RELATÓRIO DE ATIVIDADES DESENVOLVIDAS

1 – DADOS CADASTRAIS

1.1 Nome do Beneficiário **JUNIOR JOEL DEWES**	1.2 Matrícula UFSM **201960158**
1.3 Instituição **UFSM – UNIVERSIDADE FEDERAL DE SANTA MARIA**	1.4 Programa CAPES/ nº do AUXPE **88887.369426/2019-00**
1.5 Projeto **ECOSSISTEMAS SUSTENTÁVEIS**	1.6 Coordenador Projeto **PROF. GILBERTO VILMAR KOZLOSKI**
1.7 Programa de Pós-Graduação **PROGRAMA DE PÓS-GRADUAÇÃO EM ENGENHARIA FLORESTAL**	

2 – BENEFÍCIO

2.1 Modalidade (X) Bolsa **DOUTORADO SANDUÍCHE**		
2.2 Instituição de Destino (nome da instituição e nome do centro/instituto/departamento/grupo de pesquisa) **Universität für Bodenkultur Wien, Viena, Áustria**	2.3 Período da Atividade	
	2.3.1 Início **01/03/2021**	2.3.2 Término **31/08/2021**

3 – RECURSOS RECEBIDOS (€ - euros)

3.1 Auxílio-deslocamento	€950,00
3.2 Auxílio-instalação	€1300,00
3.3 Seguro-saúde	€540,00
3.4 Adicional-localidade	€400,00 x 6 = €2400,00
3.5 Mensalidade	€1300,00 x 6 = €7800,00
3.6 Auxílio-diário	-

4 – DESCRIÇÃO DAS ATIVIDADES

4.1 Objetivos da missão: (estabelecer correlação com os objetivos do projeto)

O objetivo deste doutorado sanduíche no exterior é conhecer, aperfeiçoar e compartilhar conhecimentos relacionados à Engenharia Natural e ao Manejo Sustentável dos Recursos Naturais/Florestais, para serem adaptados, desenvolvidos e aplicados à realidade brasileira, no contexto do projeto de cooperação Ecossistemas Sustentáveis. Além disso, objetiva estreitar relações institucionais e melhorar a qualidade da produção acadêmica no nosso país.
Os objetivos específicos foram:

1. Cursar disciplinas relacionadas à Engenharia Natural, controle de processos erosivos e catástrofes naturais;
2. Aperfeiçoar conhecimentos sobre técnicas de Engenharia Natural de âmbito fluvial e alpino;
3. Estudar procedimentos para avaliação da eficácia técnica e ecológica de intervenções de Engenharia Natural;
4. Estudar parâmetros para o monitoramento de obras;
5. Aprofundar os conhecimentos relativos às características biotécnicas que a vegetação deve apresentar para incrementar a sua eficácia ecológica. Acompanhar intervenções de Engenharia Natural em âmbito fluvial para recuperação de áreas degradadas;
6. Estudar metodologias e técnicas para controle de espécies exóticas;
7. Apresentar e discutir o estado da arte da Engenharia Natural no Brasil e possíveis aperfeiçoamentos;
8. Desenvolver artigos científicos de impacto internacional produzidos por pesquisadores das duas instituições (Universidade Federal de Santa Maria e Universität für Bodenkultur Wien (BOKU);
9. Fortalecer a internacionalização e consolidar a parceria entre o Programa de Pós-Graduação em Engenharia Florestal e a Universität für Bodenkultur Wien (BOKU);
10. Fortalecer a cooperação interinstitucional entre a Universidade Federal de Santa Maria e a Universität für Bodenkultur Wien (BOKU) pela aproximação entre pesquisadores e instituições copartícipes.

4.2 Atividades Realizadas: (listar atividades)

Todas as atividades previstas no plano de atividades previamente estabelecido foram cumpridas em sua plenitude. Nesse sentido foram realizadas:

- Reuniões com o supervisor na universidade austríaca, Prof. Dr. Hans Peter RAUCH para discussão de ideias relacionadas à pesquisa de doutorado do intercambista;
- Reuniões com o supervisor na universidade austríaca, Prof. Dr. Hans Peter RAUCH para aperfeiçoamento sobre técnicas de Engenharia Natural, especialmente em âmbito fluvial e lacustre, discussão sobre parâmetros para o monitoramento de obras e procedimentos para avaliação da eficácia técnica e ecológica de intervenções de Engenharia Natural;
- Apresentação para o supervisor e alunos da pós-graduação da universidade austríaca o estado da arte da Engenharia Natural no Brasil e discussão sobre aperfeiçoamentos técnicos e metodológicos;
- Participação em visitas e trabalhos realizados a campo para estudo de metodologias e técnicas para controle de espécies exóticas e acompanhamento de intervenções de Engenharia Natural em âmbito fluvial para recuperação de áreas degradadas (Apêndice);
- Participação em atividades de monitoramento de técnicas de Engenharia Natural para controle de espécies exóticas (Apêndice);
- Visitas técnicas a diversas obras de Engenharia Natural realizadas na cidade de Viena para aprofundamento de conhecimentos técnicos sobre intervenções de Engenharia Natural e consolidação de conhecimentos relativos às características biotécnicas que a vegetação deve apresentar para incrementar a eficácia ecológica das intervenções (Apêndice);

- Participação em disciplina intitulada *Weidenbestimmungspraktikum* (determinação de salicáceas) com nota final *Excelente (1)* (certificado em Anexo e fotografias em Apêndice);
- Participação em disciplina intitulada *Ingenieurbiologische Maßnahmen* (Técnicas de Engenharia Natural) com nota final *Excelente (1)* (certificado em Anexo e fotografias em Apêndice);
- Participação em disciplina intitulada *Exkursion zu Ingenieurbiologie* (Excursão de Engenharia Natural) com nota final *Excelente (1)* (certificado em Anexo e fotografias em Apêndice);
- Participação em disciplina intitulada *Objektplanerisches Projekt* (Projeto de planejamento da paisagem) com nota final *Excelente (1)* (certificado em Anexo e fotografias em Apêndice);
- Participação em disciplina intitulada *Vertiefungsprojekt zu Landschaftsbau, Vegetationstechnik und Ingenieurbiologie* (Projeto de aprofundamento em Planejamento da paisagem, técnicas vegetativas e Engenharia Natural) com nota final *Excelente (1)* (certificado em Anexo e fotografias em Apêndice);
- Execução de telhado verde e revegetação de bota-fora por meio de semeadura de espécies herbáceas em ambiente alpino no âmbito do projeto *Sustainable high-altitude greening in the Weißsee Glacier World area* (Revegetação sustentável em altitude na área do lago Weißsee Glacier World), Berghotel Rudolfshütte.

4.3 Resultados e/ou Impactos:

Revisão e aceite de artigo, publicado em revista internacional com classificação Qualis A2:

Sousa, R. S., Dewes, J. J., Maffra, C. R. B., Sutili, F. J. "**Economic viability of streambank stabilization work with nature-based solutions applied to a pipeline stream crossing in South America**". *International Journal of Development Research* 11, nº 5 (2021): 46864–68. https://doi.org/10.37118/ijdr.21776.05.2021.

Apresentação de trabalho *online* desenvolvido em conjunto com o professor supervisor e pesquisador de doutorado austríacos no evento **5th International Conference on Soil, Bio- and Eco-Engineering (SBEE)** realizado em Berna (Suiça) nos dias 21 a 25 de Junho de 2021:

Dewes, J. J., Sousa, R. S, Sutili, F. J., Hörbinger, S., Rauch, H. P. "**Economic Viability of Streambank Stabilization Work with Soil Bioengineering in South Brazil**". 5th SBEE, Bern, Switzerland, 21 – 25 June, 2021.

A colaboração científica entre instituições e pesquisadores é fundamental para a aquisição de competências que qualificam o conhecimento científico e seus produtos (artigos científicos, patentes, etc). Além disso, a ampliação e fortalecimento de relações interinstitucionais é importante na formação de recursos humanos mais qualificados.
A qualificação de recursos humanos pela participação do doutorando promoveu o aperfeiçoamento da formação acadêmica, amadurecimento científico e tecnológico, que irá repercutir positivamente no contexto do trabalho desenvolvido pelo Laboratório de Engenharia Natural dentro do Programa de Pós-Graduação em Engenharia Florestal.
A interação e troca de experiências entre os grupos de pesquisa da UFSM e da BOKU qualificam o conhecimento científico dos temas de pesquisa envolvidos, e por consequência têm proporcionado uma contribuição mais consistente para a literatura científica. Atualmente, novos artigos científicos estão a ser desenvolvidos em conjunto pelos dois grupos de pesquisa, fortalecendo desta forma a internacionalização dos trabalhos de pesquisa realizados em contexto brasileiro e o desenvolvimento de produção científica com maior impacto internacional.
Os docentes-pesquisadores da BOKU apresentam muita experiência e conhecimentos científicos sobre a Engenharia Natural e sua aplicação, representada pelo histórico de produção intelectual qualificada, fruto de conhecimento acumulado e estrutura física qualificada, e por isso a interação com esta instituição têm se mostrado proveitosa para a transferência de tecnologia, conhecimentos e experiências nesta área, contribuindo para a formação de profissionais no ramo da Engenharia Natural dentro da UFSM e no Brasil.

Santa Maria, 25 de Setembro de 2021

Junior Jol Dewes

APÊNDICE TÉCNICO

Participação em visitas e trabalhos realizados a campo para estudo de metodologias e técnicas para controle de espécies exóticas e acompanhamento de intervenções de Engenharia Natural em âmbito fluvial para recuperação de áreas degradadas:

Atividades realizadas nos dias 16, 17 e 18 de Março (Donauinsel), Viena:

Figura 1. Aspecto geral da área com plantas exóticas (*Fallopia japonica*).

Figura 2. Limpeza geral da área de intervenção.

Figura 3. Colocação de geotêxtil biodegradável e solo sobre a área de intervenção.

Figura 4. Aplicação da técnica de Engenharia Natural (esteira viva e estacas vivas de plantas autóctones) para controle de plantas exóticas na área de intervenção.

Atividades realizadas nos dias 22, 23, 24 e 25 de Março Rio Viena e Rio Schwechat (Wienerwald Biosphere Reserve):

Figura 1. Coleta de material vegetal autóctone para realização das técnicas de Engenharia Natural.

Figura 2. Transporte de material vegetal para o local de intervenção.

Figura 3. Aspecto geral da área com plantas exóticas (*Fallopia japonica*).

Figura 4. Limpeza da área com remoção das plantas exóticas.

Figura 5. Execução das técnicas de Engenharia Natural para recuperação da área degradada.

Figura 6. Execução das técnicas de Engenharia Natural para recuperação da área degradada.

Figura 7. Execução das técnicas de Engenharia Natural (esteira viva) para recuperação da área degradada.

Figura 8. Execução das técnicas de Engenharia Natural (feixes vivos) para recuperação da área degradada.

Figura 9. Execução das técnicas de Engenharia Natural (semeadura com espécies herbáceas autóctones) para recuperação da área degradada.

Figura 10. Execução das técnicas de Engenharia Natural (estacaria viva) para recuperação da área degradada.

Figura 11. Finalização da intervenção de recuperação da área degradada.

Figura 12. Finalização da intervenção de recuperação da área degradada.

Participação em atividades de monitoramento de técnicas de Engenharia Natural para controle de espécies exóticas (Wienerwald Biosphere Reserve):

Figura 1. Atividades de monitoramento de técnicas de Engenharia Natural para controle de espécies exóticas.

Figura 2. Atividades de monitoramento de técnicas de Engenharia Natural para controle de espécies exóticas.

Figura 3. Atividades de monitoramento de técnicas de Engenharia Natural para controle de espécies exóticas.

Figura 4. Atividades de monitoramento de técnicas de Engenharia Natural para controle de espécies exóticas.

Visitas técnicas a diversas obras de Engenharia Natural realizadas na cidade de Viena para aprofundamento de conhecimentos técnicos sobre intervenções de Engenharia Natural e consolidação de conhecimentos relativos às características biotécnicas que a vegetação deve apresentar para incrementar a eficácia ecológica das intervenções.

Figura 1. Intervenções de Engenharia Natural para recuperação e estabilização de margens de rios (detalhe defletores em pedra). Fotografia à esquerda em Março de 2021 e fotografia à direita em Julho de 2021.

Figura 2. Intervenções de Engenharia Natural para recuperação e estabilização de margens de rios (detalhe enrocamento e esteira viva). Fotografia à esquerda em Março de 2021 e fotografia à direita em Julho de 2021.

Figura 3. Intervenções de Engenharia Natural para recuperação e estabilização de margens de rios (detalhe muro de suporte em madeira). Fotografia à esquerda em Março de 2021 e fotografia à direita em Julho de 2021.

Figura 4. Intervenções de Engenharia Natural para recuperação e estabilização de margens de rios (detalhe enrocamento vegetado). Fotografia à esquerda em Março de 2021 e fotografia à direita em Julho de 2021.

Figura 5. Intervenções de Engenharia Natural para recuperação e estabilização de margens de rios. Fotografia à esquerda em Março de 2021 e fotografia à direita em Julho de 2021.

Figura 6. Intervenções de Engenharia Natural para recuperação e estabilização de margens de rios (vista geral montante). Fotografia à esquerda em Março de 2021 e fotografia à direita em Julho de 2021.

Participação em disciplina intitulada *Weidenbestimmungspraktikum* (Identificação de salicáceas):

Figura 1. Realização de visita a campo para identificação de espécies autóctones do género *Salix*, utilizada em obras de Engenharia Natural.

Figura 2. Realização de visita a campo para identificação de espécies autóctones do género *Salix*, utilizada em obras de Engenharia Natural.

Participação em disciplina intitulada *Exkursion zu Ingenieurbiologie* (Excursão de Engenharia Natural). A excursão foi realizada nos dias 14, 15 e 16 de junho de 2021:

- Seebarn bei Grafenworth dia 14/07/2021 durante a manhã

Figura 1. Intervenções de hidrossemadura com sementes de espécies autóctones realizada em taludes de aterro de reservatório de água artificial.

Figura 2. Intervenções de hidrossemadura com sementes de espécies autóctones realizada em taludes de aterro de reservatório de água artificial.

Figura 3. Intervenções de Engenharia Natural com muro de terra reforçada verde e plantio de estacas de espécies autóctones realizado com o objetivo de barreira sonora.

Figura 4. Intervenções de Engenharia Natural com muro de terra reforçada verde e plantio de estacas de espécies autóctones realizado com o objetivo de barreira sonora.

- National Park Donauauen dia 14/07/2021 durante a tarde

Figura 5. Intervenções de Engenharia Natural com muro de suporte vivo combinado com plantio de estacas de espécies autóctones realizado para estabilização de talude fluvial no rio Danubio após reabertura de meandro do rio fechado artificialmente.

Figura 6. Intervenções de Engenharia Natural com muro de suporte vivo combinado com plantio de estacas de espécies autóctones realizado para estabilização de talude fluvial no rio Danubio após reabertura de meandro do rio fechado artificialmente.

- Rio Liesing (Viena) dia 15/07/2021 durante todo o dia

Figura 7. Intervenções de Engenharia Natural com muro de suporte vivo combinado com plantio de estacas e feixes vivos de espécies autóctones realizado para revitalização e recuperação ecológica das margens do Rio Liesing.

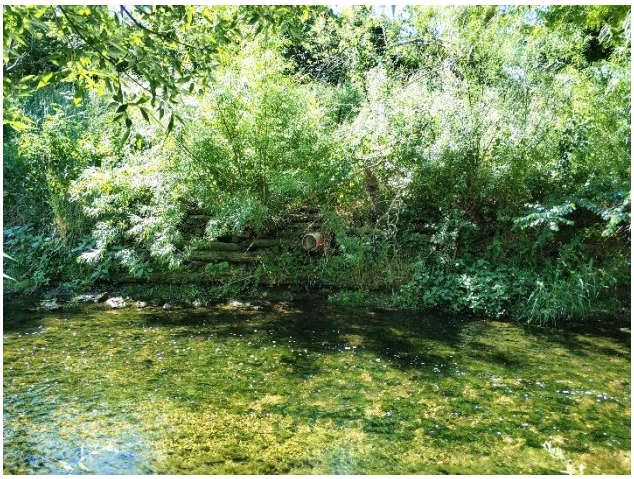

Figura 8. Intervenções de Engenharia Natural com muro de suporte vivo combinado com plantio de estacas e feixes vivos de espécies autóctones realizado para revitalização e recuperação ecológica das margens do Rio Liesing.

Figura 9. Intervenções de Engenharia Natural com enrocamento vivo realizado para revitalização e recuperação ecológica das margens do Rio Liesing.

Figura 10. Intervenções de Engenharia Natural com feixes vivos realizados para revitalização e recuperação ecológica das margens do Rio Liesing.

Figura 11. Intervenções de Engenharia Natural com defletores realizados para revitalização e recuperação ecológica das margens do Rio Liesing. Obra executada em Março de 2021.

Figura 12. Intervenções de Engenharia Natural com muro de suporte vivo realizado para revitalização e recuperação ecológica das margens do Rio Liesing. Obra executada em Março de 2021.

Figura 13. Intervenções de Engenharia Natural com estara viva realizada para revitalização e recuperação ecológica das margens do Rio Liesing. Obra executada em Março de 2021.

Figura 14. Intervenções de Engenharia Natural com muro de suporte vivo realizado para revitalização e recuperação ecológica das margens do Rio Liesing. Obra executada em Março de 2021.

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Estações de esqui Mitterbach e Annaberg dia 16/07/2021 durante todo o dia

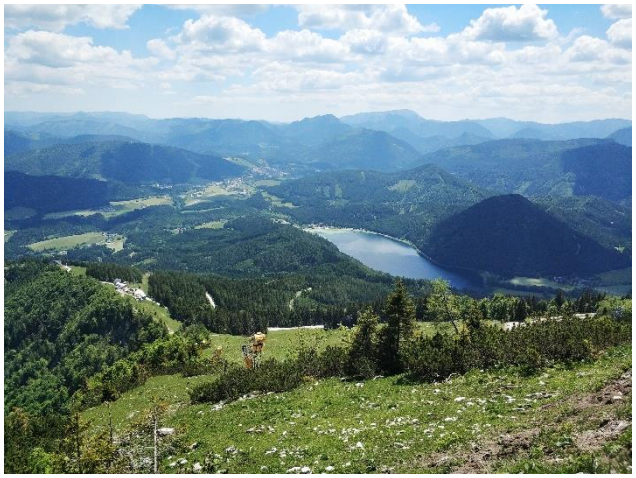

Figura 15. Intervenções de hidrossemadura com sementes de espécies autóctones realizada em taludes de acesso às estações esqui.

Figura 16. Intervenções de muro de solo reforçado com hidrossemadura com sementes de espécies autóctones realizada em taludes de aterro.

Figura 17. Intervenções de hidrossemadura com sementes de espécies autóctones realizada em taludes de acesso às estações esqui.

Figura 18. Intervenções de hidrossemadura com sementes de espécies autóctones realizada em taludes de acesso às estações esqui.

Rio Mödling dia 19/08/2021

Figura 19. Visita à trecho renaturalizado do rio Mödling com técnicas de Engenharia Natural, Mödling.

Figura 20. Visita à trecho renaturalizado do rio Mödling com técnicas de Engenharia Natural, Mödling.

Berghotel Rudolfshütte dias 16 e 17/08/2021

Figura 21. Preparação do substrato para semeadura de espécies herbáceas para implantação de telhado verde.

Figura 22. Semeadura e cobertura de sementes herbáceas para implantação de telhado verde.

Figura 23. Preparação do substrato para semeadura de espécies herbáceas para revegetação de aterro.

Figura 24. Semeadura e cobertura de sementes herbáceas para revegetação de aterro.

Rio Eckbach dia 23/07/2021

Figura 25. Visita à trecho renaturalizado do rio Eckbach com técnicas de Engenharia Natural, Viena.

Figura 26. Visita à trecho renaturalizado do rio Eckbach com técnicas de Engenharia Natural, Viena.

ANEXOS

Certificado de participação e aprovação em disciplina intitulada *Weidenbestimmungspraktikum* (determinação de salicáceas) com nota final *Excelente (1)*

Universität für Bodenkultur Wien
University of Natural Resources and Life Sciences, Vienna

Matrikelnummer	Kennzeichnung des Studiums
12047554	**UH 990**

Lehrveranstaltungszeugnis

FAMILIEN- oder NACHNAME Vorname(n)	Geburtsdatum
DEWES Junior Joel	**25.05.1993**

Studium
Besuch einzelner Lehrveranstaltungen

Stellung der Lehrveranstaltung im Studienplan

Titel der Lehrveranstaltung
Weidenbestimmungspraktikum

Nummer, Semester und Art der Lehrveranstaltung	Semesterstunden WS / SS
874313 21S PR Praktikum	**2,00**
Beurteilung: **sehr gut (1)**	ECTS-Credits: **3**

Anmerkungen

Prüfungsdatum	Prüfer*in
24.06.2021	**Hörbinger, Stephan Dipl.-Ing.**

C 1728206016

Beurteilung:
Österreichisches Notensystem
sehr gut (1), gut (2), befriedigend (3), genügend (4), nicht genügend (5)
mit Erfolg teilgenommen, ohne Erfolg teilgenommen

Dieses Zeugnis wurde automationsunterstützt erstellt und ist ohne Unterschrift und Siegel gültig.

DVR 0059234

BOKU-Lehrveranstaltungszeugnis

Certificado de participação e aprovação em disciplina intitulada *Ingenieurbiologische Maßnahmen* (Técnicas de Engenharia Natural) com nota final *Excelente (1)*

Universität für Bodenkultur Wien
University of Natural Resources and Life Sciences, Vienna

Matrikelnummer	Kennzeichnung des Studiums
12047554	**UH 990**

Lehrveranstaltungszeugnis

FAMILIEN- oder NACHNAME Vorname(n)	Geburtsdatum
DEWES Junior Joel	**25.05.1993**

Studium
Besuch einzelner Lehrveranstaltungen

Stellung der Lehrveranstaltung im Studienplan

Titel der Lehrveranstaltung
Ingenieurbiologische Maßnahmen

Nummer, Semester und Art der Lehrveranstaltung	Semesterstunden WS	Semesterstunden SS
874330 21S VO Vorlesung		**1,50**

Beurteilung	ECTS-Credits
sehr gut (1)	**2**

Anmerkungen

Prüfungsdatum	Prüfer*in
08.06.2021	**Rauch, Johann Peter** **Priv.-Doz. Dipl.-Ing. Dr.nat.techn.** **Ass.Prof.**

C 3072976886

Beurteilung:
Österreichisches Notensystem
sehr gut (1), gut (2), befriedigend (3), genügend (4), nicht genügend (5)
mit Erfolg teilgenommen, ohne Erfolg teilgenommen

Dieses Zeugnis wurde automationsunterstützt erstellt und ist ohne Unterschrift und Siegel gültig.

DVR 0059234

BOKU-Lehrveranstaltungszeugnis

Certificado de participação e aprovação em disciplina intitulada *Exkursion zu Ingenieurbiologie* (Excursão de Engenharia Natural) com nota final *Excelente (1)*

Universität für Bodenkultur Wien
University of Natural Resources and Life Sciences, Vienna

Matrikelnummer	Kennzeichnung des Studiums
12047554	**UH 990**

Lehrveranstaltungszeugnis

FAMILIEN- oder NACHNAME Vorname(n)	Geburtsdatum
DEWES Junior Joel	**25.05.1993**

Studium
Besuch einzelner Lehrveranstaltungen

Stellung der Lehrveranstaltung im Studienplan

Titel der Lehrveranstaltung
Exkursion zu Ingenieurbiologie

Nummer, Semester und Art der Lehrveranstaltung	Semesterstunden WS	SS
874314 21S EX Exkursion		**2,00**

Beurteilung	ECTS-Credits
sehr gut (1)	**3**

Anmerkungen

Prüfungsdatum	Prüfer*in
23.07.2021	**Rauch, Johann Peter** **Priv.-Doz. Dipl.-Ing. Dr.nat.techn.** **Ass.Prof.**

C 4027270638

Beurteilung:
Österreichisches Notensystem
sehr gut (1), gut (2), befriedigend (3), genügend (4), nicht genügend (5)
mit Erfolg teilgenommen, ohne Erfolg teilgenommen

Dieses Zeugnis wurde automationsunterstützt erstellt und ist ohne Unterschrift und Siegel gültig.

DVR 0059234

BOKU-Lehrveranstaltungszeugnis

Certificado de participação e aprovação em disciplina intitulada *Objektplanerisches Projekt* (Projeto de planejamento da paisagem) com nota final *Excelente (1)*

Universität für Bodenkultur Wien
University of Natural Resources and Life Sciences, Vienna

Matrikelnummer	Kennzeichnung des Studiums
12047554	**UH 990**

Lehrveranstaltungszeugnis

FAMILIEN- oder NACHNAME Vorname(n)	Geburtsdatum
DEWES Junior Joel	**25.05.1993**

Studium
Besuch einzelner Lehrveranstaltungen

Stellung der Lehrveranstaltung im Studienplan

Titel der Lehrveranstaltung
Objektplanerisches Projekt (Landschaftsarchitektur, Landschaftsbau)

Nummer, Semester und Art der Lehrveranstaltung	Semesterstunden WS	SS
874302 21S PJ Projekt		**5,00**

Beurteilung	ECTS-Credits
sehr gut (1)	**7**

Anmerkungen

Prüfungsdatum	Prüfer*in
30.07.2021	**Hörbinger, Stephan** **Dipl.-Ing.**

C 4269560818

Beurteilung:
Österreichisches Notensystem
sehr gut (1), gut (2), befriedigend (3), genügend (4), nicht genügend (5)
mit Erfolg teilgenommen, ohne Erfolg teilgenommen

Dieses Zeugnis wurde automationsunterstützt erstellt und ist ohne Unterschrift und Siegel gültig.

DVR 0059234

BOKU-Lehrveranstaltungszeugnis

Certificado de participação e aprovação em disciplina intitulada *Vertiefungsprojekt zu Landschaftsbau, Vegetationstechnik und Ingenieurbiologie* (Projeto de aprofundamento em Planejamento da paisagem, técnicas vegetativas e Engenharia Natural) com nota final *Excelente (1)*

Universität für Bodenkultur Wien
University of Natural Resources and Life Sciences, Vienna

Matrikelnummer	Kennzeichnung des Studiums
12047554	**UH 990**

Lehrveranstaltungszeugnis

FAMILIEN- oder NACHNAME Vorname(n)	Geburtsdatum
DEWES Junior Joel	**25.05.1993**

Studium
Besuch einzelner Lehrveranstaltungen

Stellung der Lehrveranstaltung im Studienplan

Titel der Lehrveranstaltung
Vertiefungsprojekt zu Landschaftsbau, Vegetationstechnik und Ingenieurbiologie

Nummer, Semester und Art der Lehrveranstaltung	Semesterstunden WS	Semesterstunden SS
874304 21S PJ Projekt		**4,00**

Beurteilung	ECTS-Credits
sehr gut (1)	**6**

Anmerkungen

Prüfungsdatum	Prüfer*in
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RESEARCH ARTICLE OPEN ACCESS

ECONOMIC VIABILITY OF STREAMBANK STABILIZATION WORK WITH NATURE-BASED SOLUTIONS APPLIED TO A PIPELINE STREAM CROSSING IN SOUTH AMERICA

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ABSTRACT

Pipelines are critically essential transportation infrastructures in most nations since they are essential to both standards of living, and economies. Traditional streambank stabilization in pipelines river crossings is carried out with civil engineering techniques. Environmental concerns have increased the demand for low environmental impact techniques that value the ecological characteristics and the hydraulic connectivity of fluvial systems. Soil bioengineering as a nature-based solution can be a suitable alternative to the civil engineering, which aside from being usually expensive, do not consider ecological issues. This work aimed to analyze the economic viability of a soil bioengineering work to stabilize a stream bed and banks with a pipeline stream crossing compared to a traditional engineering solution. Thus, to carry out the economic analysis, a comparison was made between the proposed budget for the civil engineering and the total cost of a soil bioengineering work performed. The financial analysis showed that the bioengineering intervention had a 49.06% lower cost than the solution foreseen by civil engineering, with the highest percentage of total value (39.97%) related to the materials acquisition. In conclusion, the soil bioengineering work presented economic viability to stabilize the streambed and banks when compared to the civil engineering solution.

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INTRODUÇÃO

According to the American Society of Mechanical Engineers, the total length of transmission pipelines transporting gas and oil around the world has been estimated at 3.5 million km (64% carry natural gas, 19% carry petroleum products, and 17% carry crude oil). Additionally, 32,000 km of new onshore and 8,000 km offshore pipelines are constructed each year worldwide (Hopkins, 2007a; Sovacool and Dworkin, 2014). Brazil has a network of pipelines with 19,717 km of extension (5,959 km carry refined petroleum product, 11,696 km carry natural gas, 1,985 km crude oil, and 77 km carry ethanol/petrochemical) (CIA, 2020). Pipeline systems are critically essential transportation infrastructures in most nations since they are essential to both standards of living, and economies (Hopkins, 2007b). Although accidents on pipelines have low probability of occurrence (Zhou and Chen, 2015), when it happens has serious consequences in human health and safety, production, assets, and environmental losses (Norhamimi *et al.*, 2015), especially for transportation and distribution hazardous liquid pipelines. Pipelines may cross rivers, streams, and washes, and typically those pipelines are buried in the streambed, but may also be elevated aboveground on bridges (Day *et al.*, 1998). Pipelines in river crossings are more vulnerable to be exposed when heavy rain and floods occur. Exposed pipelines are submitted to tension stresses and are more susceptible to suffer from hydraulic–geotechnical risks, like support problems, vortex-induced vibration, debris flow, and other mass movements, and mechanical integrity issues, such as thermal variation and damage to cathodic protection (Maffra, Sousa and Sutili, 2017; Maffra and Sutili, 2020). Traditional streambank stabilization is carried out with conventional techniques of civil engineering such as gabion walls, concrete walls, and riprap. In pipelines river crossings are also employed techniques such as reinforced soil with woven polypropylene geotextiles, cellular confinement systems filled with soil-cement (Costa *et al.*, 2005), concrete revetment mattresses

(Witheridge, 2017), rock armoring, among other traditional techniques from civil engineering. However, these techniques, apart from expensive, may also cause severe impacts in the environment, adversely affecting the health and biodiversity of aquatic life, the hydraulic connectivity and the green corridor along the river. Environmental concerns have increased the demand for nature-based solutions with low environmental impact, that value the ecological characteristics and the hydraulic connectivity of fluvial systems, even in infrastructure works. In confronting this problem, nature-based solutions such as soil bioengineering can be a feasible alternative to the traditional techniques of civil engineering, which aside from being expensive, do not take into account ecological issues (Coppin and Richards, 2007; Sousa, Dewes and Sutili, 2018). Soil bioengineering pursues technological, ecological, and economic goals, as well as designs and seeks to achieve these primarily by using live materials (seeds, plants, parts of plants, and plant communities), which can be combined with inert materials (Schiechtl, 1980). Bioengineering techniques can be applied to structural problems for geotechnical and hydraulic stabilization, to control surface erosion processes, and simultaneously to design ecosystems in dynamic equilibrium (Sousa, 2015). The financial analysis and the cost-benefit ratio of bioengineering interventions are fundamental to specify the most appropriate solution that meets the technical and environmental conditions without neglecting economic conditions. Furthermore, benefit-cost analysis is a powerful tool to assist in decision making, since when benefits are quantified more efficient decisions can be made (Hagen *et al.*, 2001). As indicated by several authors, soil bioengineering presents more cost-efficient solutions than traditional civil engineering solutions (Donat, 1995; Schiechtl and Stern, 1996; Cornelini and Sauli, 2005; Coppin and Richards, 2007; Studer and Zeh, 2014; Bloemer *et al.*, 2015). However, evidence is needed to improve our understanding of the range of economic and environmental benefits provided by nature-based solutions like soil bioengineering techniques in infrastructure works such as pipelines. This work aimed to analyze the economic viability of a soil bioengineering work to stabilize a stream bed and banks with a pipeline stream crossing compared to a traditional civil engineering solution.

MATERIALS AND METHODS

Study area description: The study area is located in Cariacica, Espírito Santo state in Brazil. The area is in the rural zone, where the terrain conditions are very steepened, geotechnically characterized by the talus occurrence and the presence of solid blocks of variable dimensions. The vegetation cover is composed by forest areas, banana plantations, and pastures (Maffra, Sousa and Sutili, 2017). The region's climate is tropical Aw, where the rainy season is between October and January (Alvares *et al.*, 2013). In the summer of 2011/2012, there were intense rainfall events, especially in the week between 3rd and 10th January 2012, where there was an accumulated rainfall of 260 mm with a peak of 100 mm recorded on 06th January. The action of these rains exposed the gas pipeline and fiber optic cables due to the occurrence of an erosive process along 20 m of the stream bed and banks. As a consequence of the high velocity of water flow and the watershed characteristics, the pipeline was partially exposed and started to function as a dam and began to support additional tensions and whirling flow forces. In addition, the exposed pipeline has a higher risk of being damaged by third-party actions and greater susceptibility to geotechnical events typical of the region such as rock falls and debris flow. Furthermore, the technical standard of PETROBRAS N 464, specifies that pipelines must be protected with coverage with a thickness between 1.0 - 1.5 m, depending on their location (Petrobras, 2012). The characteristics of the stream stretch with the submerged gas pipeline crossing, after erosion processes, can be observed in Figure 1. In order to avoid erosion processes developing, as well as the loss of slope stability and likely damage to the pipeline, a civil engineering project was designed in October 2011. Afterward, the company that owns the pipeline requested another project that meets the technical conditions imposed by the erosion process typology but also presents an ecological feature to reduce the impact of the work on the environmental characteristics of the site. This project was mainly designed with soil bioengineering techniques and then submitted to the analysis and approval of the Brazilian Environmental Agency (*IBAMA*). The project was developed between September and December 2012, by the Soil Bioengineering Laboratory (LabEN) of the Federal University of Santa Maria (UFSM).

Figure 1. Stream after erosion processes with unstable bed and banks.a Landslide at the left side of the streambank; b Detail of exposed fiber the optical cables

Economic analysis: To carry out an economic analysis a comparison was performed between the proposed budget for the civil engineering work and the total cost of bioengineering work performed in 2014. The cost conversion was made from Brazilian Reais to Euros considering the exchange value in September 2019. The costs, considering all the expenses involved in executing the work, namely labor, materials, and equipment, as well as all the necessary infrastructure for execution (construction site, local administration, mobilization, and demobilization) were then analyzed for the two constructive solutions.

Description of intervention techniques: The civil engineering design was composed by gabion walls for stabilizing the streambanks and gabion mattress for stabilizing the streambed (Figure 2). The gabion was designed as being 2.5 m high, 24.0 m in length and 2.0 m deep at the base and 1.0 m deep at the top of the structure, filled with 210 m^3 of rock. The mattress was designed having 200 m^2 of area and 0.23 m thickness, filled with 60 m^3 of rock. The application of non-woven geotextile with a density of 200 g/m^2 in a quantity of 460 m^2 was also considered.

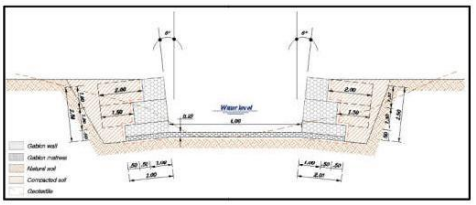

Figure 2. Site type section with Civil Engineering interventions

The soil bioengineering project was composed by the left bank stabilization with vegetated log cribwall having 2.6 m height, 7.5 m length, and 2.25 m depth. The structure was filled with 45 m^3 of soil, 675 autochthonous shrubs, and live cuttings, and 18 straw wattles of 0.3 m in diameter. The constructive details of the live cribwall can be observed in Figure 3. The right bank was protected with straw wattles of 0.3 m in diameter, straw geotextile, planting of autochthonous seedlings, and seeding. Streambed stabilization was performed with a small dam executed with 16 m^3 of concrete. A drainage system was also designed on the top of the cribwall to redirect rainwater surplus from the slope. The drainage consisted of 25 m of channels with dimensions of 30 x 30 cm executed in cement grouted rocks and reinforced concrete.

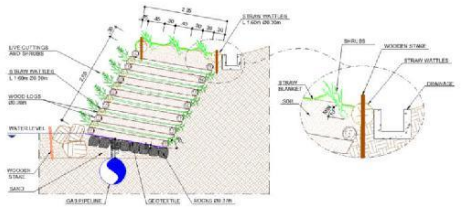

Figure 3. Left streambank type section with vegetated log cribwall

In the design phase, were performed hydrological and hydraulic analyzes, and geotechnical calculations for all structures. The solutions adopted were sized for a recurrence interval of 25 years, exceeding the lifetime considered for the pipeline by 5 years.

RESULTS AND DISCUSSION

The civil engineering solution budget was € 93,997.60, and the total cost of the soil bioengineering execution was € 47,885.10. The financial analysis showed that the bioengineering intervention had a 49.06% lower cost than the solution foreseen by civil engineering. This percentage is within the values reported by Venti et al. (Venti *et al.*, 2003), who state that biotechniques are 40% to 90% less expensive than traditional interventions. Sousa et al. (Sousa, Dewes and Sutili, 2018) found a 50% lower value for bioengineering in a comparative study carried out in Brazil. Lewis et al. (Lewis, Salisbury and Hagen, 2001) found that bioengineering was 42,93% less expensive than traditional methods considering the evaluation of three sites with soil bioengineering works. Hagen et al. (Hagen *et al.*, 2001) also found that soil bioengineering techniques can also be considered a viable solution with a higher benefit-cost ratio than the traditional interventions for roadside management problems. It is important to note that since the civil engineering solution has not been implemented, it is not possible to make a real analysis of its final execution cost. Usually, the costs are higher in the execution phase than projected. This occurs because the conditions during work execution cannot be fully predicted at the design stage, such as rainy days, delays with suppliers, smaller or less efficient working teams than those considered in the project, among others. Therefore, the bioengineering work could potentially be even more economical. Besides that, soil bioengineering solutions have a longer life cycle and less maintenance than traditional methods (Hagen *et al.*, 2001).

The comparative cost for the two interventions based on the total cost of each work phase is shown in Figure 4. The costs of the initial services, temporary work, and final services are the same for the two solutions. The cost difference for earthworks is related to the need for greater soil movement to execute the gabion wall and the mattress. Building the transversal structures cost € 4,984.50. This phase does not exist in the civil engineering solution, since building structures that act transversally to the water flow was not foreseen. The longitudinal structures in the civil engineering project would cost € 63,179.20, and in the bioengineering project cost € 11,863.20. This means that the longitudinal structures in the biotechnical intervention had an 81.22% lower cost than those predicted for the traditional solution. This difference of values is because the impacted area for biotechniques execution is smaller than the area required for gabion walls. The materials are also more economical than the gabion mesh and rocks. The execution time of the biotechnical structures (5 days) is also shorter than expected for the execution of the gabions (25 days). These differences explain the large difference between the final values. Only the execution value for the gabion walls represents a total of 24.21% higher cost than all the soil bioengineering work. A comparative percentage of manpower, materials, and machines can be performed for each solution in relation to the total costs, as observed in Figure 5. The civil engineering design had a total budget of € 93,997.60, of which 47.61% refers to materials acquisition, 29.70% corresponds to manpower, 22.30% to the use of machines, and 0.39% for the topography services, as shown in Figure 5 (to the right). The total cost for soil bioengineering work was €47,885.10, for which 39.97% refers to materials, 30.12% to machines, 29.15% to manpower, and 0.76% to topography services, as shown in Figure 5 (to the left).

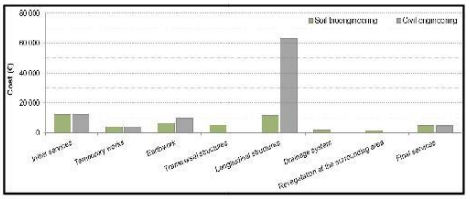

Figure 4. Comparative cost of civil engineering and soil bioengineering works based on the total costs of each phase

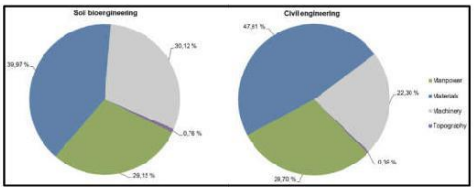

Figure 5. Percentage of costs regarding the use of manpower, materials, machinery, and topography for civil engineering and soil bioengineering works

Figure 6. Evolution of soil bioengineering work. a Work immediately after execution in August 2014; b Intervention after 16 months.

The highest costs in the soil bioengineering intervention are related to materials acquisition. In this type of work, preference is usually given to using existing materials on site (wood, rocks, and plants) (Fernandes and Freitas, 2011), which means that acquisition costs are low, and the higher costs are usually assigned to manpower, as verified in works performed in Europe (Italy) and Central America (Ecuador, Guatemala, and Nicaragua) (Petrone and Preti, 2005). Labor costs in Italy are higher due to higher employee salaries, while these costs in Ecuador, Guatemala, and Nicaragua are high because of the use of local manpower instead of technologies (more sophisticated materials and machines), as a way of supporting the creation of jobs. In this case, the workforce presented lower percentage costs than materials, since there were no materials at the intervention site likely to be used, except for live cuttings. In addition, manpower in Brazil, mainly in the construction industry, has lower salaries when compared with European or North American countries. However, for works where all materials are available at the intervention place, there will be no costs related to their acquisition (Sotir and Gray, 1992; Watson, Abt and Thornton, 1994), which could make these interventions even cheaper. In addition to presenting economic viability, the performed soil bioengineering work met the criteria for which it was designed. The execution of the live cribwall on the left bank provided the consolidation of the slope, while the drainage system allowed the redirection of rain surpluses to the stream.

The techniques of the right bank prevented the progression of the erosive process and the enlargement of the watercourse. The construction of the small dam promoted the formation of a new longitudinal profile and therefore soil and rocks deposition and retention above the pipeline. Furthermore, to the technical benefits, the intervention provided ecological and aesthetic gains. The use of autochthonous plants promoted the establishment of a more developed plant community in the frame of the natural vegetation succession and increased biodiversity and habitat functionality. Figure 6 shows the work after the execution and the results after 16 months of evolution.

CONCLUSION

The civil engineering solution budget was € 93,997.60, and the total cost for executing the soil bioengineering project was € 47,885.10. The financial analysis showed that the soil bioengineering intervention had a 49.06% lower cost than the solution foreseen by civil engineering. The highest percentage of the total value of the soil bioengineering work was related to the materials acquisition (39.97%), while machinery, manpower, and topography represented 30.12%, 29.15%, and 0.76%, respectively. In conclusion, the soil bioengineering work presented economic viability to stabilize the stream bed and banks when compared with a traditional civil engineering solution. Besides, the bioengineering work proved to be technically and ecologically feasible. The reduction of environmental impacts plays a fundamental role in ecological restoration and conservation actions, and therefore it can be assumed that soil bioengineering techniques have a higher intrinsic value due to their ecological and aesthetic functions. Furthermore, in emerging markets such as Brazil and other South American countries, where transportation infrastructures like pipelines have such economic importance, the use of nature-based solutions should be encouraged since they have low environmental impacts, are technical and ecological suited, and besides these are cost-competitive.

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Trabalho apresentado online desenvolvido em conjunto com o professor supervisor e pesquisador de doutorado austríacos no evento **5th International Conference on Soil, Bio- and Eco-Engineering (SBEE)** realizado em Berna (Suiça) nos dias 21 a 25 de Junho de 2021:

Dewes, J. J., Sousa, R. S, Sutili, F. J., Hoerbinger, S., Rauch, H. P. "**Economic Viability of Streambank Stabilization Work with Soil Bioengineering in South Brazil**". 5th SBEE, Bern, Switzerland, 21 – 25 June, 2021.

Economic Viability of Streambank Stabilization Work with Soil Bioengineering in South Brazil

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5th international conference on Soil, Bio- and Eco-Engineering SBEE 2021
Bern, Switzerland, 21 – 25 June 2021

[1] Introduction

Traditional streambank stabilization is carried out with conventional techniques of civil engineering such as gabion walls, concrete walls and riprap. Environmental concerns have increased the demand for low environmental impact techniques that value the ecological characteristics and the hydraulic connectivity of fluvial systems. Soil bioengineering can be a feasible alternative to the traditional techniques of civil engineering which aside from being expensive, do not consider ecological issues (Coppin and Richards, 2007). Soil bioengineering techniques can be applied to structural problems for geotechnical and hydraulic stabilization, to control surface erosion processes, and simultaneously to design ecosystems in dynamic equilibrium (Sousa, 2015). The financial analysis and the cost-benefit ratio of bioengineering interventions are fundamental to specify the most appropriate solution that meets the technical and environmental conditions without neglecting economic conditions. As indicated by several authors, bioengineering presents more cost-efficient solutions than traditional civil engineering solutions (Studer and Zeh, 2014). The aim of this work was to analyse the economic viability of a soil bioengineering work to stabilize a streambank banks compared to a traditional civil engineering solution.

[2] Methodology

I) Study area description: Cariacica, Espírito Santo state (Brazil), at the coordinates 20°16'41,36" S and 40°27'37,06" W. The intervention was executed on an actively eroding riverbank section with a length of more than 80 m situated directly below the Dourado reservoir dam. The cause of the erosion processes was the deviation of the river axis towards the left bank due to the construction of a water pipeline. The water flow caused a continuous process of erosion, collapse and landslides. These processes resulted in an embankment with steep angles and low characteristics of soil resistance. Additionally, the presence of tall trees along the slope top increased the instability through forming an overhead.

II) Economic analysis: Was performed a comparison between the proposed budget for the civil engineering work and the total cost of bioengineering work. The cost conversion was made from Brazilian reais to Euros considering the exchange value in June 2021. The costs, considering all the expenses involved in executing the work, namely labour, materials and equipment, as well as all the necessary infrastructure for execution (construction site, local administration, mobilization and demobilization) were then analysed for the two solutions.

III) Description of the techniques: The civil engineering design was composed by a streambank rip-rap designed with 80 m in length, 17,2 m width and 0,70 m of thickness. The soil bioengineering techniques are shown in Figure 1.

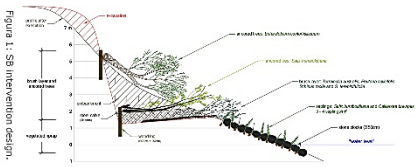

Figura 1: SB intervention design.

[3] Results and Discussion

The civil engineering solution budget was € 25,260.03 and the total cost of the soil bioengineering execution was € 12,921.94. The financial analysis showed that the bioengineering intervention had a 48,8% lower cost than the solution foreseen by civil engineering.

The comparative cost for the two interventions based on the total cost of each phase is shown in Figure 2.

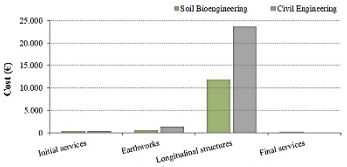

Figure 2. Comparative cost of civil engineering and soil bioengineering works based on the total costs of each phase.

The highest costs in the bioengineering intervention are related to materials acquisition (Figure 3). In this type of work preference is usually given to using existing materials on site (wood, rocks and plants), which means that acquisition costs are low, and the higher costs are usually assigned to manpower, as verified in works performed in Italy and Central America (Petrone and Preti, 2005). However, in this case, the workforce presented lower percentage costs than materials, since there were no materials at the intervention site likely to be used, with the exception of live cuttings. In addition, manpower in Brazil, mainly in the construction industry, has lower salaries when compared with European countries.

Figura 4: Stream before bioengineering work with unstable bank in 2009 (a) (Sutili); Soil Bioengineering intervention in December 2003 (b) (Hörbinger); Soil Bioengineering intervention in December 2017 (c) (Sousa).

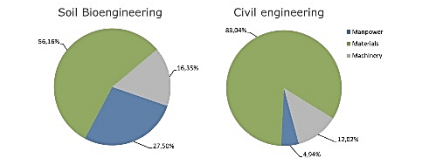

Figura 3. Percentage of costs regarding the use of manpower, materials, machinery and topography for civil engineering and soil bioengineering works.

The performed soil bioengineering work met the criteria for which it was designed. In addition to the technical benefits, the intervention provided ecological and aesthetic gains as showed in Figure 4.

[4] Conclusion

- The financial analysis showed that the soil bioengineering intervention had a 48.8% lower cost than the solution foreseen by civil engineering. The highest percentage of total value of the soil bioengineering work was related to the materials acquisition (56.16%), while manpower and machinery presented 27.05% and 16.35%, respectively.
- In conclusion, the soil bioengineering work presented economic viability to stabilize the streambank when compared with a traditional civil engineering solution. In addition, the bioengineering work proved to be technically and ecologically feasible.