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Presentation

Agriculture is a continuum of processes. Problems and solutions emerge from processes. To treat them, it is necessary to understand them minimally.

Conserving the productive capacity of soil is a need that can be perpetuated; soil utilization, however, is an ephemeral opportunity in the effort to survive.

To combat erosion, it is sufficient to prevent raindrops from touching bare soil and/or excessively fast water flowing over or through the soil. Thinking of this, there are countless processes promoted by the science of soil conversation. However, sporadic innovations emanate from work dedicated to adapting these processes to different land strata, with an emphasis on those of small extent, associated or not with soils having certain use limitations.

The high wide ridge is a typically purposeful innovation, allied with conservation precepts, in crop management on small farms, cultivated with species producing grains, tobacco, forage and others. Its benefits in terms of tobacco performance have already been proven. In this study, its effective contribution in preserving the productive capacity of the soil was proven and is now being promoted by soil conservation science as a conservation practice.

This work was a result of a partnership between BAT Brasil and Embrapa Wheat , backed by the Edmundo Gastal Foundation for Support to Agricultural Research and Development and based on interests convergence, and complimentary missions and objectives, focused on soil conservation management. Resourcer sharing, institutional capacity and credibility expansions, and activity and quality results increase effectiveness, are contributions to Brazilian agriculture development.

Embrapa Trigo is pleased to share this activity results, in partnership with BAT Brasil, which, unequivocally, contributes to Brazil honouring its commitment to the UN to achieve the Sustainable Development Objectives, by demonstrating alignment with ODS6.

Osvaldo Vasconcellos Vieira
Head of Embrapa Wheat

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Hydrological validation of High Wide Ridges as a soil conservation technology applied to tobacco crop

Abstract

High Wide Ridge Soil Management is a conservation practice associated with the no-tillage, reduced tillage, and conventional tillage systems, usual in small farms in southern Brazil. Integrated with winter grain or ground cover crops such as wheat (*Triticum aestivum*), rye (*Secale cereale*), black oats (*Avena strigosa*) and white oats (*Avena sativa*), millet (*Pennisetum glaucum* L.), Sudan grass (*Sorghum sudanense*), sorghum (*Sorghum* spp.), mucuna (*Mucuna* spp.), and brachiaria (*Brachiaria* spp.), high wide ridge is being used for tobacco (*Nicotiana tabacum*), soybean (*Glycine max* L.), maize (*Zea mays*), and beans (*Phaseolus vulgaris*) during the spring and summer seasons. The benefits expected from this technology, related to the performance of the tobacco crop, have already been proven experimentally and on a farm scale. However, the benefit in regard to the effectiveness in controlling runoff resulting from intense rainfall, has not yet been quantified. The aim of this study was to validate the effectiveness of the high wide ridge in containing runoff from intense rainfall, with return periods equal to, or greater than, 10 years. The study was carried out on 11 farms, located in nine municipalities (four in Rio Grande do Sul state, three in Santa Catarina state, and four in Paraná state), where tobacco was grown following winter cereal as a ground cover crop, on three types of topography (gently undulating topography, undulating topography, and highly undulating topography) with 11 soil types that were texturally and taxonomically different. It was concluded that high wide ridge is capable of containing the flooding generated by rainfall with return periods of more than 10 years, allowing the science of soil conservation to promote it as a conservation soil management practice.

Index terms: soil conservation; infiltration of water in the soil; intense rain; return period.

Validação hidrológica do “Camalhão Alto de Base Larga” como tecnologia conservacionista aplicada à cultura do tabaco

Resumo

O manejo de solo com Camalhão Alto de Base Larga é uma prática conservacionista associada ao sistema plantio direto, preparo reduzido do solo e preparo convencional do solo, usual em pequenos estabelecimentos rurais, na região Sul do Brasil. Integrado a espécies produtoras de grãos e cobertura de solo, como trigo (*Triticum aestivum*), centeio (*Secale cereale*), aveia preta (*Avena strigosa*), aveia branca (*Avena sativa* L.), milheto (*Pennisetum glaucum* L.), capim Sudão (*Sorghum sudanense*), sorgo (*Sorghum* spp.), mucuna (*Mucuna* spp.) e braquiária (*Brachiaria* spp.), o camalhão alto de base larga vem sendo aplicado ao cultivo de tabaco (*Nicotiana tabacum*), soja (*Glycine max* L.), milho (*Zea mays*) e feijão (*Phaseolus vulgaris*) durante as estações de primavera e verão. Os benefícios preconizados por essa tecnologia, referentes ao desempenho da cultura do tabaco, já foram comprovados experimentalmente e em escala de lavoura. Porém, o benefício, referente à sua eficácia em disciplinar as enxurradas resultantes de chuvas intensas, ainda não foram quantificados. O objetivo deste estudo foi validar a efetividade do camalhão alto de base larga em conter o escoamento de chuva intensa, com períodos de retorno iguais ou superiores a 10 anos. O estudo foi efetuado em 11 lavouras, localizadas em nove municípios (quatro no estado do Rio Grande do Sul, três no estado de Santa Catarina e quatro no estado do Paraná), cultivadas com cereal de inverno, como planta de cobertura, seguido por tabaco, posicionadas em três classes de relevo (suave ondulado, ondulado e forte ondulado) e com 11 tipos de solo, taxonômica e texturalmente diferentes. Concluiu-se que o camalhão alto de base larga é capaz de conter a enxurrada gerada por chuvas com períodos de retorno superiores a 10 anos, facultando à ciência da conservação do solo apregoá-lo como prática conservacionista de manejo de solo.

Termos para indexação: conservação do solo; infiltração de água no solo; chuva intensa; período de retorno.

Introduction

Soil constitutes an important resolution centre for humanity's main problems. Its use interferes with natural resources or elements of the biosphere – air, water, biodiversity and climate – and, as a result, with agricultural production, food safety, human health and environmental quality, among others. From an elementary point of view, soil is simply a body of the natural landscape, represented by a matrix of solids that shelter liquids, gases and living organisms. However, under the functional agriculture focus, soil constitutes the natural environment where plants develop, acting as a support element and provider of water, air and nutrients and a determinant of the yield of the productive agricultural system, due to limitations of its fertility. In addition, soil is the regulator of flow of water that touches the earth's surface (VEZZANI e MIELNICZUK, 2009).

In this perspective, soil is a renewable natural resource, collective patrimony, essential to life and the sovereignty of the nation, regardless of its use and ownership. In the human timeframe, however, soil is considered as a non-renewable natural resource given that its rates of degradation, induced by anthropic activity, can far exceed the natural rates of renewal and reconstitution of its properties. This aspect fully and absolutely justifies the legitimacy of conservationism precepts, which express the use management of natural resources or elements of the biosphere, so as to produce benefits for humanity and maintain its necessary potentialities for future generations. While conservationism considers actions for the preservation, maintenance and recovery of natural resources, soil conservation studies develop and promote essential actions to preserve, maintain and recover these resources, establishing criteria for their use without compromising their primitive potential (DENARDIN, 2012).

As such, conservation agriculture is conceptualised as agriculture practised in accordance with the precepts of conservationism and the techniques promoted by the science of soil conservation. It is agriculture conducted under the protection of a complex array of technologies of a systemic nature, aimed at preserving, maintaining and recovering natural resources or elements of the biosphere, through the integrated management of soil, water and biodiversity, duly compatible with the use of external inputs (KOCHHANN, 1992).

The complex of processes conceived by conservation agriculture forms the basis of sustaining agriculture, conserving the soil, water, air, and biodiversity of agroecosystems, as well as preventing degradation and pollution of the surrounding systems. As such, conservation agriculture is understood as being efficient and effective agriculture in the use of available resources and, for this reason, is considered as the mechanism for transformation, organisation and support of agroecosystems, with the aim of conferring competitiveness to agribusiness, meeting socioeconomic needs with guarantees of food safety and maintaining environmental quality (DENARDIN et al., 2012).Analysing the actions inherent to the concepts of conservationism, soil conservation and agricultural conservation, means that all have man as the subject and natural resources as passive agents.

The adoption of conservationism, therefore, is simply the establishment of relations between man and the elements of the biosphere, from which man enjoys benefits of an economic, social and environmental nature, for both present and future generations. It is this quality of the relationship between man and the elements of the biosphere, with the emergence of economic, social and environmental benefits of terrestrial biodiversity, which can truly be called sustainability. Thus, sustainability refers to the emergence of supreme ambience or of extreme well-being of the Planet's biodiversity, based on the established relationship between man and natural resources or elements of the biosphere (D'AGOSTINI, 2004).

Technological innovations and changes imposed on the productive agricultural systems, due to the permanent and incessant demands of agribusiness, unconditionally based on the relationship between man and natural resources, have provided the farmer with a complex array of technologies, potentially effective in contributing to the emergence of agricultural sustainability. Among these technological innovations and changes, aimed at crop management on small farms using production models that integrate species producing grains, forage and/or green manure, such as wheat (*Triticum aestivum*), rye (*Secale cereale*), black oats (*Avena strigosa*), white oats (*Avena sativa*), millet (*Pennisetum glaucum*), Sudan grass (*Sorghum sudanense*), mucuna (*Mucuna* spp.) and brachiaria (*Brachiaria* spp.), associated with crops of tobacco (*Nicotiana tabacum*), soya (*Glycine max*), maize (*Zea mays*), beans (*Phaseolus vulgaris*) and other temporary species, the high wide ridge stands out, associated with the no-tillage, reduced tillage, and even conventional soil tillage systems.

High Wide Ridge Soil Management is a technology applied to these production models, focused on tobacco production, resulting from consistent investment by BAT Brasil, applied over recent years in research, development, innovation and diffusion projects, leading to its adoption by more than 90% of the integrated farms (SOUZA CRUZ, 2019).

This technology was idealised for the purpose of physically conditioning the soil in the planting line, with expected effect of optimising the factors involved in root development of plants, crop health and yield, quality of the harvested product, stability of production over time and minimising losses through erosion, such as: particle: pore ratio less than 1.0; balance between the volumes of macropores, micropores and cryptopores, conducive to the flow of water, air, heat and nutrients in the soil; and low soil resistance to root penetration. As well as these aspects, the macroroughness imposed by the high wide ridge on the soil surface presupposes the potential for disciplining or retaining surface rainwater, increasing water infiltration rate in the soil and controlling surface runoff, with a consequent reduction in losses through erosion and prevention of contamination and pollution of the surrounding systems.

The high wide ridge can be constructed with: i) three-line butterfly type plough (Figure 1)[1]; ii) one-line butterfly type plough; and iii) butterfly hoes coupled to a scarifier, all configured to prepare trapezoidal ridges. The ridges are demarcated and prepared level and/or unlevel. When unlevel, it is recommended that the ridge is a maximum of 2%. High Wide Ridge Soil Management is generally carried out during the months of: i) January to May; period favourable to the sowing of ground cover plants, approximately 140 days prior to tobacco planting; or ii) between the months of July and October, before transplanting of tobacco, without ground cover (SOUZA CRUZ, 2019).

Illustration: Gilberto Luiz Siqueira Zvarezz

Figure 1. Butterfly plough configured to form three high wide ridges simultaneously.

[1] Patent required.

The high wide ridge, prepared using any of the aforementioned equipment, generally has the following dimensions: width of the larger base = 0.80 m to 0.90 m; width of the smaller base = 0.30 m to 0.40 m; spacing between the crests of the ridges = 1.20 m to 1.30 m; and ridge height = 0.35 m to 0.40 m. These dimensions define that channel, as well as trapezoidal shape, configured between ridges prepared on flat ground, have the following dimensions: larger side = 0.90 m; smaller side = 0.40 m; depth = 0.35 m to 0.40 m and section = 0.2275 m^2 to 0.2600 m^2 (SOUZA CRUZ, 2019). However, channel dimensions varies depending on the equipment setting, operating speed, soil type, textural class of soil, the slope of the terrain and soil moisture at time of construction.

Preserving these dimensions over the agricultural year depends not only on the soil type, textural class, and terrain slope, in addition to other factors, but also on the presence or absence of ground cover and occurring rainfall regime. It should be emphasised, however, that the larger side, depth and section of the configured channel between high wide ridges, reduce linearly with the increase in terrain slope, regardless of the other factors. Figure 2 illustrates the magnitude of the variation of these dimensions, solely in regard to terrain slope variation, considering a high wide ridge built with the lesser recommended dimensions: larger side of the channel is reduced from 0.90 m to 0.75 m; depth of the channel is reduced from 0.35 m to 0.13 m; and section of the channel is reduced from 0.2275 m^2 to 0.0897 m^2.

Prior to constructing the high wide ridge, it is recommended to correct soil acidity, or application of fertilizers, in accordance with chemical indicators of soil fertility analytical results, and cross-scary to ensure soil de-compaction. It is essential that both scarifying and construction of high wide ridge, should be carried out with soil moisture equivalent to the point of friability (SOUZA CRUZ, 2019).

If sowing of ground cover plants is carried out, they should be sown with distribution of 70% of the seeds before preparation of the ridges and 30% after. In case of lack of precipitation for the immediately period after ridges construction, it is recommended that 100% of the seeds are sown before construction of the high wide ridge. The ideal time for lodging winter cereals cultivated as ground cover on ridges, is at milky grain phenological stage, and for summer grasses, such as Sudan grass and millet, when the plants reach approximately 1.5 m and/or before panicles appear, to prevent the risk of these plants becoming weeds in the tobacco crop. Lodging of these species should be carried out with the use of a desiccant herbicide or brush cutter, a homemade knife roller with a rack of tyres or wooden log coupled to a scarifier chassis, or with a three line butterfly plough that has this functionality. A summary of High Wide Ridge Soil Management steps is shown in Figure 3 (SOUZA CRUZ, 2019).

The expected benefits of the high wide ridge, concerning the enhancement of factors involved in the performance of tobacco crop, were proven, both on experimental and farm scale, including: minimizing soil waterlogging, lower incidence of root disease, improved quality of harvested product, increase in yield of up to 20% and greater production stability over the years (SOUZA CRUZ, 2019). However, the benefits from rainwater – infiltration of water into the soil and controlled surface runoff have not been quantified yet. The objective of this study was to evaluate the potential of high wide ridge technology, adopted in crops established on different soil types, varied classes of texture and topography, in containing excess water from intense rainfall, with a return period equal to, or greater than, 10 years.

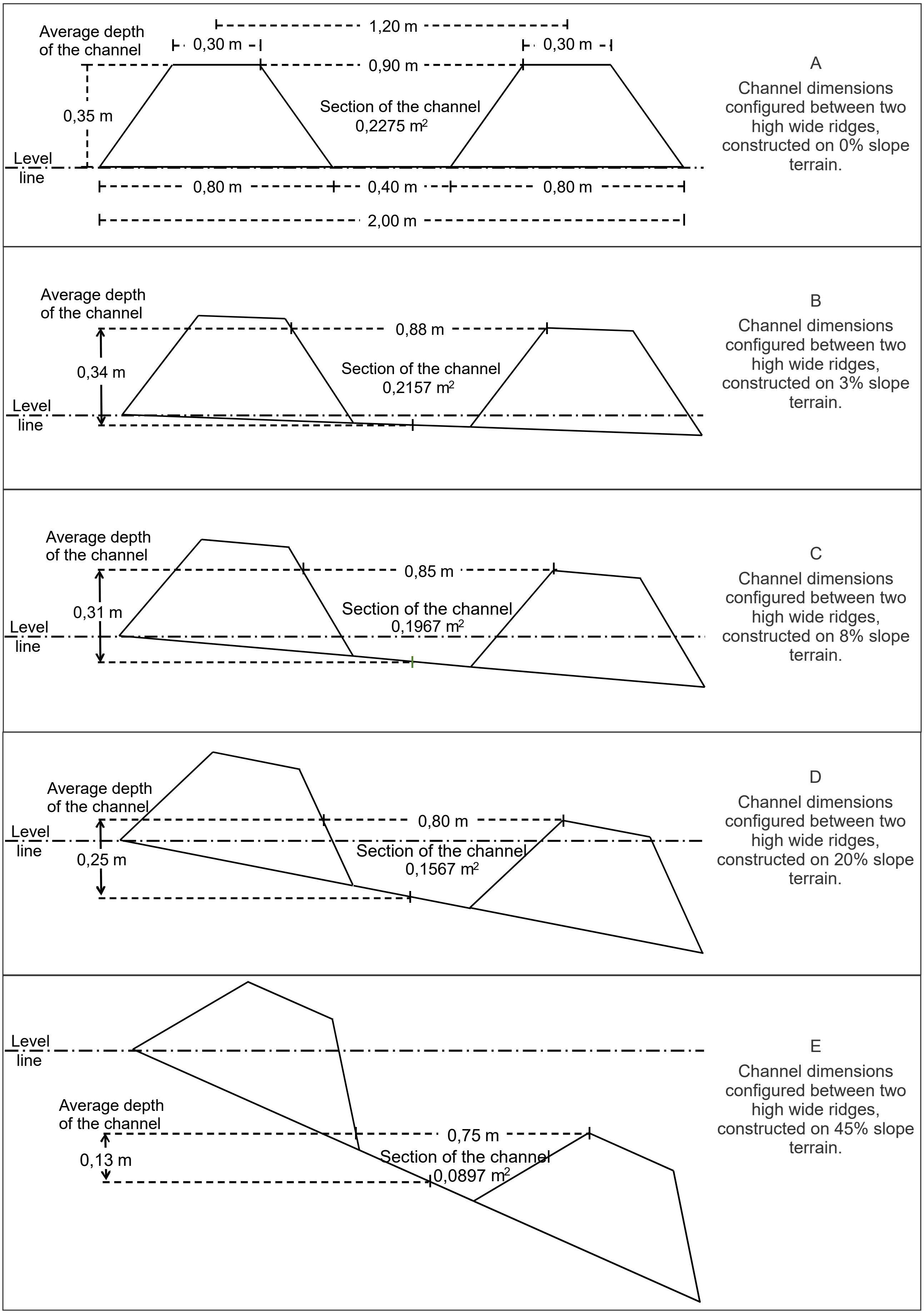

Figure 2. Channel reduction in dimensions demonstration configured between high wide ridges, as a result of terrain slope.

A. Lime and/or fertilizer application for chemical indicators of soil fertility correctionl.

B. Cross-scarifying in soil with moisture equivalent to the point of friability.

C. High wide ridges under construction with butterfly plough.

D. Recently constructed high wide ridges, on level and unlevel terrain.

E. Ground cover plants emerging on high wide ridges.

F. Lodging of ground cover plants on high wide ridges.

G. Dessicated and lodged ground cover plants on high wide ridges.

H. Tobacco plants in development stage on high wide ridges.

Figure 3. Steps of high wide ridge construction for tobacco cultivation.

Materials and methods

The research, aimed at the validation of high wide ridge technology as soil management practice, was developed in nine municipalities, in 11 crops (four in Rio Grande do Sul state, three in Santa Catarina state and four in Paraná state). The areas were selected by BAT Brasil research teams and the National Wheat Research Centre – Embrapa Trigo, ensuring that crops were: cultivated with winter cereals preceding tobacco; established on terrain with a slope from 3% to 8% (slightly undulating topography), 8% to 20% (undulating topography) and 20% to 45% (highly undulating topography); and on different soil types.

The research actions, developed on a field scale, in each of the selected crops, involved: measurement of the terrain slope; measurement of the spacing between the crests of the high wide ridges; measurement of the channel section configured between the high wide ridges; determination of the basic rate of water infiltration in the soil at the bottom of the channel configured between the high wide ridges; soil sampling from the layer at a depth of 0 to 20 cm, using a gouge type auger with 2.54 cm diameter, for granulometric soil analysis; and soil sampling using a Dutch auger for morphological and physical-chemical analyses required for taxonomic classification of soils.

Measurement of the section of the trapezoidal channel configured between the high wide ridges was performed using the rod profilometer technique, with 5 cm spacing between the rods. From this data, the factors required by the mathematical model to be used for estimating the return period of expected maximum rainfall, capable of being contained by the channel configured between the ridges, were calculated (Pruski et al., 2009), namely: channel section; depth, longer and shorter side of the channel; and Z value (slope) of the channel gradient.

The expected benefits of the high wide ridge, concerning the enhancement of factors involved in the performance of tobacco crop, were proven, both on experimental and farm scale, including: minimising soil waterlogging, lower incidence of root disease, improved quality of harvested product, increase in yield of up to 20% and greater production stability over the years (SOUZA CRUZ, 2019). However, the benefits from rainwater – infiltration of water into the soil and controlled surface runoff have not been quantified yet. The objective of this study was to evaluate the potential of high wide ridge technology, adopted in crops established on different soil types, varied classes of texture and topography, in containing excess water from intense rainfall, with a return period equal to, or greater than, 10 years.

Determination of the basic rate of water infiltration in the soil was done by the Cornell Infiltrometer technique (OGDEN et al., 1997; VAN ES & SCHINDELBECK, 2003); granulometric analysis was performed by the Pipette Method (TEIXEIRA et al., 2017) and soil classification, up to the fourth category level (order, suborder, large group and subgroup), followed the taxonomic key and methodology described in Santos et al. (2018).

Terrain and channel section slope measurements were replicated 10 times in each studied crop. Repetitions number of determination water infiltration rate in the soil, in each studied crop, ranged from five to eight, depending on the variability of the results obtained during evaluations.

All determinations, except the channel sections, were carried out during two seasons in 2019: the first during June and July, when the fields were under cultivation of cover plants; and the second during October and November, when the fields were already under tabacco cultivation and the beginning of the first harvests. Channel sections determinations were carried out during the second season only. Final data, for each evaluated crop, resulted from arithmetic means of values obtained in various replications. In calculating the means, no data was disregarded.

The estimated return period of maximum expected rain to be contained by the channels configured between the high wide ridges was processed using the application of the “Terrace 4.1” software (Dimensioning and management of soil conservation and surface drainage systems), developed by the Water Resource Research Group from the Agricultural Engineering Department of Federal University of Viçosa - DEA-UFV (PRUSKI et al., 2009). The intense rainfall equations (Intensity-Duration-Frequency - IDF) of the “Terrace 4.1” software, have been updated for the municipalities covered in the study, using those adjusted by Damé et al. (2014), Back (2013), Sampaio (2011) and made available by Álvaro José Back, researcher for the Agricultural Research and Rural Extension Company of Santa Catarina - Epagri-SC, adjusted from historical records of recent rainfall, as shown in Table 1. The estimated return periods of maximum expected rainfall were processed for the full capacity of the channels configured between the high wide ridges constructed on level terrain.

Table 1. Equations for Intensity-Duration-Frequency - IDF of rainfall used for estimating return period of intense rainfall in the municipalities involved in the validation of “high wide ridge” as a soil management conservation practice.

Municipality	IDF Equation	IDF Equation
Canguçu - RS	$I = \dfrac{838{,}44\,T^{0,1341}}{(t+9{,}6377)^{0,7271}}$	Damé et al. (2014)
São Lourenço do Sul - RS	$I = \dfrac{1.163{,}83\,T^{0,1790}}{(t+8{,}8900)^{0,7568}}$	Sampaio (2011)
Cerro Grande do Sul - RS	$I = \dfrac{883{,}73\,T^{0,1427}}{(t+8{,}9676)^{0,7164}}$	Damé et al. (2014)
Irineópolis - SC	$I = \dfrac{784{,}21\,T^{0,1860}}{(t+8{,}9560)^{0,7000}}$	Back (2013)
Mafra - SC	$I = \dfrac{862{,}35\,T^{0,1920}}{(t+8{,}9330)^{0,6990}}$	Back (2013)
Rio do Oeste - SC	$I = \dfrac{702{,}99\,T^{0,1650}}{(t+8{,}9740)^{0,7010}}$	Back (2013)
Ipiranga - PR	$I = \dfrac{845{,}17\,T^{0,1194}}{(t+9{,}1900)^{0,7060}}$	Equation generated by Álvaro José Back - Epagri-SC Rainfall station 02450054 - period 1976-2011
Imbituva - PR	$I = \dfrac{761{,}95\,T^{0,1497}}{(t+9{,}1900)^{0,7060}}$	Equation generated by Álvaro José Back - Epagri-SC Rainfall station 02450045 - period 1976-2011
Teixeira Soares - PR	$I = \dfrac{844{,}06\,T^{0,1870}}{(t+9{,}1900)^{0,7060}}$	Equation generated by Álvaro José Back - Epagri-SC Rainfall station 02450043 - period 1976-2011

Results and discussion

The list of locations where the study was carried out, soil taxonomic, granulometric and textural class results, as well as terrain slope, are shown in Table 2.

Table 2. Locations and characterization of the crops studied with the objective of validating the high wide ridge technology as a soil management conservation practice.

Location	Soil	Granulometry			Textural class	Terrain slope (%)	Topographical class
		Clay (mg/g)	Silt (mg/g)	Sand (mg/g)			
Canguçu, RS	Typical Argissolo Bruno-Acinzentado Alumínico	163	167	670	Sandy loam	6	Slightly undulating
São Lourenço do Sul, RS	Typical Neossolo Regolítico Distro-úmbrico	149	184	667	Sandy loam	16	Undulating
Cerro Grande do Sul, RS	Typical Neossolo Regolítico Distrófico	114	117	769	Sandy loam	27	Highly undulating
	Typical Argissolo Vermelho-Amarelo Distrófico	313	107	580	Sandy clay loam	27	Highly undulating
Irineópolis, SC	Typical Latossolo Vermelho Eutrófico	556	194	250	Clay	6	Slightly undulating
Mafra, SC	Typical Latossolo Vermelho Distrófico	402	106	492	Sandy clay loam	15	Undulating
Rio do Oeste, SC	Typical Cambissolo Háplico Distrófico	387	513	100	Silty clay loam	33	Highly undulating
Ipiranga, PR	Type Cambissolo Háplico Alítico	146	37	817	Sandy loam	26	Highly undulating
Imbituva, PR	Typical Latossolo Bruno Distrófico	487	235	278	Clay	7	Slightly undulating
Teixeira Soares, PR	Typical Neossolo Litólico Eutrófico	413	450	137	Silty clay	13	Undulating
	Typical Cambissolo Háplico Eutrófico	291	209	500	Sandy clay loam	13	Undulating

The 11 studied fields were taxonomically classified to the fourth category level, into six textural classes and three topographic classes. Taxonomically, soils varied from undeveloped, such as typical Eutrophic Litolic Neossolo, to highly weathered, such as typical Eutrophic Red Latosol (Table 2).

Granulometric fractions denote clay contents between 114 mg/g and 556 mg/g, silt between 37 mg/g and 513 mg/g and sand between 100 mg/g and 817 mg/g (Table 2), with average levels of 311 mg/g, 211 mg/g and 478 mg/g, respectively. Most frequently occurring textural classes, in eight of the eleven soils, are loam soils, which are: sandy loam; sandy clay loam; sandy loam; and silty clay loam (Table 2). From these dominant textural classes, sand fraction predominated in relation to the others, with 574 mg/g, compared to clay with 246 mg/g and silt with 180 mg/g. From this, most of the soils were fragile in terms of structural stability of the earth channels configured between the high wide ridges during an agricultural year, which is, in most cases, the time these channels are used. These aspects provide significant support to the hydrological assessment to which this study was submitted.

As for the topography, all three classes – slightly undulating, undulating and highly undulating – which are attributable to agricultural use, are represented in terrain with slopevarying between 6% and 33% (Table 2).

Production models used include crops of black oats or rye, grown as ground cover crops during the autumn-winter period, preceding tobacco crop, grown as a commercial crop in the spring-summer period.

The characteristics of crops and soils, shown in Table 2, contain a broad representation of the environments where tobacco crop is cultivated in Rio Grande do Sul, Santa Catarina and Paraná states.

Collected and calculated data required to estimate the return period of maximum expected rainfall, capable of producing representable surface runoff carried by the channel configured between the high wide ridges constructed on level terrain, are shown in Table 3.

Spacing between the high wide ridges, which corresponds to spacing between the planting lines of the tobacco crop (Souza Cruz, 2019), varied between 1.20 m and 1.30 m, with an average of 1.27 m, perfectly situated between the amplitude limits of the dimensions recommended by this technology (Table 3). The homogeneity and precision of this parameter, certainly results from using a butterfly plough, or with butterflies hoes coupled a scarifier, with correct adjustment of the spacing between the butterfly hoes, in accordance with the technology promoted by high wide ridge technology (SOUZA CRUZ, 2019).

The channel sections formed between the high wide ridges, vary between 0.1001 m^2 on 21% slope terrain, to 0.1340 m^2 on 26% slope terrain, with an average of 0.1117 m^2 (Table 3). This means that the channels with the smallest and largest sections occur on the highly undulating topography. This variation in channel sections, evaluated nine months after establishing the high wide ridges, is within the range of channel sections configured between the high wide ridges, constructed with the lesser dimensions recommended by this technology, on terrain with 20% to 45% slope, which range from 0.1567 m^2 to 0.0897 m^2, respectively (Figure 2). However, it is important to emphasise that this comparison relates channel sections theoretically expected at the time of construction with earth channel sections, nine months after

Dimensions of the longer side of the channels configured between the high wide ridges, which vary linearly with the terrain slope (Figure 2), vary from 0.93 m on terrain with 6% slope, to 0.76 m on terrain with 21% slope, with an average of 0.83 m (Table 3). Considering construction of high wide ridges with the smallest dimensions recommended by the technology under evaluation, the longer side of the channel varies from 0.90 m on level terrain, to 0.75 m on terrain with 45% slope. Therefore, the dimensions of the longer side of channels configured between high wide ridges are within the variation range recommended by this technology (Figure 2 and Table 3).

Table 3. Locations and channel sizes located between high wide ridges characterization, with the objective of validating the high wide ridge technology as a soil management conservation practice.

Location	Soil	Terrain slope (%)	Space between ridges (m)	Channel section (m2)	Channel depth (m)	Channel width		Z value of slope	Basic infiltration rate (mm/h)	Return period (years)
						Greatest (m)	Smallest (m)			
Canguçu RS	Typical Argissolo Bruno-Acinzentado Alumínico	6	1.27	0.1123	0.20	0.93	0.17	1.86	21	1,664
São Lourenço do Sul RS	Typical Neossolo Regolítico Distro-úmbrico	16	1.30	0.1001	0.22	0.76	0.15	1.39	48	259
Cerro Grande do Sul RS	Typical Neossolo Regolítico Distrófico	27	1.27	0.1129	0.24	0.77	0.17	1.25	588	>10,000
	Typical Argissolo Vermelho-Amarelo Distrófico	27	1.27	0.1129	0.24	0.77	0.17	1.25	36	1,854
Irineópolis SC	Typical Latossolo Vermelho Eutrófico	6	1.25	0.1206	0.23	0.88	0.17	1.54	113	6,309
Mafra SC	Typical Latossolo Vermelho Distrófico	15	1.27	0.1101	0.22	0.82	0.18	1.45	41	253
Rio do Oeste SC	Typical Cambissolo Háplico Distrófico	33	1.30	0.1058	0.21	0.84	0.17	1.60	70	6,379
Ipiranga PR	Typical Cambissolo Háplico Alítico	26	1.20	0.1340	0.28	0.83	0.13	1.26	32	>10,000
Imbituva PR	Typical Latossolo Bruno Distrófico	7	1.27	0.1117	0.20	0.88	0.24	1.60	259	>10,000
Teixeira Soares PR	Typical Neossolo Litólico Eutrófico	13	1.28	0.1041	0.21	0.84	0.15	1.64	79	1,254
	Typical Cambissolo Háplico Eutrófico	13	1.28	0.1041	0.21	0.84	0.15	1.64	238	>10,000

Similar to dimensions of the longer side of the channels configured between the high wide ridges, the dimensions of the depth of these channels are also linearly correlated to the terrain slope but, at the same time, are dependent on silting up, which can occur throughout the agricultural year. Even faced with these constraints, the dimensions of the depth of the channels configured between the high wide ridges vary from 0.28 m on terrain with 26% slope, to 0.20 m on terrain with 6% slope, with an average of 0.22 m (Table 3), keeping precisely within the amplitude limits recommended by the technology under evaluation.

Shorter side dimensions of channels configured between the high wide ridges varies from 0.13 m on terrain with 26% slope, to 0.24 m on terrain with 7% slope, with an average of 0.17 m (Table 3). All dimensions of the shorter side of the evaluated channels are less than 0.40 m, which is determined by the equipment used to prepare them, at the time that the high wide ridges are constructed, regardless of terrain slope (Figure 2). The fact is that in earth channels, the shorter side and, consequently, the inclination of the slope (Z) and, in part, the depth of the channel section, are subject to alteration after completion of the work, especially when it is installed on loose soil that is predominately sandy texture and without compaction. Alterations to these dimensions in the channels are inherent to the collapse of the ridge walls, mainly in the period immediately after construction, when cover plants are in the initial stage of development (Figure 3, images C, D and E), or in the absence of ground cover plants. However, alterations in the dimensions of the shorter side and the Z value of the channels, evaluated nine months after establishing the ridges, while contribute in part to the reductions in depth and channel section, maintained the depths and, importantly, the channel sections inserted at the amplitude recommended by the high wide ridge technology.

As such, comparison between the evaluated channel dimensions and those theoretically expected in high wide ridges construction, infers that high wide ridge technology, applied in cultivation of tobacco, is being faithfully adopted, with dimensions within the standards recommended by this technology.

Water infiltration rates in the channels configured between the high wide ridges, varied between 21 mm/h in typical Argissolo Bruno-Acinzentado Alumínico with a sandy loam texture, to 588 mm/h in typical Neossolo Regolítico Distrófico with an equally sandy loam texture. Water infiltrates in the soil bear no relation to the clay, silt and sand content nor, directly, to soil taxonomy. However, due to management of the evaluated crops being relatively homogenous, consisting of annual scarifying of the soil, followed by construction of the high wide ridges and cultivation with winter cereals as ground cover plants, and tobacco as a commercial crop, differentiation between the water infiltration rates in the soil must, in some way, be associated to conditions related to soil taxonomy, in the scale of order, suborder, large group and subgroup.

Low rates of water infiltration in the Argissolos of Canguçu, RS, and Cerro Grande do Sul, RS, with 21 mm/h and 36 mm/h, respectively, are possibly due to the fact that the soil in the bottom of the channel, where the infiltration rate was evaluated, is already close to, or belongs to, the textural B horizon, which is recognised for its low permeability (SANTOS et al., 2018).

The extraordinary difference between water infiltration rates in the Neossolos Regolíticos of São Lourenço do Sul, RS, and Cerro Grande do Sul, RS, of 48 mm/h and 588 mm/h, respectively, is probably associated to the depth and/or the alteration of the C horizon, which, although not having been evaluated, is inferred to be more altered and/or deeper in the Neossolo Regolítico of Cerro Grande do Sul, RS. Water infiltration rate in the Neossolo Litólico of Teixeira Soares, PR, of 79 mm/h, located between infiltration rates of Neossolos Regolíticos of São Lourenço do Sul, RS, and Cerro Grande do Sul, RS, is likely to be associated with the presence of the R horizon formed by rock, having a certain degree of alteration.

The extraordinary difference between water infiltration rates in the Neossolos Regolíticos of São Lourenço do Sul, RS, and Cerro Grande do Sul, RS, of 48 mm/h and 588 mm/h, respectively, is probably associated to the depth and/or the alteration of the C horizon, which, although not having been evaluated, is inferred to be more altered and/or deeper in the Neossolo Regolítico of Cerro Grande do Sul, RS. Water infiltration rate in the Neossolo Litólico of Teixeira Soares, PR, of 79 mm/h, located between infiltration rates of Neossolos Regolíticos of São Lourenço do Sul, RS, and Cerro Grande do Sul, RS, is likely to be associated with the presence of the R horizon formed by rock, having a certain degree of alteration.

The large difference between water infiltration rates of the typical Latossolo Vermelho Distrófico of Mafra, SC, and the typical Latossolo Vermelho Eutrófico of Irineópolis, SC, of 41 mm/h and 113 mm/h, respectively, can be credited to the greater organic matter content of the soil and, consequently, more developed soil structure in the typical Latossolo Vermelho Eutrófico of Irineópolis, SC. The difference between water infiltration rates of these two Latossolos and of the typical Latossolo Bruno Distrófico típico of Imbituva, PR, with 259 mm/h, is certainly due to the structural quality of the soil, which is naturally more porous and more stable in Latossolos Brunos (SANTOS et al., 2018).

The differentiation between water infiltration rates in the Cambissolo Háplico Distrófico of Rio do Oeste, SC, with 70 mm/h, and in the Cambissolo Háplico Alítico, of Ipiranga, PR, with 32 mm/h, may be related to the degree of development of the B horizon, with it being more incipient than Cambissolo of Ipiranga, PR. However, the big difference between water infiltration rates in these two Cambissolos and the Cambissolo Háplico Eutrófico of Teixeira Soares, PR, which is 238 mm/h, is possibly a result of the structural quality of the soil which, in the Cambissolo Eutrófico, is more stable and more porous (SANTOS et al., 2018).

Return periods of estimated intense rainfall, with the potential of producing surface runoff, given the characteristics of the channels configured between the high wide ridges, of terrain slope and infiltration rate of water in the soil, to be contained in these channels, vary between 253 years and more than 10,000 years. In the designing of hydraulic work applied to agriculture, such as agricultural terraces, use is made of intense rainfall with a return period of between 5 and 10 years (BACK, 2013). To design spillways for water dams in farms, the return period used is rarely more than 20 years (BACK, 2013). In flood containment projects, such as dams, in which accidents endanger human lives, it is common to adopt return periods of 1,000 to 10,000 years (BACK, 2013). In this scenario, the high wide ridge technology, by generating channels with the capacity to retain surface runoff generated by intense rainfall with return periods equal to, or greater than 253 years, and even greater than 10,000 years is, undoubtedly, validated and considered, elected and judged as conservation practice to be promoted by soil conservation science.

Hydrological validation of high wide ridge technology assumes even greater robustness as a conservation practice when simulating its application in extreme land conditions destined for agricultural use, characterized by highly undulating topography, with 45% slope and by significant dimensions, as shown in Figure 2E, associated with infiltration rate of water in the soil of 21 mm/h, equivalent to the lowest rate recorded in the 11 crops evaluated, and the IDF equation of the municipality of Mafra, SC, which estimates the most intense rainfall of those municipalities. Return period of maximum expected rainfall, with the potential of producing surface runoff to be contained by the channel configured between the high wide ridges, established in these conditions, is 147 years. Nevertheless, it is also possible to infer from this simulation that the channels configured between the high wide ridges, constructed in these conditions, are effective for containing the surface runoff of rainfall with a return period of 10 years, in case the infiltration rate of water in the soil is only 1.8 mm/h.

From this, it is possible to affirm that High Wide Ridge Soil Management technology is qualified as a robust, complex and safe conservation practice in the prevention of soil erosion and in maintaining soil fertility chemical indicators at an appropriate level. As a result, its characteristics and properties contour the risk limitations of water erosion and satisfying soil fertility limitations, meet the criteria imposed by Grupo A, of the Soil Use Capacity Classification System (LEPSCH et al., 1991), allowing cultivation of annual species, in limited tracts of land, in Class IV, even with highly undulating topography, in the absence of limitations due to excess water and climatic order. This statement is supported by the fact that the systems of utilitarian land classification are ephemeral, interpretative processes, subject to change with the evolution of technologies (RAMALHO-FILHO & BEEK, 1995).

The application of High Wide Ridge Soil Management technology in the cultivation of tobacco, by optimising factors involved in the prevention of soil erosion, in improving soil fertility, in the development and health of plants, in the productivity of the production system, in the quality of the harvested product and in stability of production and income for the farmer, bring together aptitude and potential for establishing a character of sustainability for agriculture practiced in small dimension farms, located for the most part on rugged terrain.

Conclusion

High Wide Ridge Soil Management technology, adopted in crops established on soils of different taxonomies, varied classes of texture and topography, has the capacity for containing the excess water from intense rainfall, with a return period of more than 10 years, and can be promoted by the science of soil conservation, as a soil management conservation practice.

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