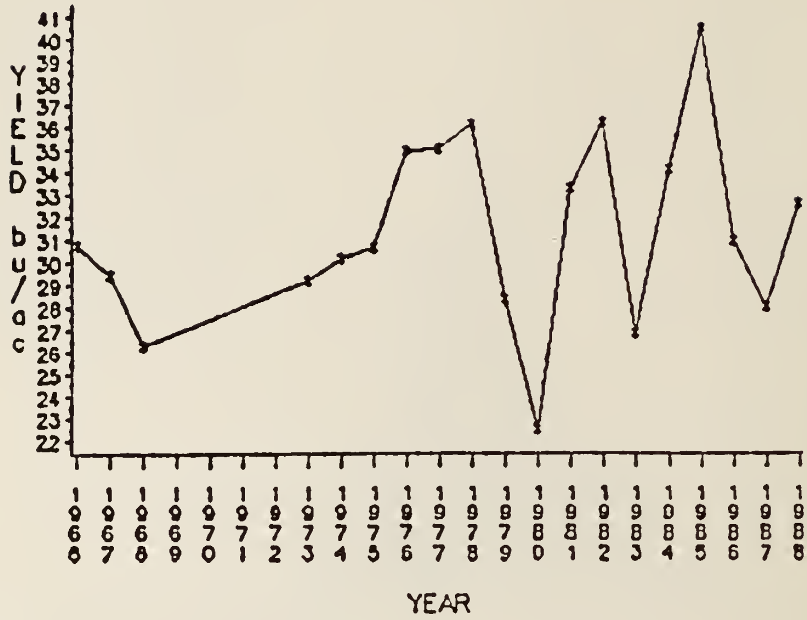
CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 21 OBS=3063



YIELD CLASS

ARA 21 Figure 3:

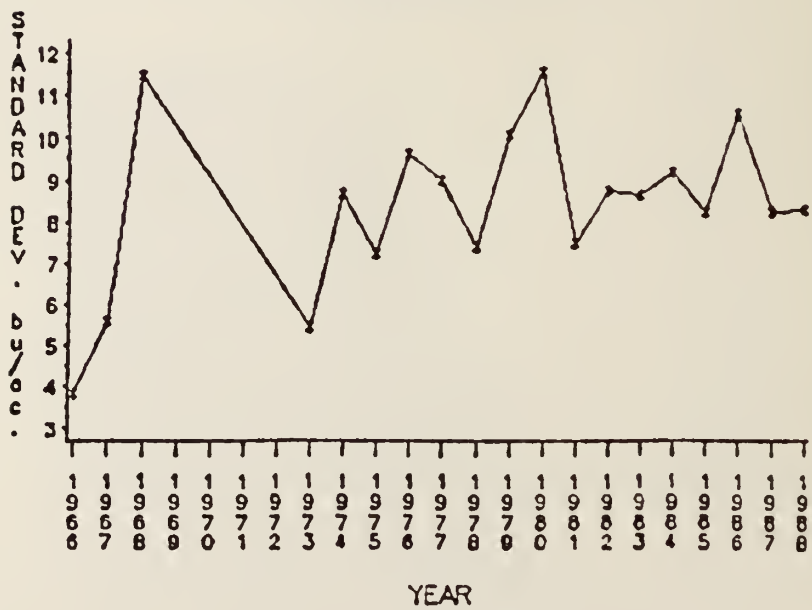
AVERAGE WHEAT YIELDS FOR ARA 21



* Represents years that have more than 10 reported yields
All other years are not included in the analysis

ARA 21 Figure 4:

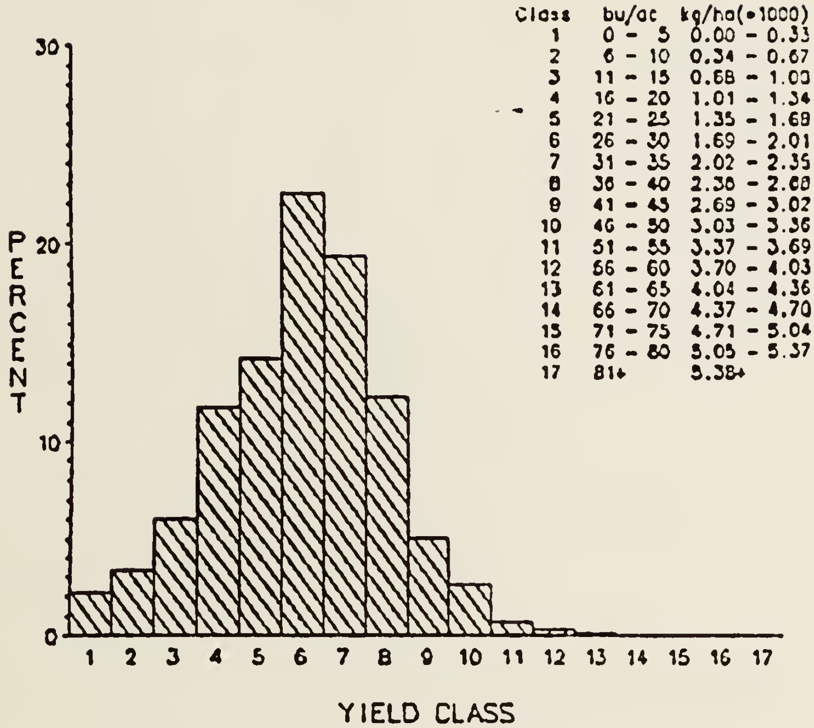
S.D. FROM THE MEAN WHEAT YIELDS
FOR ARA 21



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1966-1968, 1973-1985
Nitrogen Level: 42kg/ha+

ARA 22 Figure 1:

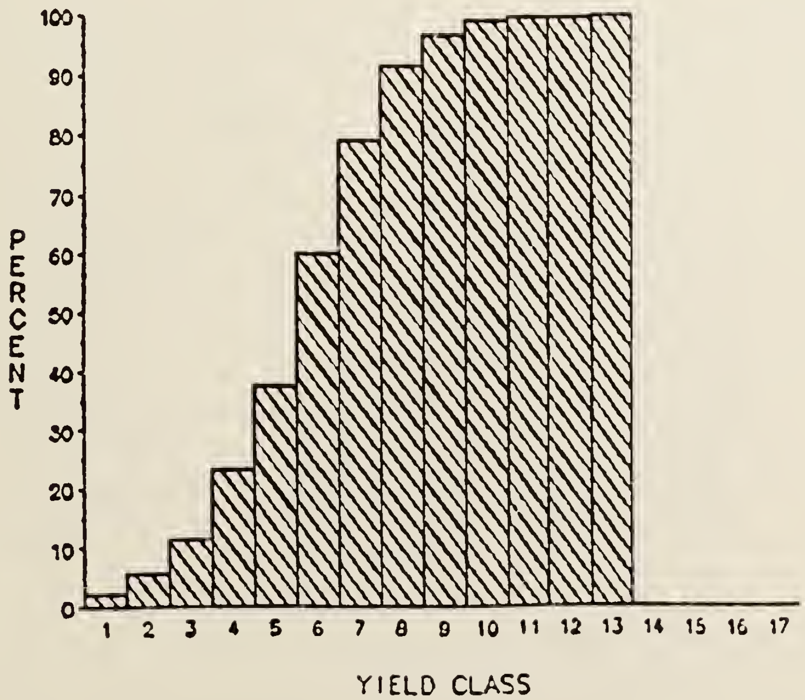
FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 22 OBS=1083



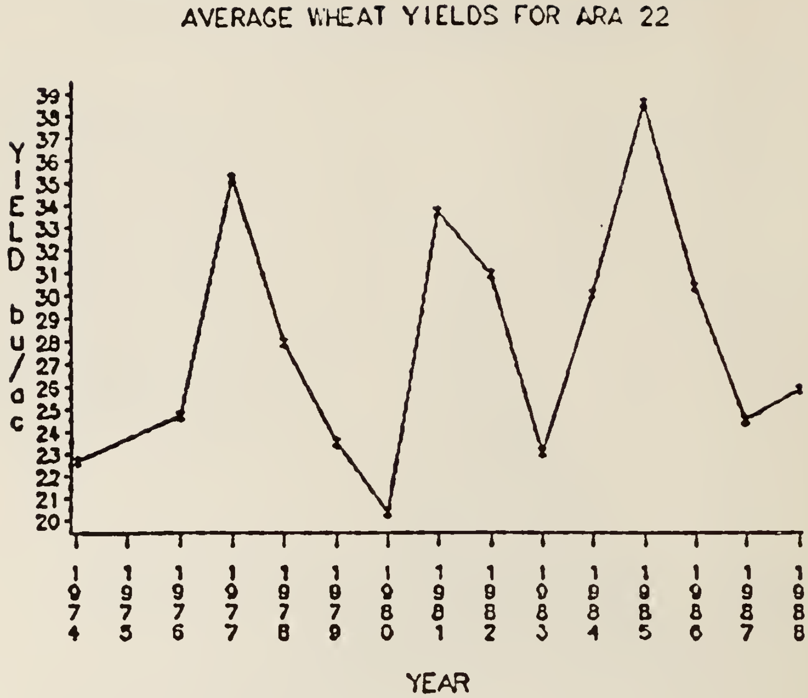
Class	bu/ac	kg/ha(*1000)
1	0 - 5	0.00 - 0.33
2	6 - 10	0.34 - 0.67
3	11 - 15	0.68 - 1.00
4	16 - 20	1.01 - 1.34
5	21 - 25	1.35 - 1.68
6	26 - 30	1.69 - 2.01
7	31 - 35	2.02 - 2.35
8	36 - 40	2.36 - 2.68
9	41 - 45	2.69 - 3.02
10	46 - 50	3.03 - 3.36
11	51 - 55	3.37 - 3.69
12	66 - 60	3.70 - 4.03
13	61 - 65	4.04 - 4.36
14	66 - 70	4.37 - 4.70
15	71 - 75	4.71 - 5.04
16	76 - 80	5.05 - 5.37
17	81+	5.38+

ARA 22 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 22 OBS=1083

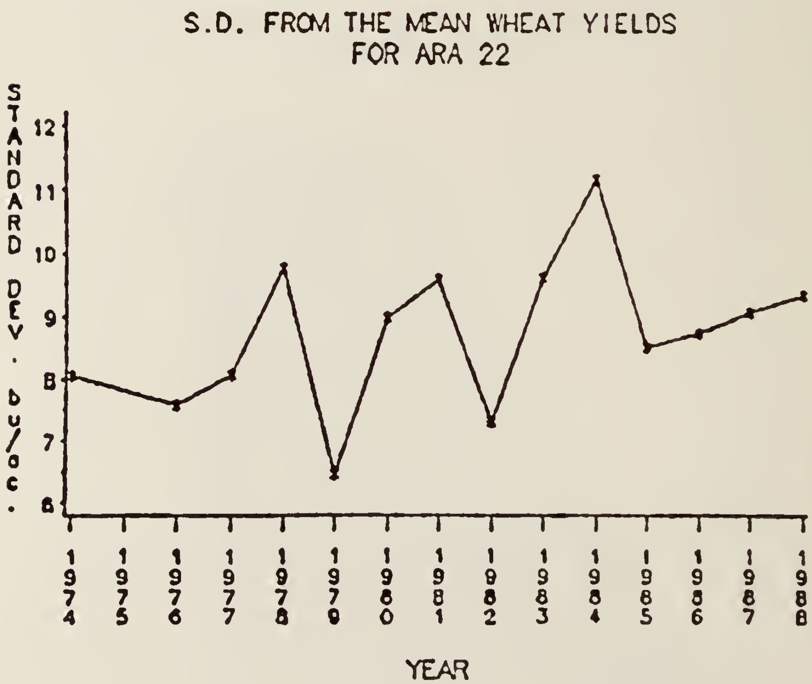


ARA 22 Figure 3:



* Represents years that have more than 10 reported yields
All other years are not included in the analysis

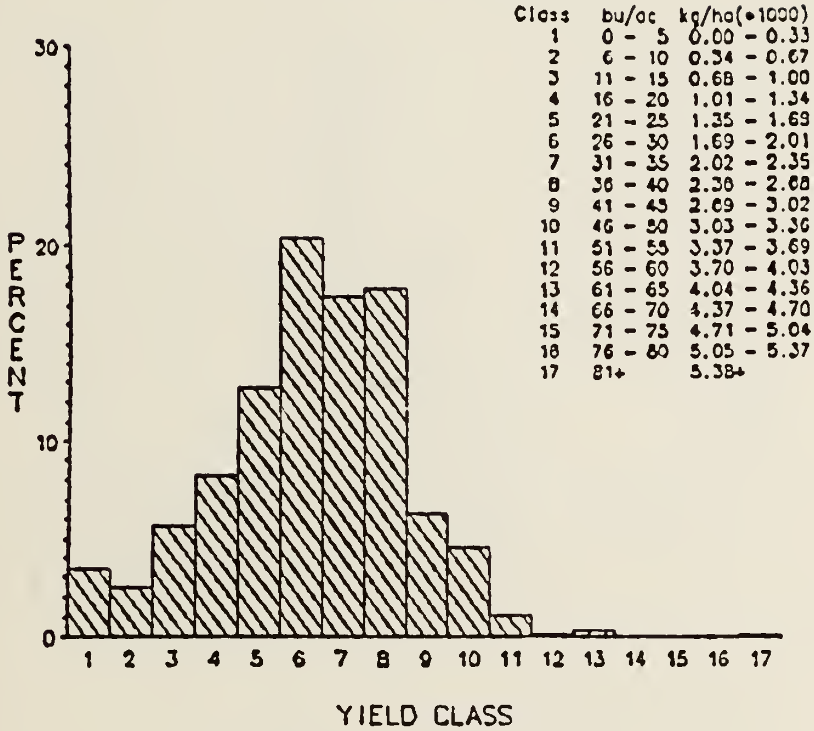
ARA 22 Figure 4:



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1974, 1976–1988
Nitrogen Level: 42kg/ha+

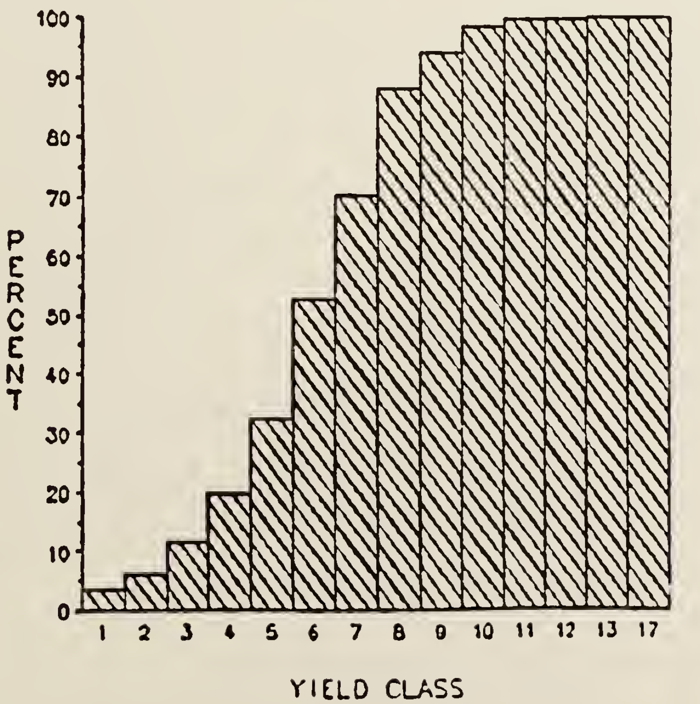
ARA 26 Figure 1:

FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 26 OBS=1560

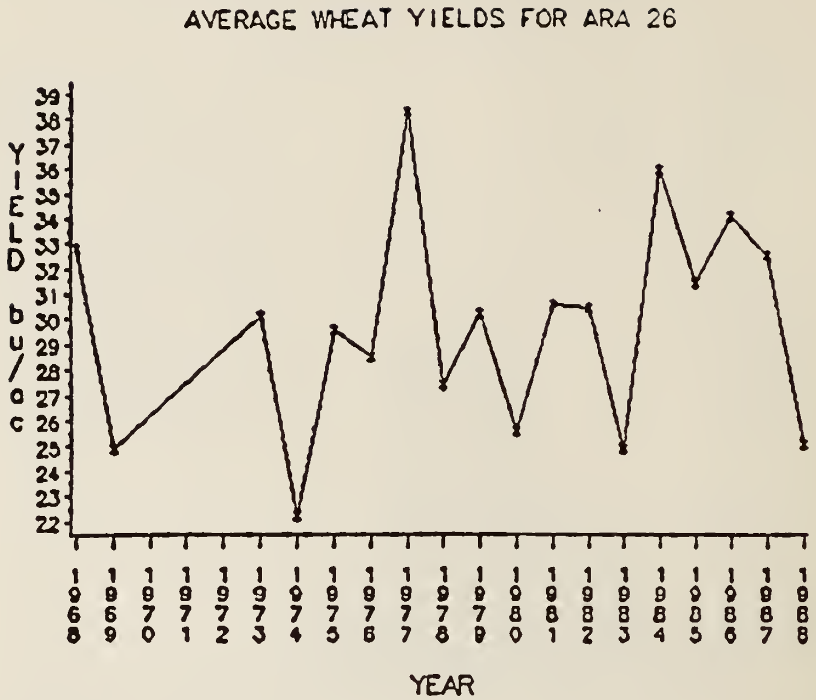


ARA 26 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 26 OBS=1560

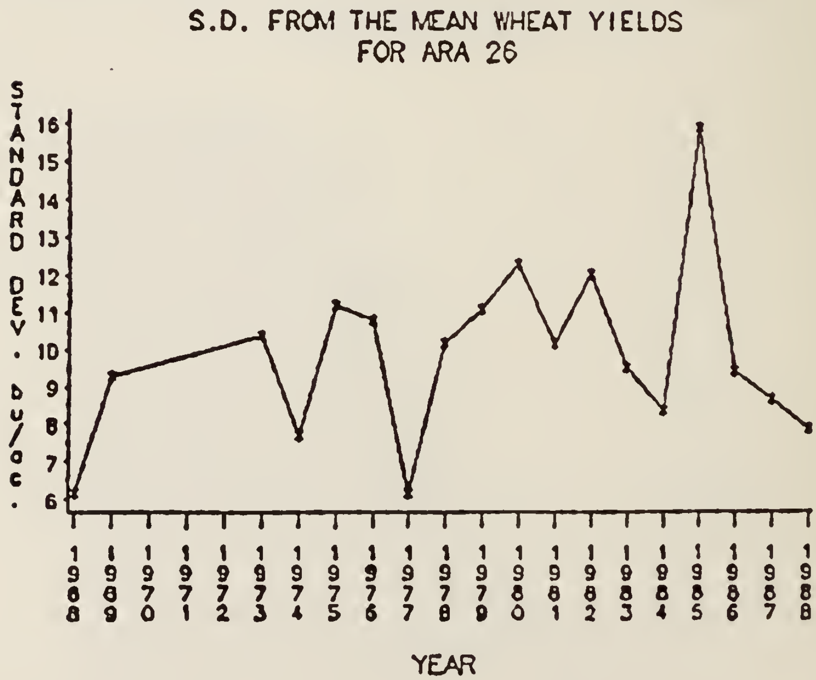


ARA 26 Figure 3:



• Represents years that have more than 10 reported yields
All other years are not included in the analysis

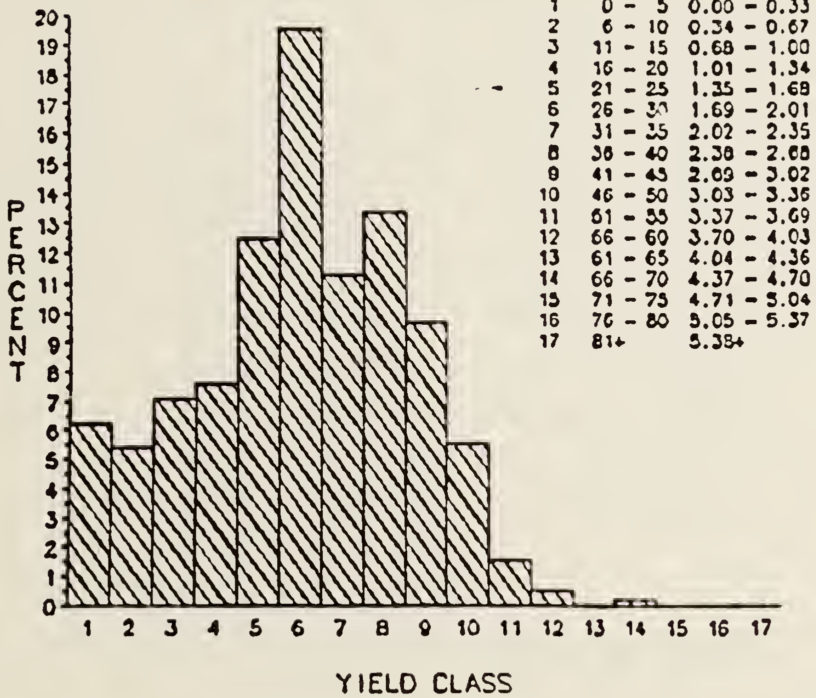
ARA 26 Figure 4:



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1968, 1969, 1973–1988
Nitrogen Level: 42kg/ha•

ARA 28 Figure 1:

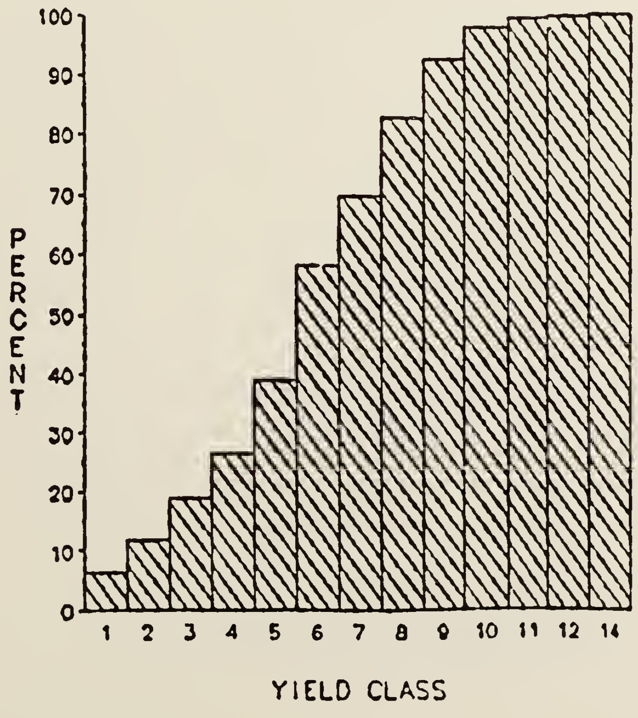
FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 28 OBS=1190



Class	bu/ac	kg/ha(*1000)
1	0 - 5	0.00 - 0.33
2	6 - 10	0.34 - 0.67
3	11 - 15	0.68 - 1.00
4	16 - 20	1.01 - 1.34
5	21 - 25	1.35 - 1.68
6	26 - 30	1.69 - 2.01
7	31 - 35	2.02 - 2.35
8	36 - 40	2.36 - 2.68
9	41 - 45	2.69 - 3.02
10	46 - 50	3.03 - 3.36
11	51 - 55	3.37 - 3.69
12	56 - 60	3.70 - 4.03
13	61 - 65	4.04 - 4.36
14	66 - 70	4.37 - 4.70
15	71 - 75	4.71 - 5.04
16	76 - 80	5.05 - 5.37
17	81+	5.38+

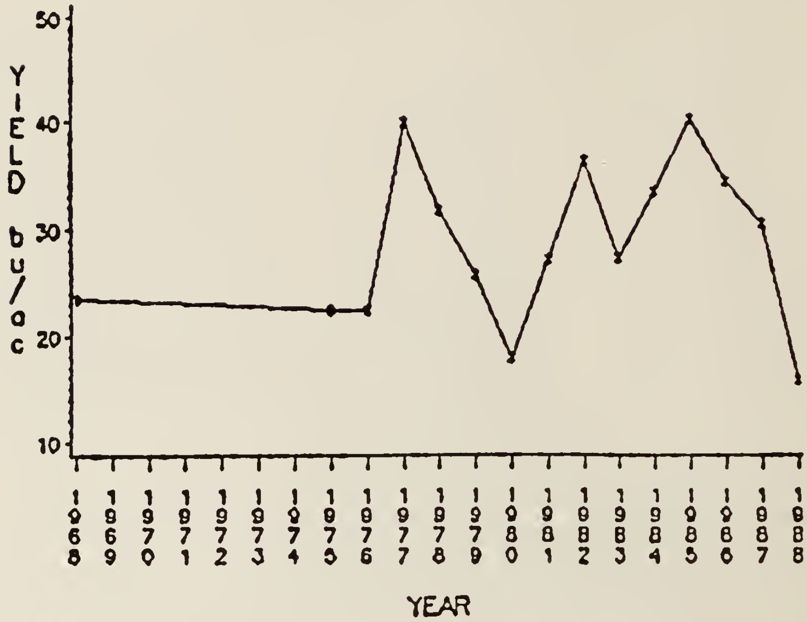
ARA 28 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 28 OBS=1190



ARA 28 Figure 3:

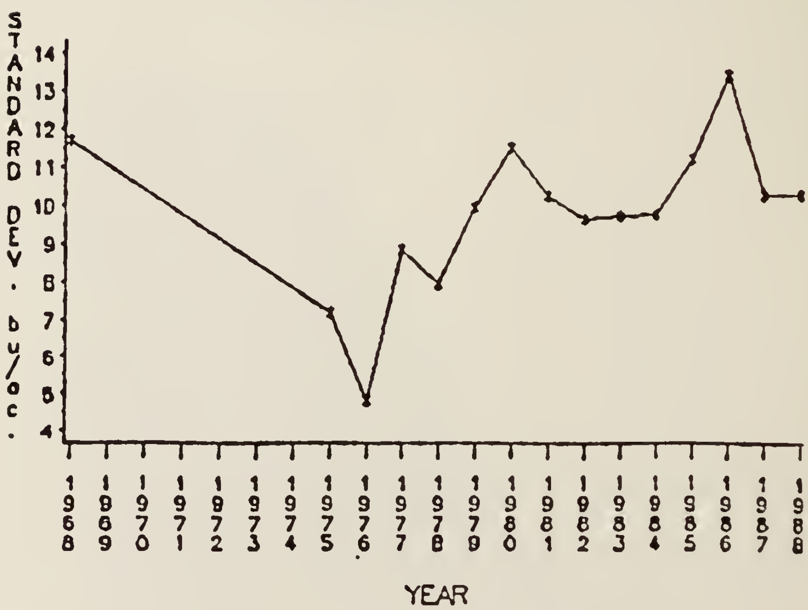
AVERAGE WHEAT YIELDS FOR ARA 28



• Represents years that have more than 10 reported yields
All other years are not included in the analysis

ARA 28 Figure 4:

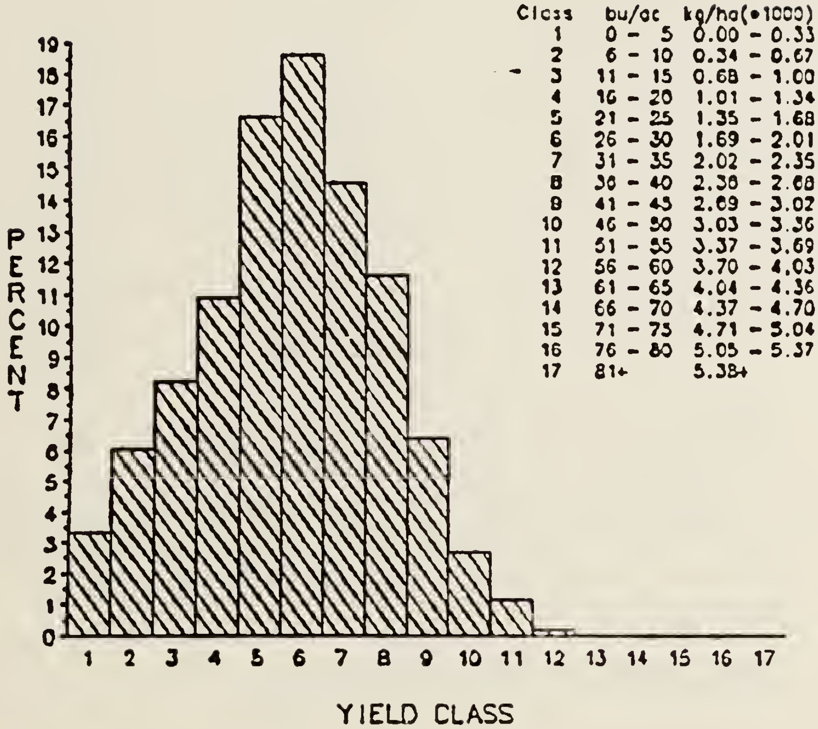
S.D. FROM THE MEAN WHEAT YIELDS
FOR ARA 28



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1968, 1975–1988
Nitrogen Level: 42kg/hat

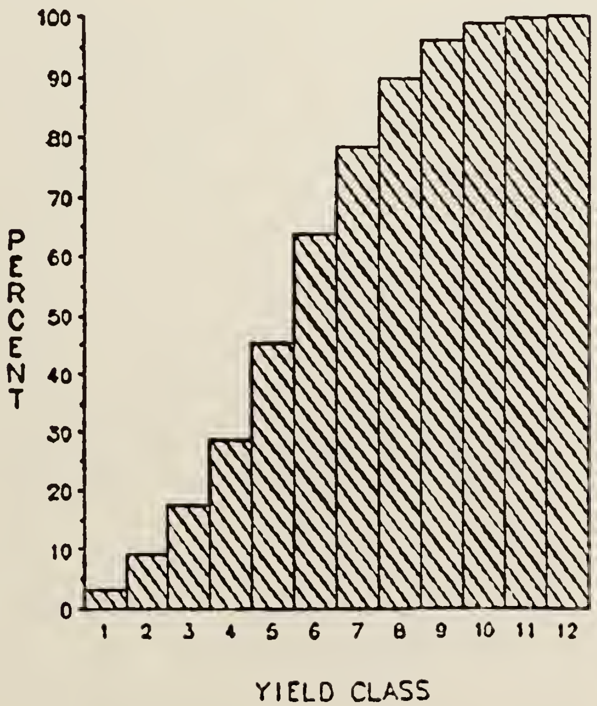
ARA 29 Figure 1:

FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 29 OBS=2388

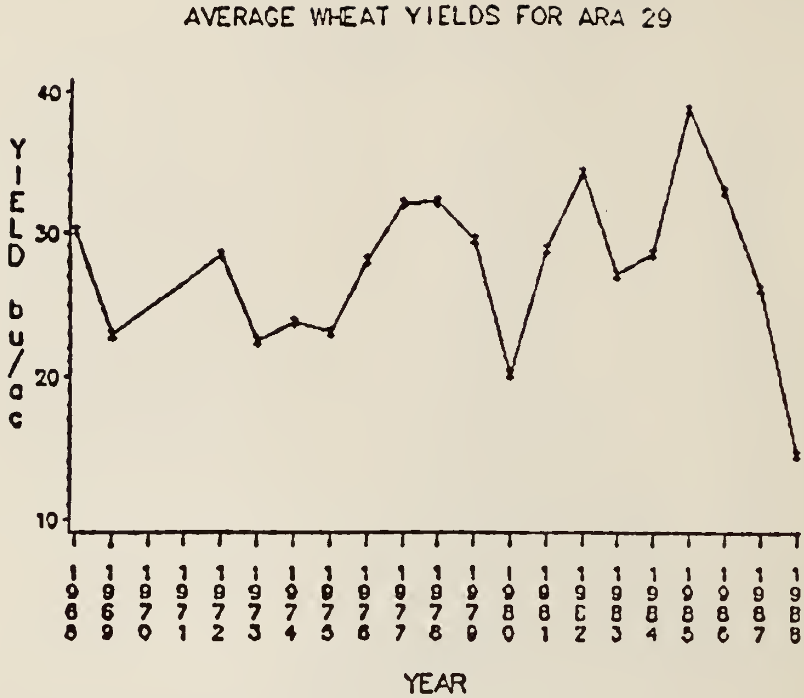


ARA 29 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 29 OBS=2388

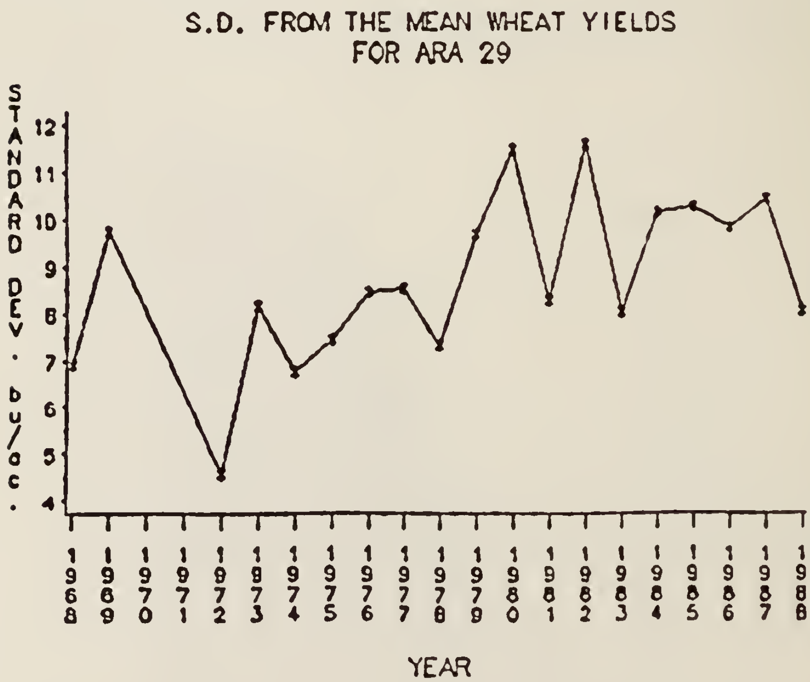


ARA 29 Figure 3:



• Represents years that have more than 10 reported yields
All other years are not included in the analysis

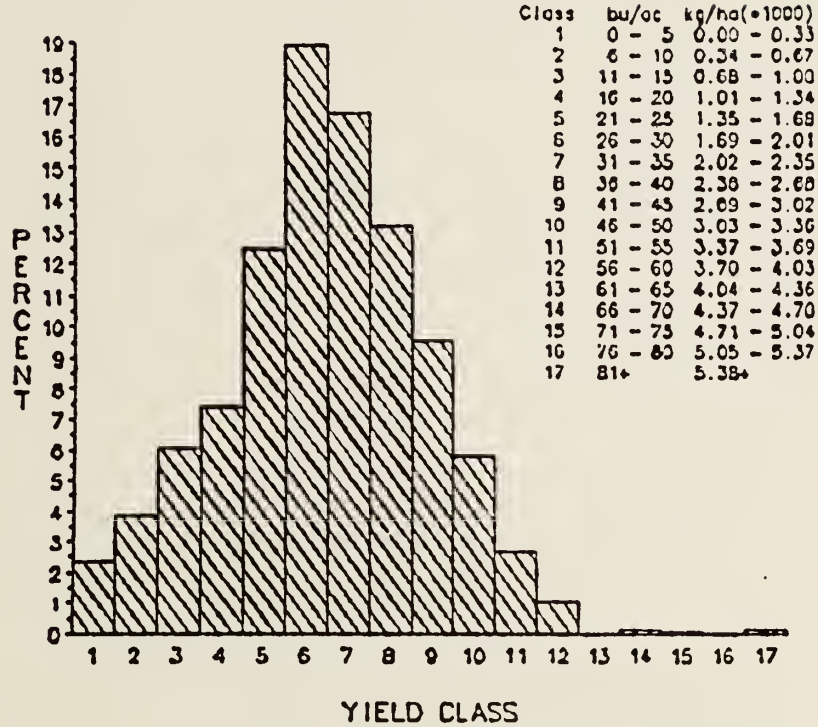
ARA 29 Figure 4:



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1968, 1969, 1972–1988
Nitrogen Level: 42kg/ha+

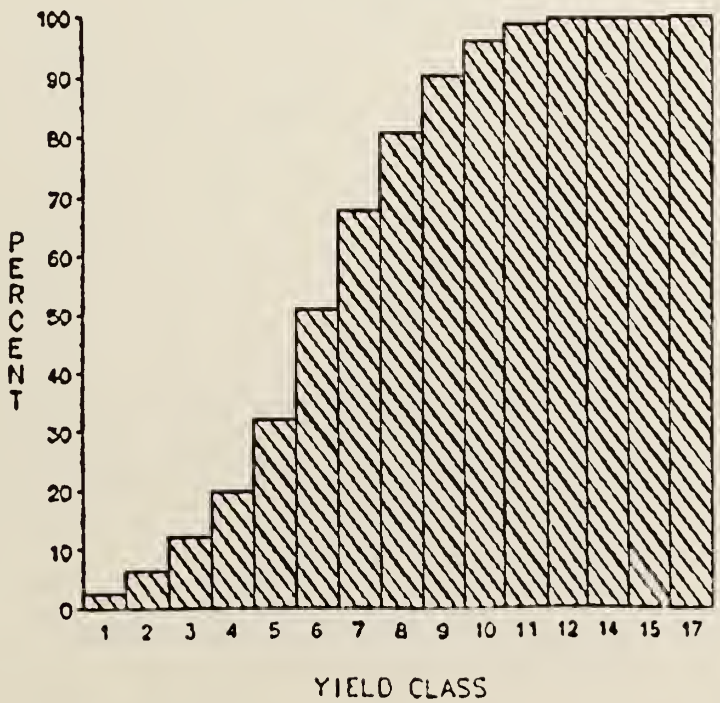
ARA 31 Figure 1:

FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 31 OBS=1497

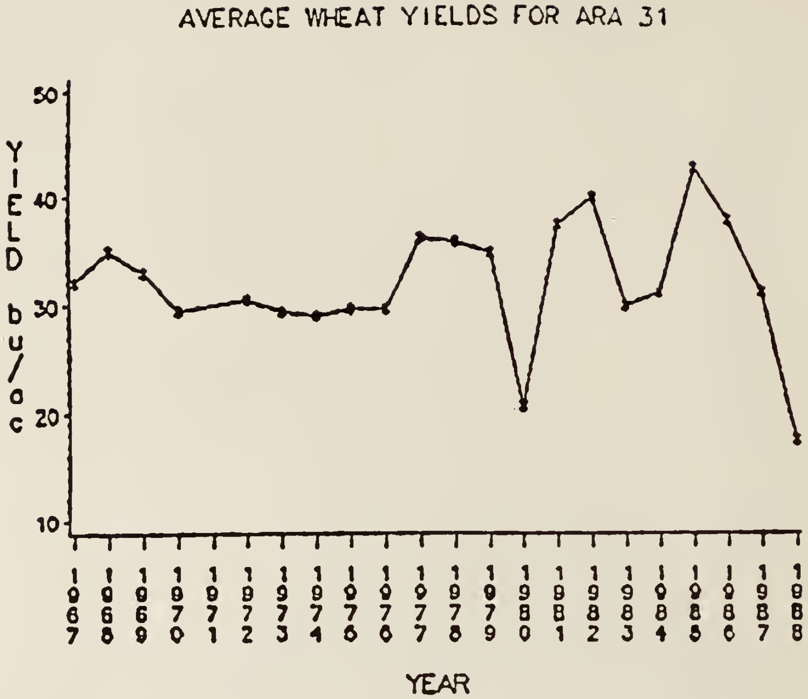


ARA 31 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 31 OBS=1497

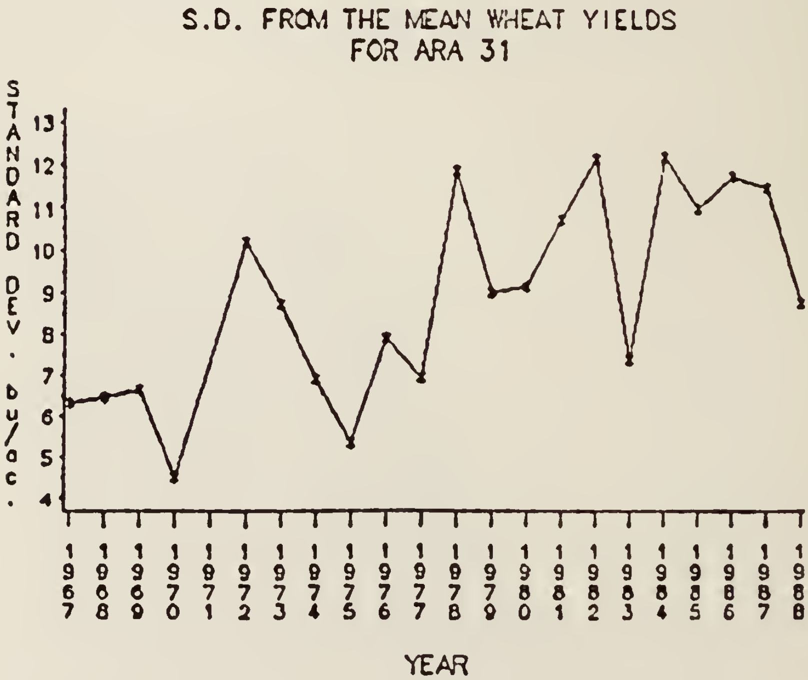


ARA 31 Figure 3:



* Represents years that have more than 10 reported yields
All other years are not included in the analysis

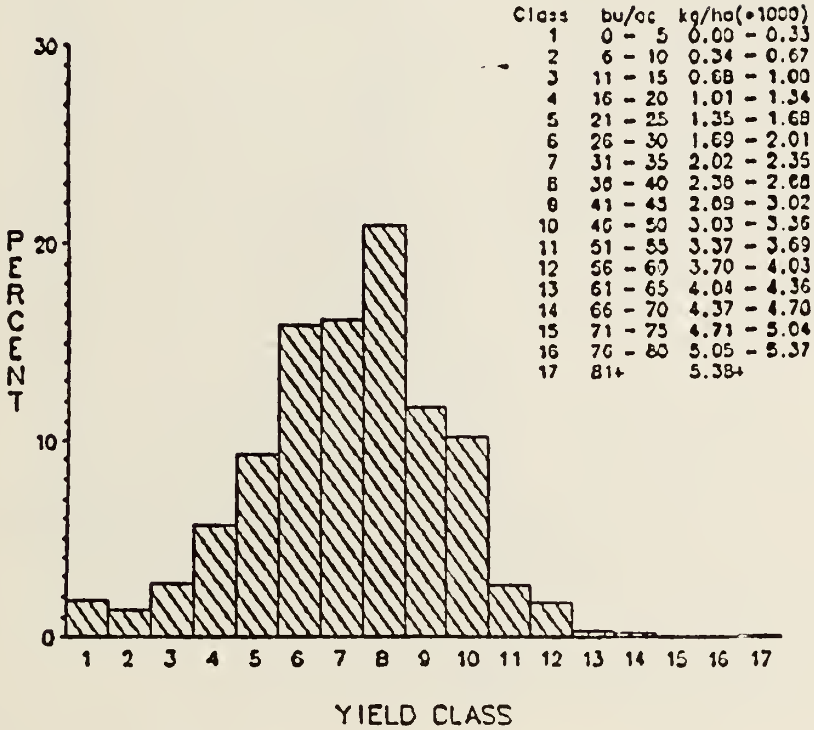
ARA 31 Figure 4:



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1967-1970, 1972-1985
Nitrogen Level: 42kg/ha+

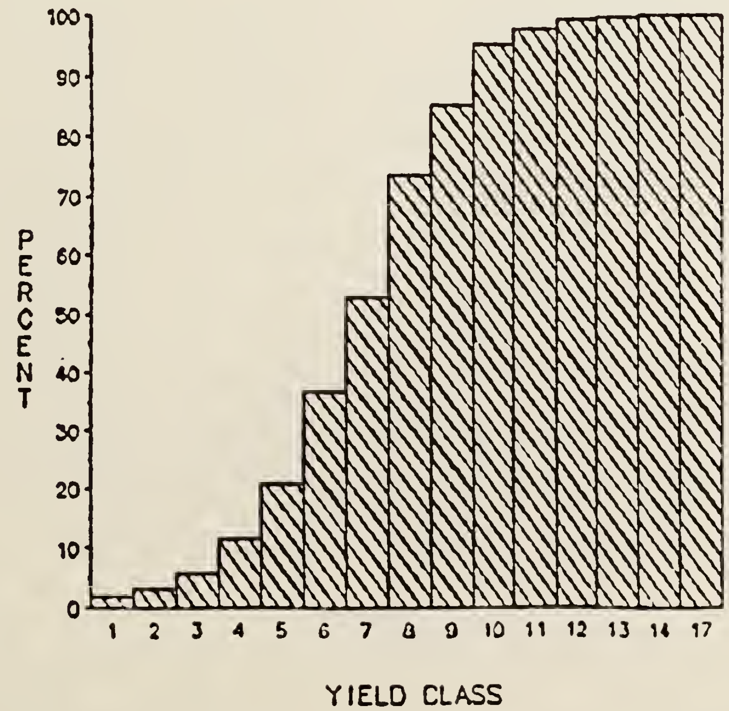
ARA 33 Figure 1:

FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 33 OBS=1965

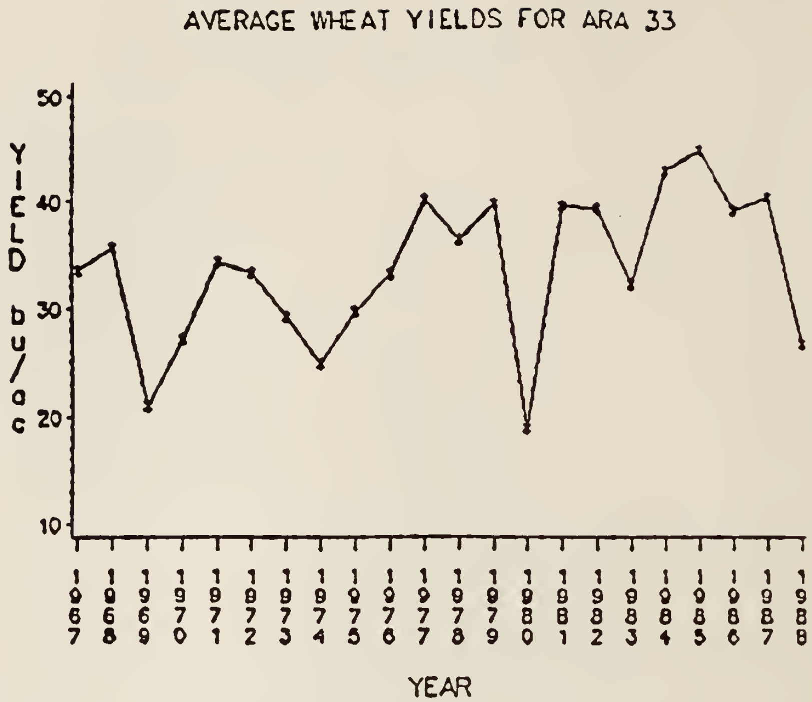


ARA 33 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 33 OBS=1965

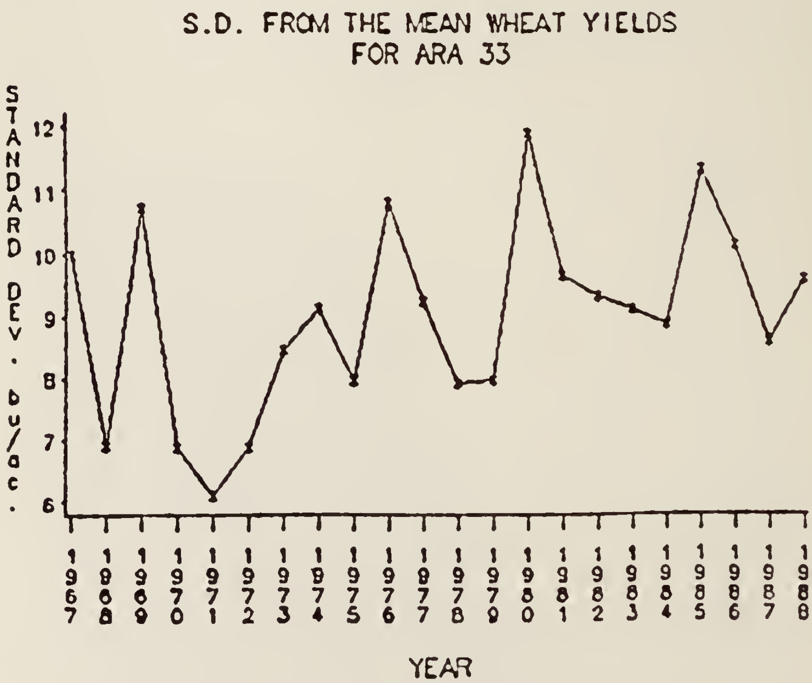


ARA 33 Figure 3:



• Represents years that have more than 10 reported yields
All other years are not included in the analysis

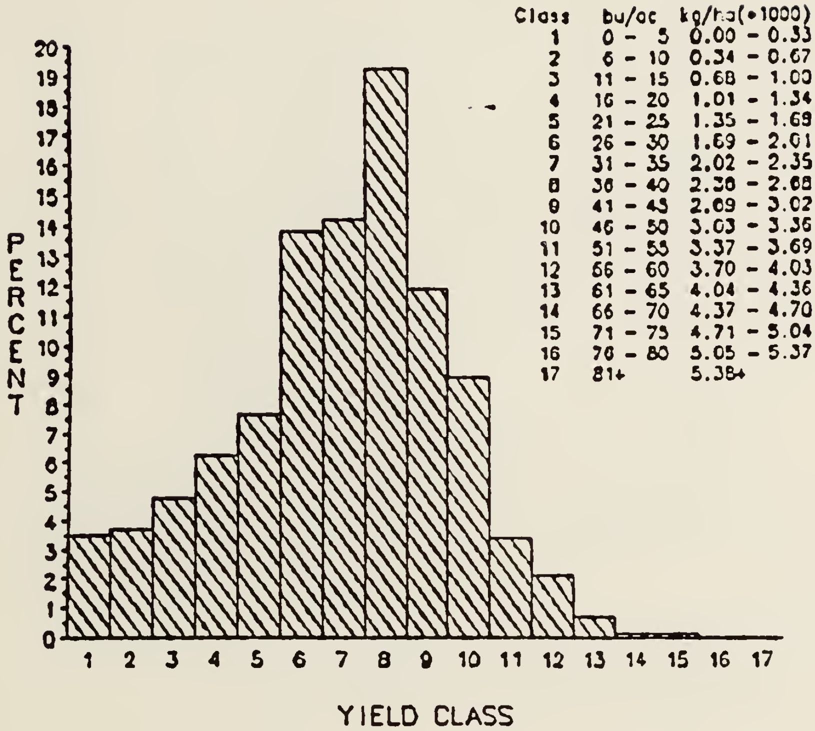
ARA 33 Figure 4:



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1967-1988
Nitrogen Level: 42kg/ha+

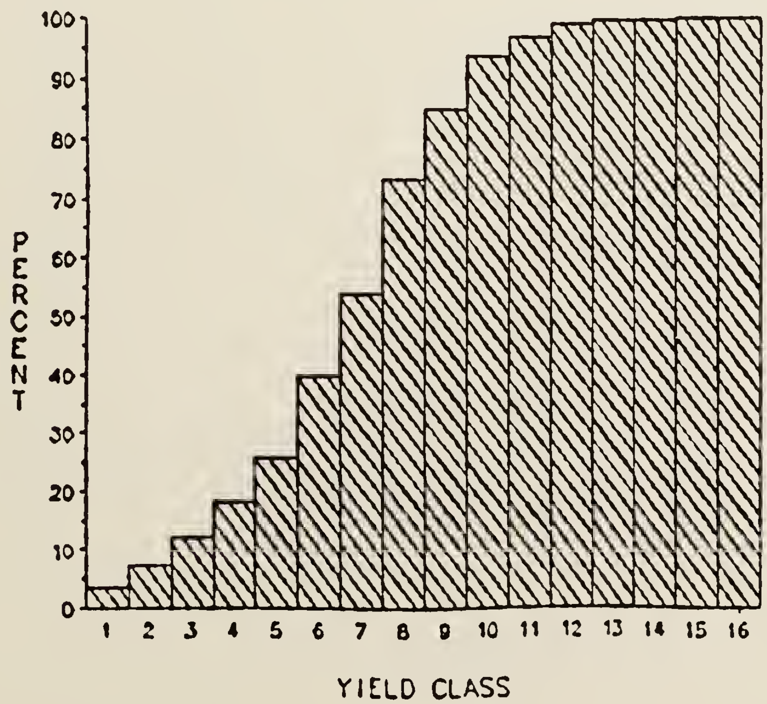
ARA 34 Figure 1:

FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 34 OBS=10821



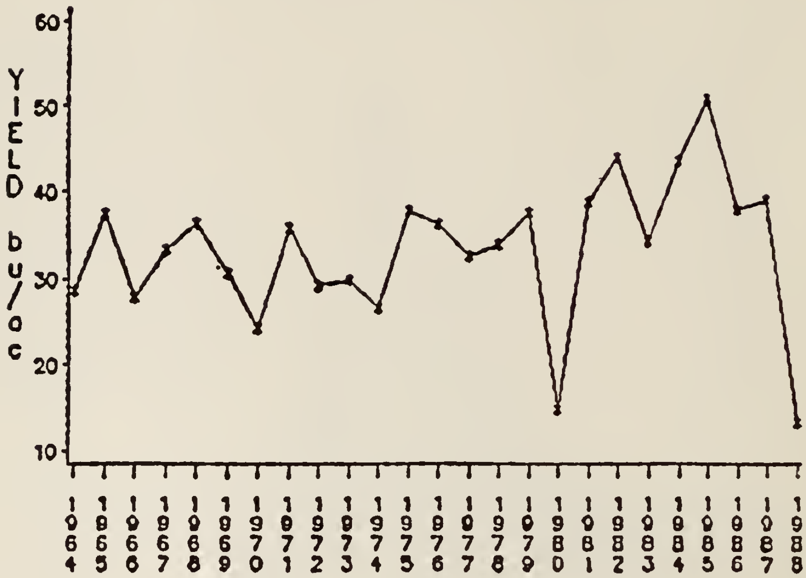
ARA 34 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 34 OBS=10821



ARA 34 Figure 3:

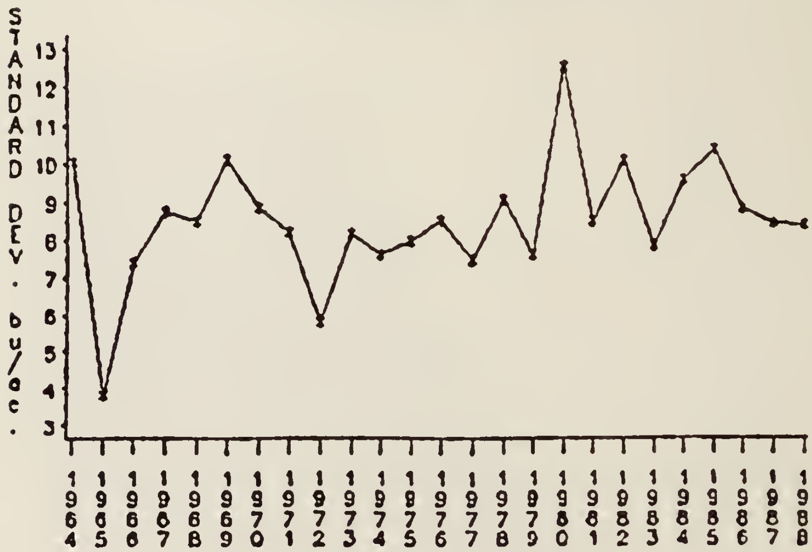
AVERAGE WHEAT YIELDS FOR ARA 34



* Represents years that have more than 10 reported yields
All other years are not included in the analysis

ARA 34 Figure 4:

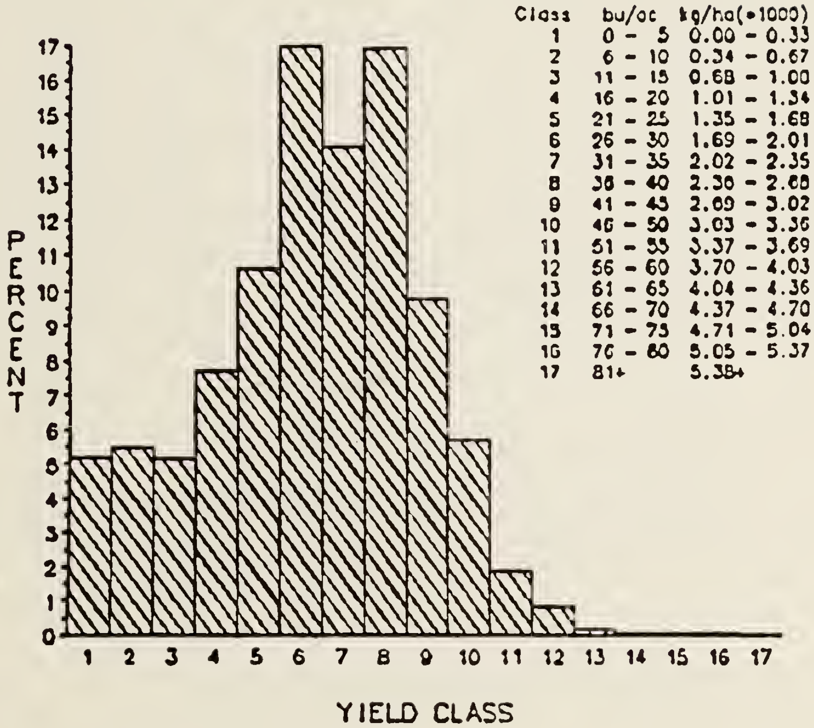
S.D. FROM THE MEAN WHEAT YIELDS
FOR ARA 34



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1964–1988
Nitrogen Level: 42kg/hac

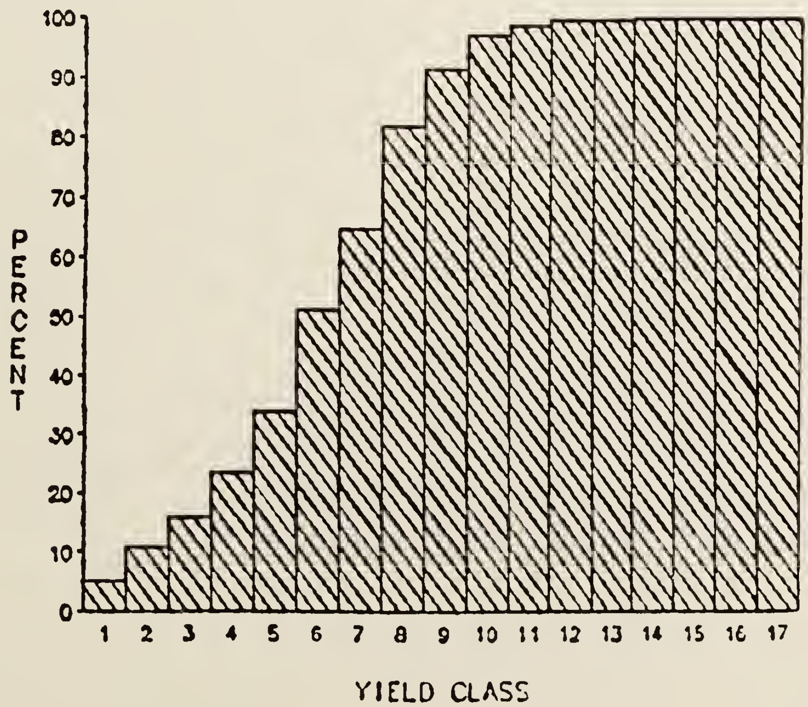
ARA 35 Figure 1:

FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 35 OBS=18478

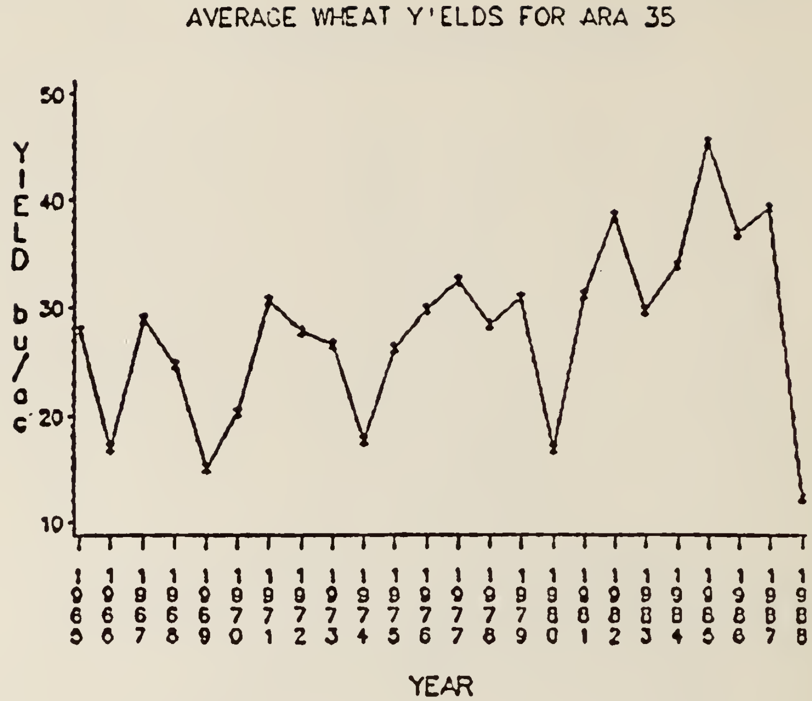


ARA 35 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 35 OBS=18478

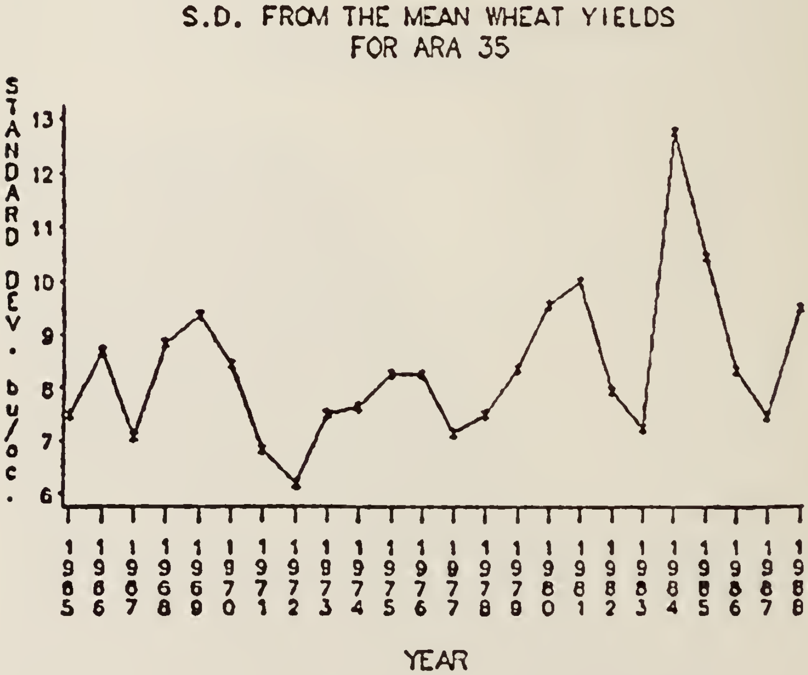


ARA 35 Figure 3:



• Represents years that have more than 10 reported yields
All other years are not included in the analysis

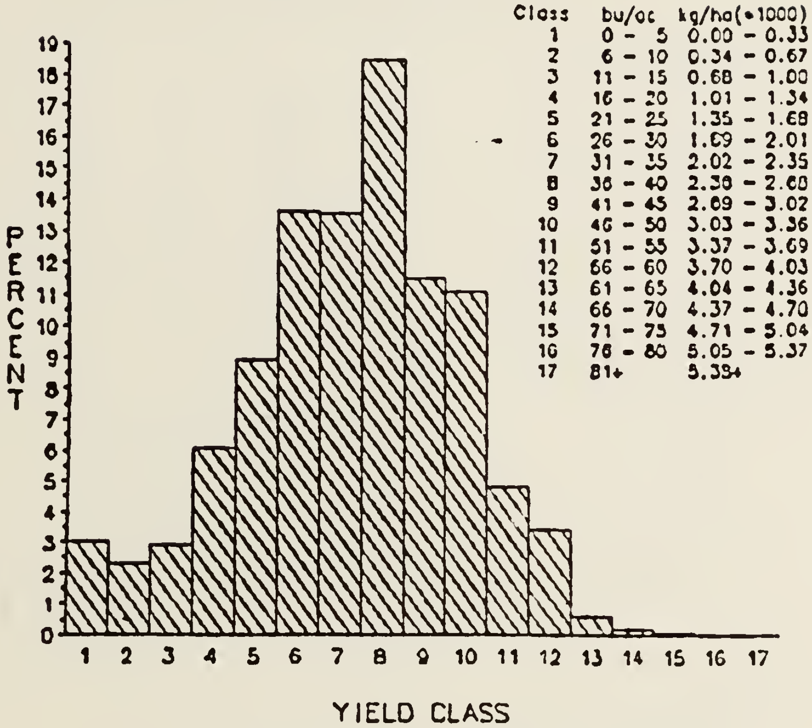
ARA 35 Figure 4:



Data Source:Manitoba Crop Insurance Corporation
Questionnaire 1965-1988
Nitrogen Level: 42kg/ha+

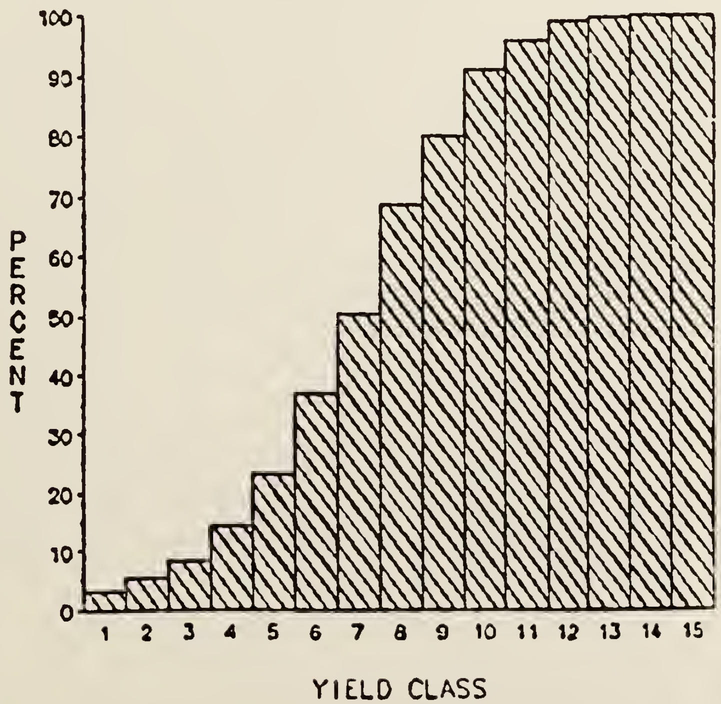
ARA 36 Figure 1:

FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 36 OBS=3263

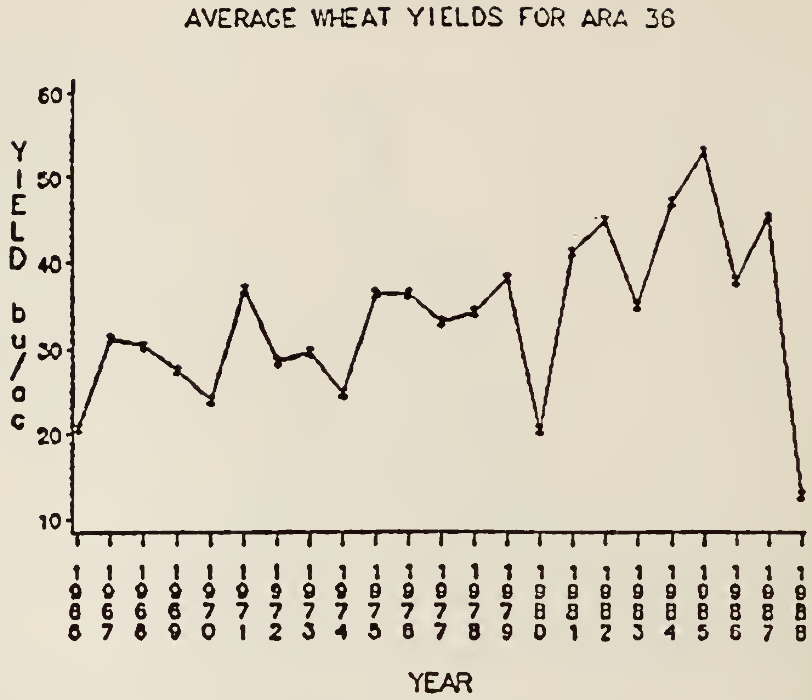


ARA 36 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 36 OBS=3263

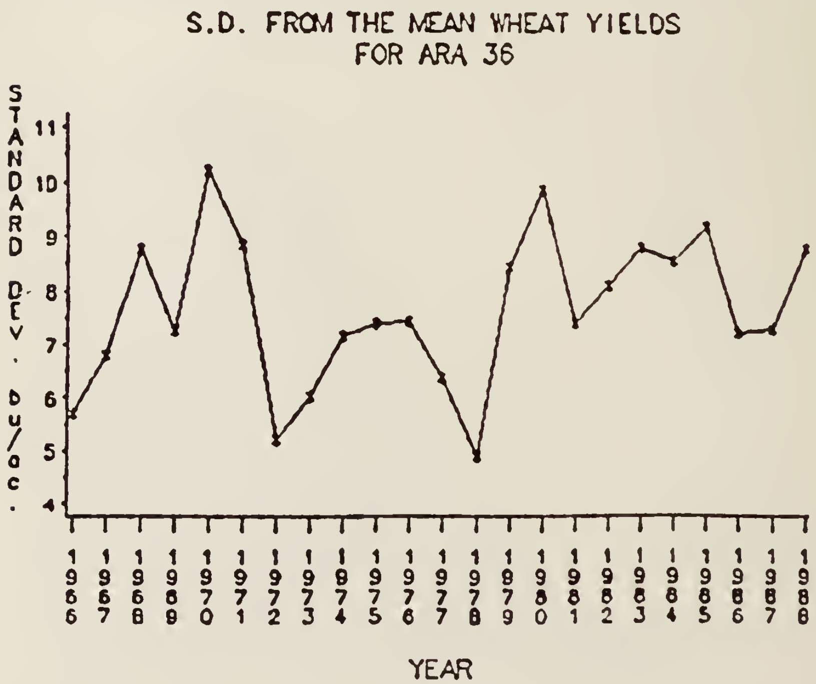


ARA 36 Figure 3:



* Represents years that have more than 10 reported yields
All other years are not included in the analysis

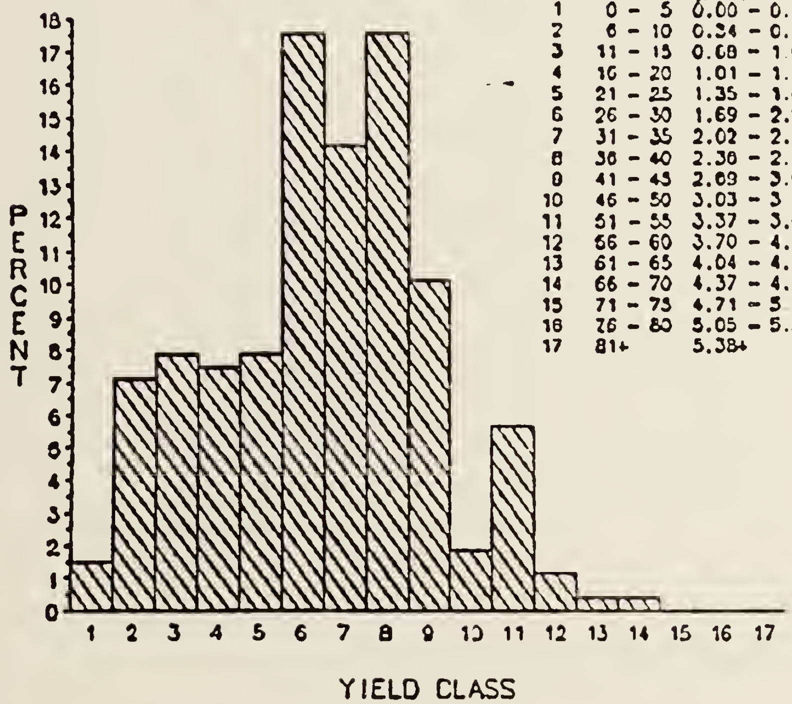
ARA 36 Figure 4:



Data Source:Manitoba Crop Insurance Corporation
Questionnaire 1966-1988
Nitrogen Level: 42kg/ha+

ARA 37 Figure 1:

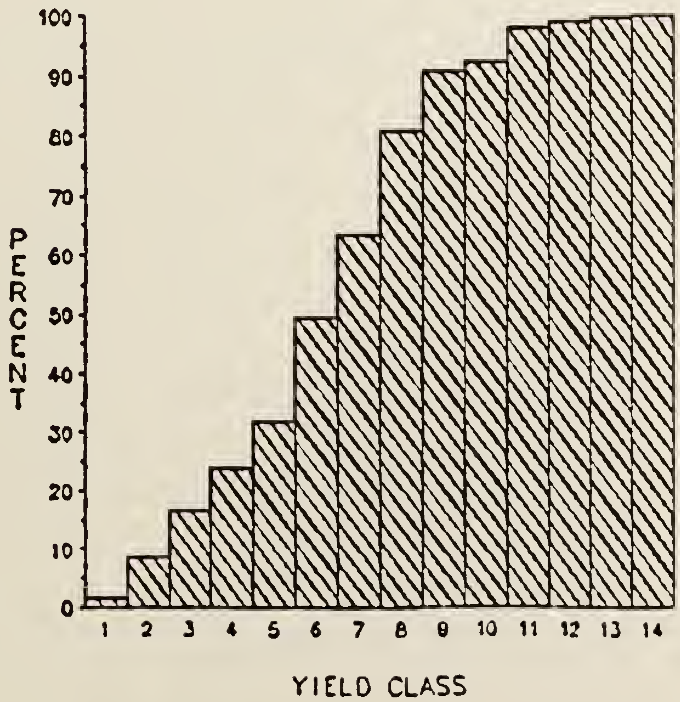
FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 37 OBS=269



Class	bu/ac	kg/ha(*1000)
1	0 - 5	0.00 - 0.33
2	6 - 10	0.34 - 0.67
3	11 - 15	0.68 - 1.00
4	16 - 20	1.01 - 1.34
5	21 - 25	1.35 - 1.68
6	26 - 30	1.69 - 2.01
7	31 - 35	2.02 - 2.35
8	36 - 40	2.36 - 2.68
9	41 - 45	2.69 - 3.02
10	46 - 50	3.03 - 3.36
11	51 - 55	3.37 - 3.69
12	56 - 60	3.70 - 4.03
13	61 - 65	4.04 - 4.36
14	66 - 70	4.37 - 4.70
15	71 - 75	4.71 - 5.04
16	76 - 80	5.05 - 5.37
17	81+	5.38+

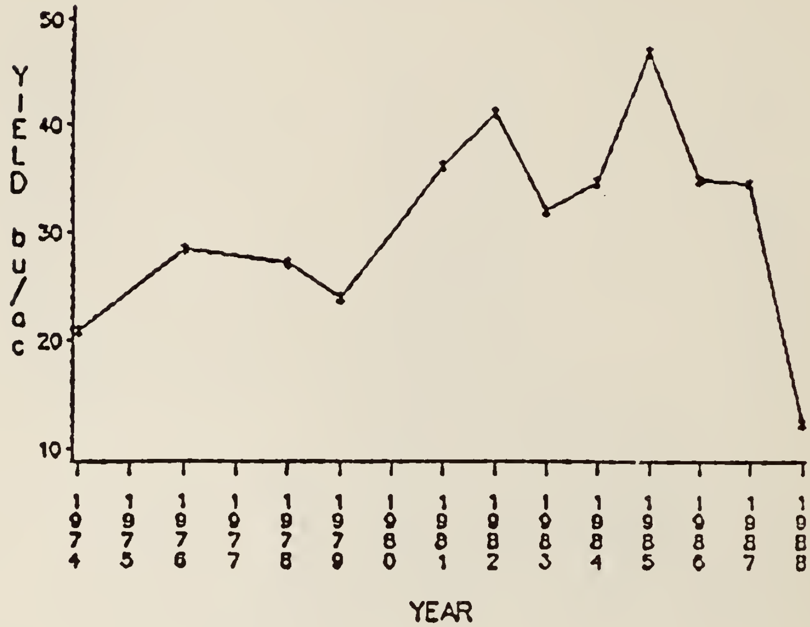
ARA 37 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 37 OBS=269



ARA 37 Figure 3:

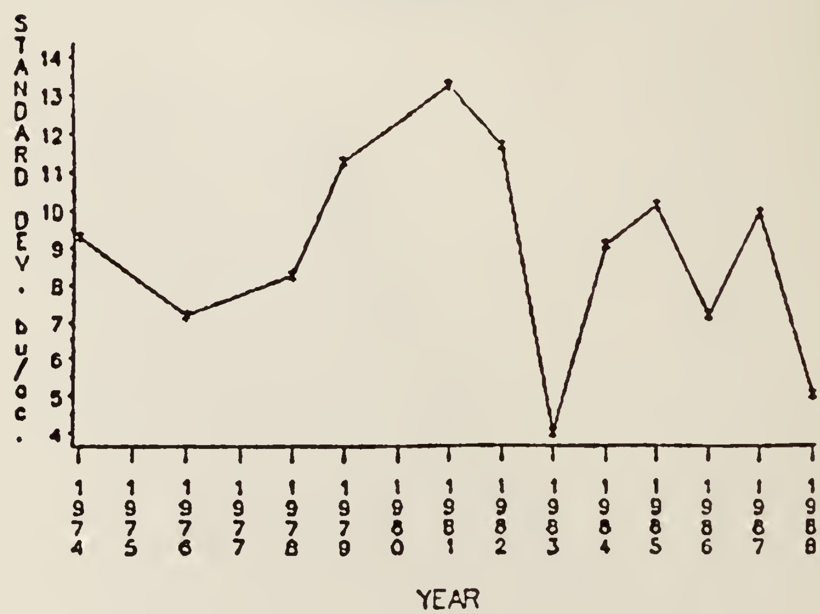
AVERAGE WHEAT YIELDS FOR ARA 37



* Represents years that have more than 10 reported yields
All other years are not included in the analysis

ARA 37 Figure 4:

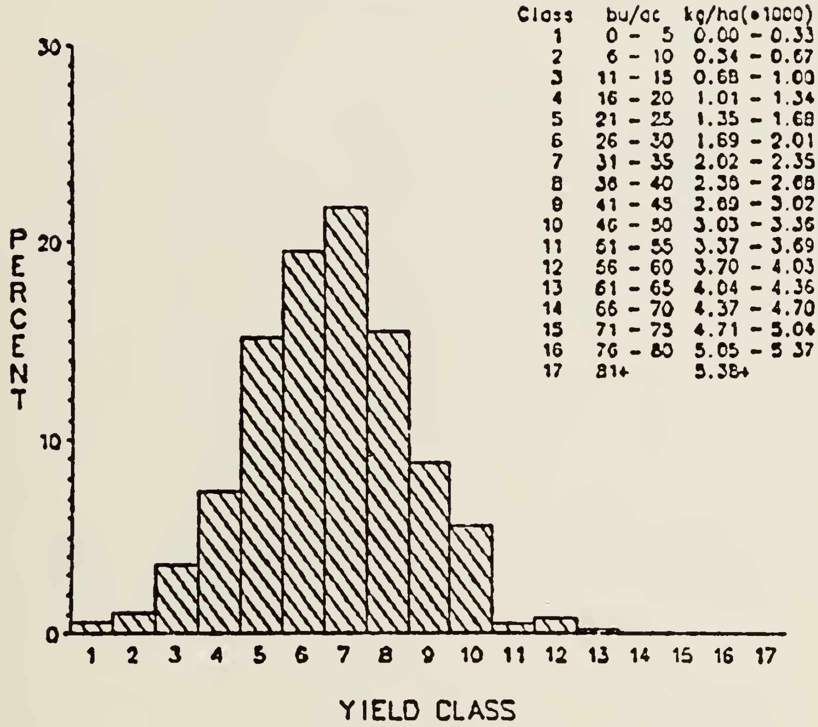
S.D. FROM THE MEAN WHEAT YIELDS
FOR ARA 37



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1974, 1976, 1978, 1979, 1981-1988
Nitrogen Level: 42kg/ha*

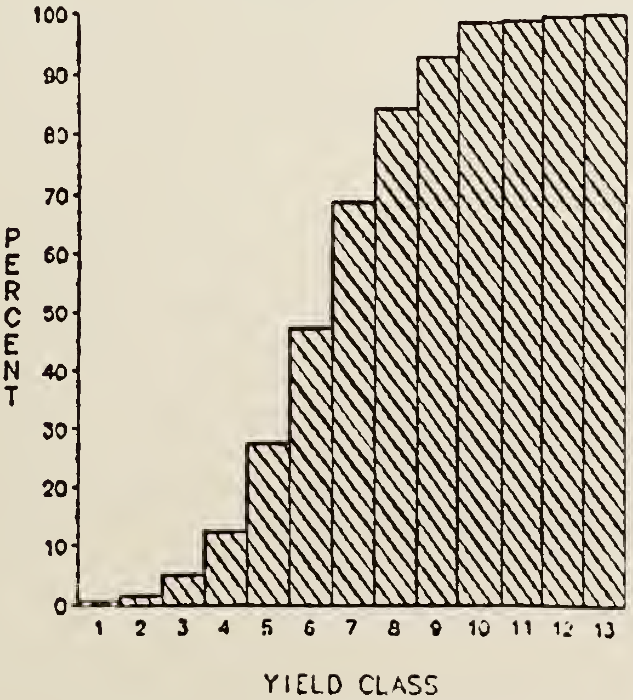
ARA 39 Figure 1:

FREQUENCY DISTRIBUTION OF WHEAT YIELDS
ARA 39 OBS=654

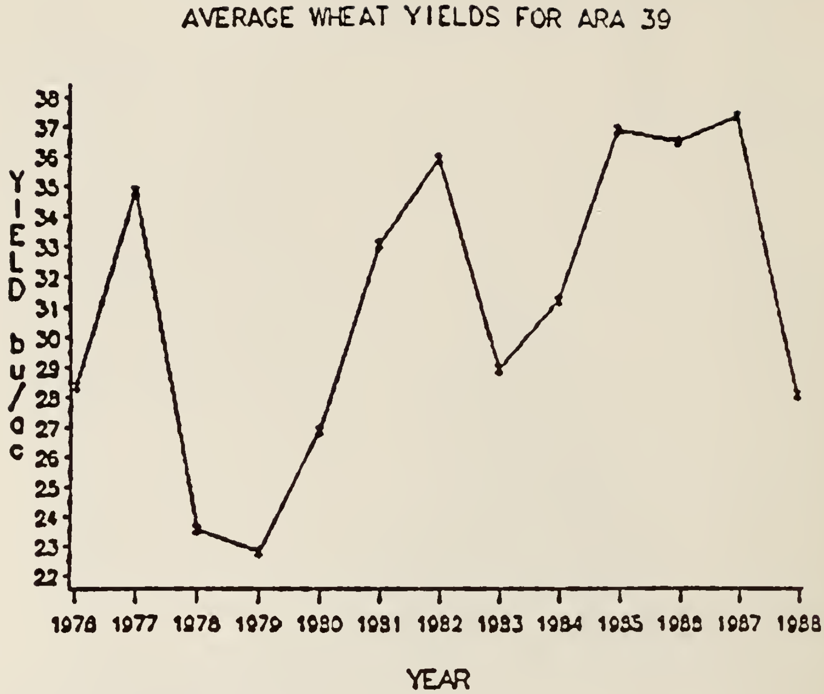


ARA 39 Figure 2:

CUMULATIVE PROBABILITY DISTRIBUTION OF WHEAT YIELDS
ARA 39 OBS=654

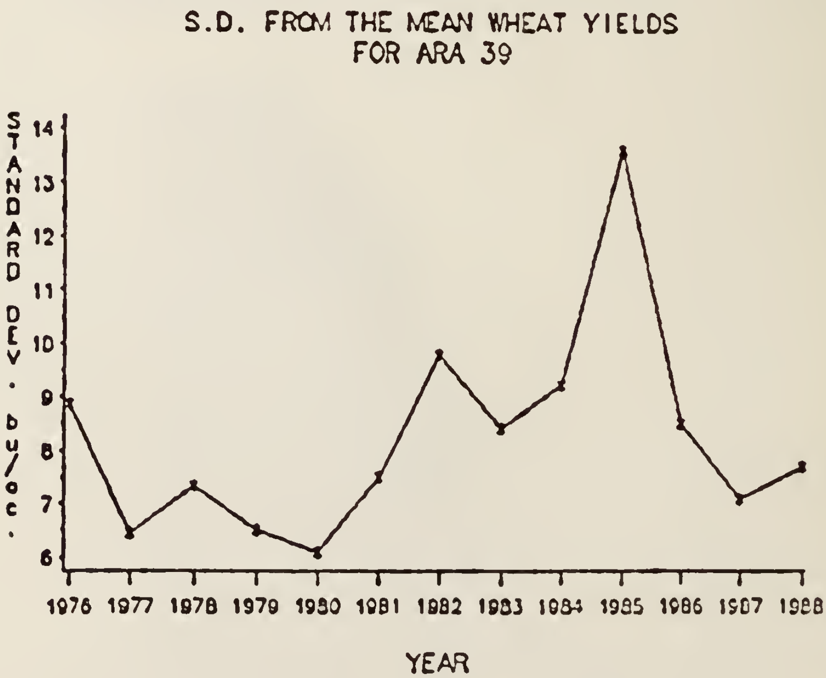


ARA 39 Figure 3:



* Represents years that have more than 10 reported yields
All other years are not included in the analysis

ARA 39 Figure 4:



Data Source: Manitoba Crop Insurance Corporation
Questionnaire 1976-1988

APPENDIX 3. Frequency of dissimilar comparisons for each step of the grouping criteria for each qualifying ARA

	Level of the criteria % (number)			Total	Passed all	
ARA	Mean	S.D.	Pattern	R value	dissimilar	criteria
1	83.3(25)	3.3(1)	0.0(0)	6.7(2)	93.3(28)	6.7(2)
2	20.0(18)	26.7(8)	3.3(1)	0.0(0)	90.0(27)	10.0(3)
3	46.7(14)	23.3(7)	13.3(4)	10.0(3)	93.3(28)	6.7(2)
4	26.7(8)	26.7(8)	6.7(2)	16.7(5)	76.7(23)	23.3(7)
5	50.0(15)	23.3(7)	10.0(3)	13.3(4)	96.7(29)	3.3(1)
6	30.0(9)	36.7(11)	10.0(3)	16.7(5)	93.3(28)	6.7(2)
7	66.7(20)	13.3(4)	3.3(1)	10.0(3)	93.3(28)	6.7(2)
8	46.7(14)	20.0(6)	10.0(3)	10.0(3)	86.7(26)	13.3(4)
9	36.7(11)	30.0(9)	6.7(2)	13.3(4)	86.7(26)	13.3(4)
10	46.7(14)	26.7(8)	13.3(4)	10.0(3)	96.7(29)	3.3(1)
11	36.7(11)	33.3(10)	20.0(6)	3.3(1)	96.7(29)	3.3(1)
12	36.7(11)	33.3(10)	10.0(3)	10.0(3)	90.0(27)	10.0(3)
13	43.3(13)	13.3(4)	16.6(5)	20.0(6)	93.3(28)	6.7(2)
14	36.7(11)	30.0(9)	30.0(9)	3.3(1)	100.0(30)	0.0(0)
15	20.0(6)	43.3(13)	26.7(8)	10.0(3)	100.0(30)	0.0(0)
16	16.7(5)	6.7(2)	23.3(7)	43.3(13)	90.0(27)	10.0(3)
17	50.0(15)	33.3(10)	3.3(1)	13.3(4)	100.0(30)	0.0(0)
18	20.0(6)	30.0(9)	30.0(9)	20.0(6)	100.0(30)	0.0(0)
19	56.7(17)	13.3(4)	10.0(3)	16.7(5)	96.7(29)	3.3(1)
21	36.7(11)	23.3(7)	10.0(3)	26.7(8)	96.7(29)	3.3(1)
22	23.3(7)	23.3(7)	20.0(6)	23.3(7)	90.0(27)	10.0(3)
26	23.3(7)	53.3(16)	20.0(6)	3.3(1)	100.0(30)	0.0(0)
28	20.0(6)	60.0(18)	10.0(3)	6.7(2)	96.7(29)	3.3(1)
29	40.0(12)	23.3(7)	23.3(7)	3.3(1)	90.0(27)	10.0(3)
31	36.7(11)	36.7(11)	10.0(3)	16.7(5)	100.0(30)	0.0(0)
33	83.3(25)	0.0(0)	10.0(3)	6.7(2)	100.0(30)	0.0(0)
34	83.3(25)	6.7(2)	10.0(3)	0.0(0)	100.0(30)	0.0(0)
35	40.0(12)	30.0(9)	30.0(9)	0.0(0)	100.0(30)	0.0(0)
36	83.3(25)	6.7(2)	6.7(2)	3.3(1)	100.0(30)	0.0(0)
37	3.3(1)	0.0(0)	93.3(28)	0.0(0)	96.7(29)	3.3(1)
39	16.7(5)	6.7(2)	46.7(14)	30.0(9)	100.0(30)	0.0(0)

APPENDIX 4. Interim grouping comparison results

4.1. Probability of a difference between the first interim grouping least squared means for mean yields and standard deviations

		Mean yield probabilities																				
	Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	1	--	0.28	0.00	0.00	0.00	0.00	0.10	0.00	0.16	0.01	0.00	0.07	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.21	--	0.06	0.00	0.00	0.01	0.64	0.00	0.55	0.08	0.00	0.29	0.00	0.06	0.11	0.00	0.00	0.00	0.00	0.00	0.02
	3	0.53	0.32	--	0.03	0.00	0.11	0.17	0.03	0.56	0.41	0.00	0.94	0.00	0.47	0.62	0.02	0.00	0.00	0.00	0.00	0.11
	4	0.06	0.99	0.04	--	0.00	0.75	0.02	0.24	0.21	0.84	0.04	0.62	0.00	0.88	0.78	0.15	0.00	0.00	0.18	0.00	0.31
S	5	0.00	0.07	0.00	0.00	--	0.00	0.00	0.44	0.01	0.35	0.92	0.12	0.92	0.08	0.09	0.90	0.02	0.00	0.01	0.00	0.97
t	6	0.00	0.02	0.00	0.00	0.33	--	0.03	0.19	0.26	0.77	0.03	0.69	0.01	0.41	0.99	0.88	0.00	0.00	0.14	0.00	0.27
d	7	0.01	0.28	0.01	0.14	0.68	0.35	--	0.01	0.80	0.15	0.00	0.46	0.00	0.13	0.21	0.01	0.00	0.00	0.00	0.00	0.04
	8	0.25	0.90	0.39	0.87	0.04	0.01	0.22	--	0.08	0.67	0.58	0.31	0.53	0.37	0.34	0.68	0.02	0.02	0.60	0.00	0.73
D	9	0.00	0.01	0.00	0.00	0.09	0.19	0.09	0.01	--	0.31	0.03	0.65	0.02	0.35	0.43	0.05	0.00	0.00	0.10	0.00	0.11
e	10	0.66	0.22	0.43	0.17	0.01	0.01	0.05	0.25	0.00	--	0.41	0.61	0.39	0.80	0.74	0.48	0.03	0.05	0.86	0.02	0.53
v	11	0.78	0.33	0.81	0.16	0.00	0.00	0.03	0.38	0.00	0.55	--	0.16	0.99	0.15	0.15	0.96	0.04	0.05	0.17	0.02	0.99
.	12	0.00	0.05	0.01	0.03	0.24	0.38	0.21	0.04	0.83	0.01	0.01	--	0.14	0.73	0.81	0.21	0.01	0.01	0.40	0.01	0.28
	13	0.00	0.06	0.00	0.00	0.64	0.79	0.52	0.03	0.17	0.01	0.00	0.34	--	0.12	0.13	0.95	0.03	0.02	0.09	0.01	0.99
p	14	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.00	0.72	0.00	0.00	0.58	0.02	--	0.91	0.24	0.00	0.00	0.50	0.00	0.34
r	15	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.00	0.61	0.00	0.00	0.49	0.02	0.84	--	0.23	0.00	0.00	0.46	0.00	0.32
o	16	0.00	0.01	0.00	0.00	0.06	0.16	0.07	0.00	0.87	0.00	0.00	0.94	0.14	0.54	0.44	--	0.08	0.14	0.35	0.05	0.97
b	17	0.00	0.02	0.00	0.00	0.15	0.36	0.16	0.01	0.57	0.00	0.00	0.78	0.32	0.25	0.21	0.63	--	0.44	0.00	0.99	0.20
.	18	0.00	0.12	0.00	0.00	0.73	0.23	0.84	0.07	0.08	0.02	0.00	0.20	0.49	0.00	0.01	0.05	0.12	--	0.00	0.34	0.33
	19	0.00	0.07	0.00	0.00	0.97	0.30	0.69	0.04	0.09	0.01	0.00	0.23	0.62	0.01	0.01	0.06	0.15	0.74	--	0.00	0.50
	20	0.33	0.71	0.53	0.60	0.01	0.00	0.12	0.81	0.00	0.31	0.50	0.03	0.01	0.00	0.00	0.00	0.00	0.02	0.01	--	0.17
	21	0.23	0.70	0.32	0.66	0.55	0.37	0.74	0.64	0.11	0.20	0.30	0.20	0.45	0.04	0.03	0.11	0.20	0.63	0.56	0.52	--

4.2. Significant correlations ($p<0.05$) between patterns of mean yields for the first interim grouping of ARAs[1,2]

	Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
		Correlation coefficients																				
	1		0.89	0.85	0.83	0.73	0.87	0.88	0.78	--	--	--	--	0.59	--	0.85	0.84	0.59	0.74	0.72	0.64	--
N	2	15		0.72	0.89	0.63	0.79	0.76	0.74	--	--	--	--	0.51	--	0.74	0.73	0.55	0.61	0.72	0.59	--
u	3	16	16		0.88	0.94	0.94	0.89	0.81	--	--	0.72	0.64	0.70	0.53	0.86	0.91	0.74	0.83	0.76	0.76	--
m	4	16	16	23		0.85	0.93	0.87	0.90	--	--	0.64	--	0.69	0.48	0.91	0.87	0.69	0.77	0.80	0.76	0.59
b	5	16	16	23	23		0.91	0.88	0.83	--	--	0.71	--	0.62	0.63	0.88	0.90	0.81	0.89	0.84	0.85	--
e	6	16	16	23	23	23		0.90	0.87	--	--	0.60	--	0.61	0.63	0.92	0.93	0.78	0.84	0.83	0.78	0.56
r	7	16	16	21	21	21	21		0.94	--	--	0.53	--	0.66	--	0.85	0.91	0.61	0.83	0.72	0.75	--
	8	16	16	23	23	23	23	21		--	--	--	--	0.60	--	0.85	0.89	0.57	0.77	0.71	0.73	--
o	9	12	12	12	12	12	12	12	12		--	--	--	--	--	--	--	--	--	--	--	--
f	10	12	12	12	12	12	12	12	12	12		0.68	0.70	--	--	--	--	--	--	--	--	--
	11	15	14	16	16	16	16	16	16	12	12		0.73	0.73	--	0.63	0.55	0.66	0.50	0.52	--	0.57
y	12	12	12	12	12	12	12	12	12	11	11	12		0.75	--	--	--	--	--	--	--	--
e	13	16	16	19	19	19	19	18	19	12	12	15	12		--	0.60	0.55	0.58	0.56	0.53	0.53	--
a	14	16	16	18	18	18	18	18	18	12	12	15	12	15		0.68	0.53	0.77	0.58	0.67	0.59	0.56
r	15	14	15	15	15	15	15	15	15	12	12	13	12	18	15		0.82	0.82	0.72	0.86	0.74	0.62
s	16	16	16	21	21	21	21	20	21	12	12	16	12	18	18	15		0.71	0.84	0.74	0.76	--
	17	16	16	22	22	22	22	21	22	12	12	16	12	18	18	15	21		0.82	0.89	0.83	--
	18	16	16	23	23	23	23	21	23	12	12	16	12	18	18	15	21	22		0.87	0.95	--
	19	16	16	23	23	23	23	21	23	12	12	16	12	18	18	15	21	22	24		0.93	0.66
	20	16	16	23	23	23	23	21	23	12	12	16	12	18	18	15	21	22	23	23		--
	21	13	13	13	13	13	13	13	13	12	12	13	12	13	13	13	13	13	13	13	13	

[1] -- indicates pairs of ARAs which were not significantly correlated ($p>0.05$)
[2] number of years in which both ARAs in the comparison had at least 10 observations.

4.3. Probability of a difference between the second interim grouping least square means for mean yields and standard deviations

	Mean yield probabilities																	
	Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	1	-	0.00	0.00	0.00	0.00	0.23	0.29	0.03	0.00	0.15	0.00	0.01	0.03	0.00	0.00	0.00	0.01
S	2	0.45	--	0.02	0.00	0.06	0.21	0.60	0.45	0.00	0.94	0.00	0.51	0.65	0.00	0.00	0.00	0.15
t	3	0.39	0.02	--	0.00	0.88	0.02	0.22	0.91	0.07	0.60	0.03	0.81	0.73	0.00	0.32	0.00	0.39
d	4	0.00	0.00	0.00	--	0.00	0.00	0.02	0.39	0.93	0.16	0.93	0.11	0.13	0.00	0.02	0.01	0.97
	5	0.00	0.00	0.00	0.11	--	0.03	0.25	0.88	0.07	0.63	0.03	0.87	0.78	0.00	0.31	0.00	0.37
D	6	0.11	0.02	0.23	0.71	0.23	--	0.82	0.19	0.00	0.49	0.00	0.17	0.25	0.00	0.00	0.00	0.05
e	7	0.01	0.00	0.01	0.13	0.32	0.12	--	0.35	0.05	0.68	0.04	0.40	0.48	0.00	0.13	0.00	0.14
v	8	0.32	0.47	0.17	0.02	0.01	0.07	0.01	--	0.46	0.64	0.43	0.81	0.76	0.07	0.87	0.04	0.57
.	9	0.47	0.83	0.13	0.00	0.00	0.05	0.00	0.58	--	0.20	0.99	0.19	0.19	0.05	0.21	0.03	0.99
	10	0.03	0.01	0.05	0.28	0.54	0.25	0.85	0.02	0.01	--	0.18	0.76	0.83	0.02	0.44	0.01	0.32
p	11	0.01	0.00	0.01	0.66	0.48	0.54	0.21	0.02	0.00	0.38	--	0.16	0.16	0.02	0.12	0.02	0.99
r	12	0.00	0.00	0.00	0.01	0.07	0.02	0.73	0.00	0.00	0.61	0.04	--	0.92	0.00	0.54	0.00	0.38
o	13	0.00	0.00	0.00	0.01	0.07	0.02	0.64	0.00	0.00	0.53	0.04	0.86	--	0.01	0.50	0.00	0.36
b	14	0.00	0.00	0.00	0.23	0.73	0.31	0.27	0.01	0.00	0.47	0.65	0.05	0.05	--	0.00	0.45	0.34
.	15	0.00	0.00	0.00	0.98	0.10	0.72	0.12	0.02	0.00	0.28	0.65	0.01	0.01	0.20	--	0.00	0.54
	16	0.99	0.55	0.50	0.02	0.00	0.15	0.01	0.35	0.53	0.04	0.02	0.00	0.00	0.00	0.01	--	0.22
	17	0.55	0.37	0.76	0.58	0.31	0.75	0.15	0.24	0.35	0.24	0.48	0.06	0.05	0.36	0.58	0.56	--

4.4. Significant correlations (p<0.05) between patterns of mean yields for the second interim grouping of ARAs[1,2]

Correlation coefficients

	Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	1		0.80	0.84	0.68	0.83	0.84	--	--	--	--	0.57	--	0.83	0.67	0.72	0.62	--
N	2	17		0.87	0.94	0.94	0.89	--	--	0.72	0.64	0.70	0.53	0.86	0.84	0.76	0.76	--
o	3	17	23		0.84	0.93	0.91	--	--	0.62	--	0.69	0.46	0.91	0.77	0.77	0.74	0.57
.	4	17	23	23		0.92	0.88	--	--	0.71	--	0.62	0.63	0.88	0.90	0.84	0.85	--
	5	17	23	23	23		0.91	--	--	0.59	--	0.61	0.62	0.91	0.86	0.82	0.78	0.55
o	6	17	21	21	21	21		--	--	0.54	--	0.66	--	0.85	0.82	0.72	0.75	--
f	7	12	12	12	12	12	12		--	--	--	--	--	--	--	--	--	--
	8	12	12	12	12	12	12	12		0.68	0.70	--	--	--	--	--	--	--
y	9	15	16	16	16	16	16	12	12		0.73	0.73	--	0.63	0.52	0.52	--	0.57
e	10	12	12	12	12	12	12	11	11	12		0.76	--	--	--	--	--	--
a	11	17	19	19	19	19	18	12	12	15	12		--	0.60	0.56	0.53	0.53	--
r	12	17	18	18	18	18	18	12	12	15	12	17		0.68	0.62	0.67	0.59	0.56
s	13	15	15	15	15	15	15	12	12	13	12	15	15		0.74	0.86	0.74	0.62
	14	17	23	23	23	23	21	12	12	16	12	19	18	15		0.89	0.96	--
	15	17	23	23	23	23	21	12	12	16	12	19	18	15	24		0.93	0.66
	16	17	23	23	23	23	21	12	12	16	12	19	18	15	23	23		-
	17	13	13	13	13	13	13	12	12	13	12	13	13	13	13	13	13	

[1] -- indicates pairs of ARAs which were not significantly correlated (p>0.05)

[2] number of years in which both ARAs in the comparison had at least 10 observations.

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